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Notes on the Bearded Seal, *Erignathus barbatus*, in the Canadian Arctic

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ABSTRACT

Smith, Thomas G. 1981. Notes on the bearded seal, Erignathus barbatus, in the Canadian arctic. Can. Tech. Rep. Fish. Aquat. Sci. 1042: v + 49 p.

Data on 260 bearded seals collected from 16 different Canadian arctic localities are examined. The largest harvests of bearded seals are taken in Hudson Strait, Foxe Basin and eastern Hudson Bay. In these regions in winter bearded seals inhabit the shifting pack ice and leads but in other regions, such as Amundsen Gulf, they are found under the land-fast ice. Ages were determined by counting claw annuli or, when possible, by counting cementum bands on upper or lower canines or pre-molars. No sexual difference in size was seen in adult seals, and adult seals from the eastern Canadian arctic were not different in size from those studied in Alaska. Female reproductive material indicated that annual reproduction occurs with reproductive rates possibly as high as 0.86. One sample of three female seals shot in a fast-ice area might indicate that discrete populations limit their size by reproductive controls. Sex ratios of adults indicate a preponderance of females, but the cause is obscure. Age frequencies of seals taken in the open water season contain more adults than adolescents and young of the year, which are probably underrepresented. Bearded seals feed primarily on benthic or epibenthic organisms with Decapoda, Pelecypoda and fish being the most common food organisms taken. The ecology of the bearded seal is poorly understood. Their patchy distribution and use of areas of high benthic production might, in some locations, make them especially vulnerable to habitat disruption.

RESUME

Smith, Thomas G. 1981. Notes on the bearded seal, Erignathus barbatus, in the Canadian arctic. Can. Tech. Rep. Fish. Aquat. Sci. 1042: v + 49 p.

Les données relatives à 260 phoques barbus échantillonés dans 16 localités différentes de l'Arctique Canadien sont analysés. Les prises les plus importantes de phoques barbus sont faites dans le détroit d'Hudson, le bassin de Foxe et l'Est de la baie d'hudson. Durant l'hiver dans ces régions, les phoques barbus occupent les zones de glace flottantes et d'eau libre. Dans d'autre régions, tel que le golfe d'Amundsen, on les trouve également sur la banquise côtière. L'age des échantillons a été determiné en comptant les anneaux de croissance des griffes et si possible en comptant les bandes de croissance du cément sur les canines superieures ou inférieures ou sur les prémolaires. Nous n'avons pas noté de dimorphisme sexuel dans la taille des adultes et les phoques barbus de l'Est de l'Arctique Canadien ne présentent pas de différence de taille avec ceux de l'Alaska. On peut conclure de l'examen des organes génitaux femelle que la reproduction est annuelle avec des taux de reproduction atteignant sans doute 0.86. Un échantillon de trois femelles tirées sur la banquise pourrait indiquer que la taille des populations de cette espéce est limitée par un control reproductif. Le rapport des sexes des adults échantillonés laisse apparaitre une prépondérance de femelles. La raison de cette prépondérance n'est pas éllucidée. La fréquence des ages des phoques capturés durant la saison des eaux libres montre un plus grand nombre d'adultes que d'adolescents et de jeunes de l'année qui sont probablement sous-représentés dans l'échantillon.

Les phoques barbus se nourissent principalement d'organismes benthiques ou epibenthiques et tout particulierement de Decapoda, Pelecypoda et de poisson. L'ecologie du phoque barbu est peu connu. Leur distribution trés localisée et leur préférence pour des zones de haute productivité benthique pouraient les rendre trés vulnérables aux modifications de leur habitat en certain endroits.

INTRODUCTION

The bearded seal, Erignathus barbatus, is found everywhere in the marine waters of the Canadian arctic. A circumpolar species, it is patchy in its distribution and occurs in much lower numbers than the ubiquitous ringed seal, Phoca hispida, with which it shares the arctic marine habitat.

Because it is not exploited commercially or in large numbers (Smith and Taylor 1977), being used for making domestic products such as boot leather and rawhide line by the Inuit, very little research has been done on this species in the Canadian north. McLaren (1958a) described the growth and reproductive biology of specimens collected mainly in the Cape Dorset area of southern Baffin Island. He indicated that in the eastern arctic, bearded seals appear to be most abundant in Ungava Bay and in Roes Welcome Sound, northern Hudson Bay (McLaren 1958b). The most recent information on population estimates of this species comes from aerial surveys flown in the southeastern Beaufort Sea (Stirling, Archibald and DeMaster 1977) and the high arctic (Finley 1976; Koski and Davis 1979; Koski 1980; Stirling, Kingsley and Calvert 1981). There is also a limited amount of information on the extent of polar bear predation for several arctic localities (Stirling and Archibald 1977; Smith 1980). A small amount of work has been done on heavy metals in bearded seal tissues from several Canadian areas (Smith and Armstrong 1975, 1978) and in Alaska (Galster 1971).

Most of our knowledge concerning the reproductive biology and natural history of this species comes from studies done in Alaska on the abundant stocks present in the Bering, Chukchi and Beaufort Seas (Johnson, Fiscus, Ostenson and Barbour 1966; Burns 1967; Lowry, Frost and Burns 1979, 1980). Much of the earlier work was carried out in the Russian arctic (Plekhanov 1933; Chapskii 1938; Pikharev 1940; and Sleptsov 1943). More recent publications have dealt with reproductive biology, morphology and growth (Tikhomirov 1966; Kosygin 1966; Fedoseev 1973; and Potelov 1975), and methods of age determination (Benjaminsen 1973).

The purpose of this paper is to summarize data on bearded seals collected in diverse Canadian arctic areas by various investigators since 1955. Most of the specimens were taken incidentally to other studies and only small numbers of animals are available from many of the localities. The largest single samples come from the Igloolik area (81 specimens in 1961 and 1968-69) and the Belcher Islands (75 specimens in 1960 and 1974-75). Altogether, data from 260 bearded seals from 16 locations across the Canadian arctic are considered.

MATERIALS AND METHODS

Specimens were collected in many different localities, either by researchers or from the catches of Inuit hunters. Table 1 lists the sites of collection and numbers of specimens obtained.

The age of a large number of the earliest collected specimens was determined by counting growth ridges on the claws, as described by Plekhanov (1933) and McLaren (1958a). The ages of the more recently collected specimens were determined from hard sections of either upper or lower canines, or occasionally from premolars by reading the annuli in the cementum, as described by Benjaminsen (1973). Teeth were imbedded in a clear plastic medium (Ward's Bioplastic) and sectioned to approximately 100μ on a dental research saw (Hamco Machines, Inc., Rochester, N.Y.). Readings were made using a dissecting microscope and transmitted light.

The bacula of males were collected and later boiled to remove the muscle and connective tissues. Total lengths were recorded to the nearest millimetre. Female reproductive tracts and ovaries were collected in the field and preserved in 10% formalin. In the laboratory the uterine cornua were examined for signs of pregnancy, and the ovaries were sectioned serially. These were then examined with a magnifying lamp. Counts were made of follicles with a diameter of 5 mm or greater. The two maximum diameters of the corpora lutea and corpora albicantia were recorded. If foetuses were present crown-rump measurements were taken.

In the field, standard measurements such as nose-tail length, maximum girth, blubber thickness over the sternum were recorded and the body weights of a few specimens were obtained. Samples of muscle and blubber were also taken from some animals for heavy metal and pesticide analyses.

Stomach contents were removed and preserved in 10% formalin. Wet weights and volumes were recorded. The contents were then sorted into fish, plankton and benthos, and an estimate of their relative proportion was obtained. When possible, food items were identified to species.

RESULTS

NUMBERS DISTRIBUTION AND HARVEST

Estimates of the population size of bearded seals are very difficult to make because of the patchy distribution of the species. The period during which bearded seals haul out on the ice to moult and thus become available for counting from aircraft, is more protracted and less well defined than the haul-out period of the ringed seal, making the date of the seasonal peak in numbers difficult to establish. Possibly the optimum time to count this species would be during the pupping season which occurs in late April and May. Since male bearded seals are usually not seen at this time, counts of females with newborn pups could be used to provide production indices for the region surveyed. Such counts could best be accomplished at least one full month earlier than aerial surveys for ringed seal population estimates.

Only one study has given quantitative estimates of bearded seals hauled up on the ice. Stirling et al. (1977) surveyed the southeastern Beaufort Sea area, from the Alaskan border to the west coast of Banks Island and north to Gore Island. In an area of 143 040 km^2 they estimated 2757 ± 728 bearded seals in 1974 and 1197 ± 239 in 1975. They concluded that there was a real change in the numbers of bearded seals from one year to the next and that bearded seals were clumped in their distribution. The distribution appeared to be influenced by water depth, bearded seals being more numerous in areas with 25-75 m of water than in deeper areas.

No reliable quantitative data on actual numbers of bearded seals exist for other Canadian localities, but an index of relative abundance can be derived from catch statistics. Table 2 shows the catch estimates taken from RCMP game reports (Smith and Taylor 1977), and a harvesting study done in northern Quebec (Anon. 1974). While the total numbers harvested are probably not very reliable, since the bearded seal is used domestically, the catch figures probably indicate the areas of greatest availability. The largest harvests are taken in Hudson Strait and Hudson Bay, with significantly lower catches being taken in the high, western and central arctic regions. Catches recorded in the RCMP game reports are not strictly comparable to those derived from the Inuit harvesting study (Anon 1974), and are thought generally to be underestimated. Where separate studies have been conducted, either on harvests or from boat surveys, the number of bearded seals has been expressed as a percentage of ringed seals taken or observed. These figures are given in Table 2, together with the source in parentheses.

Minimum harvest figures only reflect the total number of bearded seals killed when the losses by sinking are considered. While figures exist for the seasonal loss of ringed seals (McLaren 1958b; Usher 1965; Smith 1973), only crude estimates exist for the loss of bearded seals

(Burns 1967; Beaubier, Bradley and Vestey 1970). It appears that the bearded seal sinks more readily than the ringed seal at all times of the year because it remains relatively thinner and thus has a higher specific gravity. In mid summer when bearded seals are hunted in the open water, or in the spring when they are hunted from the floe edge, losses can exceed 50% of the animals shot. In such situations the more careful Inuit hunters shoot to wound the seal, and harpoon or hook it before killing it. With the decrease in number of experienced hunters and the increasing phenomenon of weekend hunting, it is expected that sinking losses will increase in the future.

AGE DETERMINATION AND TOOTH STRUCTURE

Because of the number of different collectors involved in this study, it has been necessary to use claws from both the foreflippers and hind flippers, as well as upper and lower canines and premolars, in order to determine the age of specimens. Though the techniques have been developed by other investigators and described before, it is felt that a detailed description of the materials examined in this study would be useful in clarifying any ambiguities that may exist in the age determination methods used.

In determining age from the claws of foreflippers, it has been found that it is best to let the flipper rot before removing the fur and bone and preserving the claws in a mixture of alcohol and 10% glycerin. It is important to take the longest claw from the foreflipper, since the claws are not all subject to the same rate of wear. In this study, where complete flippers were available, 13 of 21 samples showed claws from the same flipper yielding different estimates of age.

The claws are divided transversely into a series of annual light and dark bands, the light bands being formed in the spring and summer as indicated by McLaren (1958a) and Benjaminsen (1973). A ridge, most apparent on the dorsal surface of the claws, appears to be associated with the light bands. In young animals (0+ to 2+ years) the dark and light bands are very indistinct and ridging is not prominent. In older claws the distal portion begins to wear away around nine years of age. The maximum age recorded from claws of the foreflipper in this study was 14+ years.

The claws from the hind flippers of bearded seals may also be used for determination of age but these tend to give underestimates (Table 3). Although wear at the tip is not as severe as in claws from the fore-flippers, abrasion along the dorsal surface makes them difficult to read. However it is recommended that claws from hind flippers be collected along with claws from foreflippers when teeth are not available.

In using teeth for age determination, it has been found that longitudinal unstained hard sections of upper and lower canines and premolars yield adequate material for counting lines in the cement. The upper canines are the best teeth to collect for age determination since they are larger and appear to be retained longer than the other teeth (Benjaminsen 1973). However, it is also possible to retrieve the roots of the lower canines and remains of the premolars in most specimens when the upper canines are not available. The greatest number of teeth sectioned in the present study are from the lower jaws and have given quite satisfactory results.

As Benjaminsen (1973) showed for the upper canines, there is a corresponding marked reduction in length of the lower canines by wear (Fig. 1), resulting in their disappearance beneath the gums usually by the time the animal is 4+ years of age. The pulp cavities of the canines are rapidly filled with dentine, the opening of the pulp canal at the base of the lower canine closing by the time the animal is more than one year old. Because of the rapid growth of dentine and the presence of many adventitious growth lines, the dentine cannot be used for age determination.

Cementum is deposited annually on the outside of the tooth, especially around the base, resulting in gradual increase in length of the cementum layer (Fig. 2a, b). Benjaminsen (1973) indicates that the opaque annuli in the cementum are deposited in the summer months, while the translucent annuli are laid down during the winter, but results from the present study do not confirm this. Our material (N=22) shows that in newborn seals an opaque annulus is formed at birth and that a translucent zone does not begin to form until March to May the following year. In 88 percent (14/16) of seals greater than one year of age translucent annuli are seen between April and September. These observations are in agreement with those made on several other pinniped species in which the seasonal presence of translucent cementum is related to the period of reproductive effort and moult (Mansfield 1958; Laws 1962; Hewer 1964). Although the sample spans the entire year the total number of specimens is small (N=40), and includes many young of the year; consequently the definitive statement on the seasonal appearance of cementum must await further studies.

As the cementum becomes much thicker near the base of the tooth, the annuli become much more difficult to interpret. Readings were usually made distal to the halfway mark of the cementum length on the concave side of the longitudinal section. In the premolars the most readable area was along the inner portion of the roots. The older the specimen, the narrower were the latest formed cementum lines, and these were most readable toward the anterior (distal) portion of the section. It was also noted that the first formed cementum lines, up to the fifth to eighth annulus, were broader and less clearly defined than subsequent ones. The change in the thickness of the annuli might correspond to the attainment of sexual maturity, as has been suggested for other species (Hewer 1964; Bengston and Siniff 1981). This was clearest in the cementum of the upper canines, but was also observed in the lower canines and premolars. The sample size of teeth in this study is too small to provide estimates of mean age of sexual maturity by this method, but it was evident from four upper canines and six lower canines of both sexes that the change in thickness of the cementum annuli occurred between the fourth and eighth years, ($\overline{X}$=6.4).

Figure 3 shows the frequency of age classes determined by cementum lines in the teeth and by laminae in the claws of the foreflippers. While age determination from claws was the method most often used in this study, Fig. 3 shows clearly that claw wear, possibly beginning as early as the fifth year, biases the age structure derived. Maximum claw wear appears to occur between the ages of 8 to 12 years, as shown by the preponderance of those year classes determined by claw ages in Fig. 3. Where claws and teeth were available from the same animal for determing age, the agreement from both methods below the age of seven years was 100 percent (46 teeth), whereas this dropped off markedly to 50 percent (5 of 10 teeth) in older animals.

GROWTH

The relation of age determined by teeth and claws to the nose-tail length of bearded seals is shown in Fig. 4a, b. In order to test for differences between sexes, and to compare body size with that of seals from other localities, statistics of nose-tail length were computed separately for young of the year (0+), adolestents (1+ to 5+) and adults (6+ years and older). Table 4 lists the statistics from this study and several other sources.

Comparison between the lengths of adult bearded seals of either sex in this study (6+ years and older) shows no significant difference (T=0.67, d.f.=71, P>0.5). Some studies have indicated that adult female bearded seals are longer than the males (McLaren 1958a; Benjaminsen 1973; Burns and Frost 1979), but it was not stated if the differences were significant. This is not supported by the results from this study.

In Table 4 it is seen that the mean length of adult bearded seals from our study and those from other Canadian arctic areas, as well as from the Alaskan waters of the Chukchi and Beaufort seas are very similar. Bearded seals from Svalbard (Benjaminsen 1973) are significantly smaller than those in our study (T=5.71, d.f.=239, P<0.001). It is also likely that the bearded seals described by Kosygin (1966) from the Bering Sea might possibly represent the largest form of this species, with a mean nose-tail length of 239.5 cm.

The total weight of bearded seals is related directly to age and thus to both the length and to the girth of the animal, the latter varying seasonally with the thickness of the blubber layer. Figure 5 shows the biweekly variation in the index of condition (Girth X 100/length) of bearded seals collected in this study for the period 1 June to 30 September. A reduction in the blubber reserve is shown to occur in the mid summer months.

In order to develop a predictive equation for weight from body size, a stepwise multiple regression analysis was run on log transformed nose-tail lengths and maximum girths, as in Usher and Church (1969a). Since adult body size did not differ between Alaskan and Canadian bearded seals, specimens described by Foote (1965) and Usher and Church (1969b), who listed both lengths and girths, were lumped with those of the present study. The multiple regression equation obtained was: log W = 1.4714 log girth + 1.3971 log length - 4.1480. The cumulative proportion of total variation was reduced by 0.953 with these two independent variables, resulting in a multiple correlation coefficient of $R = 0.976$ ($F<0.0001$). The regression equation may be used to estimate weight in the form of:

$$\text{Weight} = \frac{\text{Girth}^{1.4714} \times \text{Length}^{1.3971}}{14060.48}$$

Figure 6 shows the actual weights plotted against the weights estimated from the equation. In general the agreement is quite good. There is a tendency for the estimates to be somewhat low for adolescent seals and high for larger specimens. Since these samples are all taken in the summer when there is possibly a greater variation in the blubber thickness between individuals it might well be that a predictive equation based on bearded seals caught in late fall or winter would be more accurate.

REPRODUCTION

No testes were available for determination of the male reproductive season or age specific sexual status. However 19 bacula were available from the Belcher Island seals taken in 1974-75 (Fig. 7). Although there are no specimens from year classes 1 to 5 the general trend seems to indicate that bacula reach their asymptotic length between 6 and 8 years of age. This agrees with the findings of McLaren (1958a), Burns (1967), and Burns and Frost (1979) who believe that bearded seal males attain sexual maturity between ages 6 to 7 years.

Evidence of ovulation in the form of a corpus luteum is taken as a sign that a female has attained sexual maturity. In addition, corpora albicantia indicate that corpora lutea were present in the previous year. Table 5 lists the number of females of different age classes showing corpora lutea and corpora albicantia. The formula

$$\frac{CL(n) + CA(n+1)}{n+(n+1)}$$

is used to calculate the percentage of females in each age class that are sexually mature, where CL(n) is the number in age class n bearing corpora lutea and CA(n+1) the number in age class n+1 bearing corpora albicantia.

The sample size is too low (n=87) for establishing exact age specific percentages of mature females, especially in the younger age classes.

However the results indicate that bearded seals are capable of ovulating as young as 4+ years of age.

All of the reproductive material was collected between early June and late September, and no clear picture can be obtained of either follicular activity or variation in size of the corpora lutea or corpora albicantia. Based on macroscopic examination only, the corpora lutea in this study appear to be fully luteinized; moreover, no accessory corpora lutea or other abnormalities were noticed.

A decrease in the diameter of the corpus albicans was seen as the summer progressed (Fig. 8b). The maximum number of corpora albicantia observed with a low power dissecting microscope in individual animals was two and this occurred in only 2 out of 42 (4.8%) of the seals examined. It is concluded, therefore, that corpora albicantia usually disappear after one year. Ovulation alternates from one ovary to the other since 43 (98%) of the 44 recently formed corpora albicantia were found in the ovary not containing the corpus luteum.

Four of the 52 females (0.08%) of ages 6+ years or older, were found not to have ovulated. Three of these were females shot together on 5 May 1973 when they were hauled out at a single hole in the landfast ice in northern Amundsen Gulf. Bearded seals in this area are known to spend the winter under the fast ice along pressure ridges formed between Banks Island and Victoria Island. The ovaries of all three females showed a large corpus albicans, but none had a corpus luteum or any follicles greater than 3 mm in diameter. The uterine cornua were assumed to be multiparous, but there was no sign of a recent birth or abortion, and none of the animals was lactating. All three females were in good physical condition with a blubber layer over the sternum 7 mm or more in thickness. One other female of 12+ years, collected in open water in Ungava Bay on 22 June 1960, had not ovulated. This animal had a corpus albicans in one ovary with the largest follicle less than 3 mm in diameter.

Fourteen foetuses were available from the material examined. Nose-tail lengths were combined with similar measurements of eight other foetuses from the eastern arctic reported by McLaren (1958a). Assuming 1 May as the "mean mating date", linear regression of foetal length on days after mating resulted in the foetal growth equation, $y = -144.036 + 1.801(x)$. Although the date is seen to explain a significant part of the variance ($F = 7.26$, $P<0.01$) the correlation coefficient $r = 0.66$ is low, indicating that this is in fact a poor predictive equation for foetal length. This is obviously caused by the lack of foetal lengths for the winter and the later part of the gestation period. Thus the equation does not give realistic predictions of length at birth.

In order to improve the equation, data on foetal lengths from Alaska (Johnson et al. 1966; Burns and Frost 1979) were added (Fig. 9).

The resulting equation, $y = -578.69 + 5.21(x)$, was highly significant ($F = 1968.62$, $P<0.001$) and a high correlation coefficient $r = 0.99$ was obtained from those pooled data. The predicted length of the foetus at birth is 132.3 cm which agrees well with the data of Burns and Frost (1979).

Using the above equation and following the method of Huggett and Widdas (1951), as described by Hewer and Backhouse (1968), it is estimated that bearded seals have an active gestation period of about 301 days with a period of suspended development, or delayed implantation, of 64 days. The embryo, once implanted, grows at a rate of 4.41 cm per day and the spread in implantation date, as shown by the material from the eastern Canadian arctic, is in the order of 58 days.

The rate of reproduction can be calculated either by assuming that all ovulations, as indicated by the presence of corpora lutea, result in pregnancies or by using the percentage of mature animals, collected after the mean date of implantation, that bear a recognizable embryo or foetus. If the presence of corpora lutea and corpora albicantia are assumed to indicate that the animals were pregnant, the mean rate of reproduction for the bearded seals in this study is 0.86 (Table 5), similar to the results of Burns and Frost (1979). However, they note that this approach overestimates the reproductive rate since in the younger age classes (3- and 4-year-olds) ovulation does not result in pregnancy, as shown by the condition of the reproductive tract and by the absence of corpora albicantia. Calculating the reproductive rate from the percentage of pregnant females taken after the period of delayed implantation (mid August) yields an estimate of 0.64 (7/11), which is thought to err on the low side. It is not possible with the small amount of material available in this study to derive an accurate estimate of the overall reproductive rate, but both methods indicate that most of the bearded seals in the Canadian arctic reproduce annually.

POPULATION STRUCTURE

Materials from this study were divided into two groups: (1) the western arctic area, including Amundsen Gulf (Holman) and the southeastern Beaufort Sea (Brown's Harbour, Sachs Harbour and Herschel Island); and (2) the Hudson Bay region (Belcher Islands, Southampton Island, Igloolik, Ungava Bay and Cape Dorset).

The sample of seals from Hudson Bay showed a preponderance of females with a significant departure from a one to one sex ratio (Table 6). A further breakdown of the Hudson Bay sample into young of the year (0+), adolescents (1+ to 5+), and adults (6+) was analysed. While adolescent and adult females were noticeably more numerous, the sex ratio in these cases did not significantly depart from unity.

Of the 63 animals whose ages were determined from the cementum lines, the oldest was a 25 year old female collected at the Belcher Islands.

The oldest male was 23 years of age and was collected near Winton Bay on the coast of eastern Baffin Island. The age structures of seals collected in the open water of the western Canadian arctic and Hudson Bay were examined by grouping the ages into young of the year, (0+), adolescents (1+ to 5+ years), and adults (6+ and older). The smaller western arctic sample shows an almost equal representation of the three age groups, while the Hudson Bay sample shows a preponderance of adult seals with a very low proportion of pups and adolescents (Fig. 10).

Most of the seals collected in Hudson Bay were shot from June to early October. A monthly examination of the age structure indicates a preponderance of adults throughout the summer, with an increase in the percentage of adolescents from June to a peak in July. Young of the year also reach their peak percentages in July and then drop off noticeably (Fig. 11). In the few samples taken in the winter and early spring months from both areas, 16 out of 19 (84%) were young of the year or adolescents. These seals were shot while lying on the ice near their breathing holes or cracks, or in the water near the floe edge.

FEEDING

A total of 106 stomachs containing food was examined. Food items and their percentage occurrence are listed in Table 7. Whenever possible the organisms were identified to species. Only the Hudson Bay sample was large enough to be considered representative of the food spectrum of the bearded seal. There, 28 different food items were identified. Food items ranked in order of importance, based on percentage occurrence, were: Decapoda (49%), Pelecypoda (34%), Fish (29%), Holothuroidea (14%), Gastropoda (7%), and Polychaeta (5%).

All food items were either benthic, hyperbenthic or fish. From 35 seals taken at the Belcher Islands the mean percentage volume of stomach contents was: 70% benthos, 17% fish, and 13% parasitic Cestoda and Nematoda.

Of the decapod crustacea, *Sclerocrangon boreas* was most common in the east Baffin coast sample, whereas crabs, *Hyas coartacus*, and *Argis dentata* were most frequently found in the sample from the Belcher Islands. Hippolytid decapods were most common in the Foxe Basin sample.

The pelecypod most frequently identified in our samples was *Clinocardium ciliatum*, which occurred in Hudson Bay and once in a high arctic locality (Creswell Bay, Prince Regent Inlet). *Serripes* sp. was recorded only once, from the Foxe Basin sample.

The most frequently identified fish was *Boreogadus saida*, which appeared equally important in all localities. Less frequently found fish include sculpins, Myoxocephalus scorpius, Gymnocanthus tricuspis; lumpfish, Eumicrotremus spp.; eelpouts, Lycodes sp.; fish doctors, Gymnelis viridis and unidentified blennies, Blennioidei.

Holothuroideans were not recorded from the recent Baffin Island sample, but they were common in stomachs from Hudson Bay and they also occurred in stomachs from Amundsen Gulf. The only species positively identified was Cucumaria frondosa from the Belcher Islands. Gastropod opercula and feet were found in all but the Belcher Island sample. Buccinum sp. was identified from Foxe Basin. Polychaetes were commonly found in stomach contents, but never in significant amounts, and none were identified to genus.

Only the Belcher Island sample was documented in a semi-quantitative manner. Of 54 stomachs examined, 19 (35%) were empty. No significant difference was found in the proportion of empty stomachs between young of the year and older animals. A greater proportion of empty stomachs was seen in the winter sample from the Belcher Islands (5/11, or 45%), but this was not significantly different from the number of empty stomachs in the summer (14/43, or 33%; chi square = 3.20, P>0.05).

DISCUSSION

Bearded seals are generally thought to reside in areas of pack ice and reoccurring polynyas. Such regions as Foxe Basin, Hudson Strait and northern Hudson Bay appear to support greater numbers of this species than other regions in the Canadian arctic. It is not clear whether the high numbers of bearded seals reflect the presence of open water in the winter or whether they are more directly related to high benthic production in these localities. The latter is probably the proximate factor influencing the distribution and abundance of bearded seals since they have been observed to overwinter in fast ice areas elsewhere. In Amundsen Gulf, bearded seals are known to inhabit pressure ridges and refrozen leads during the winter and to appear in the same general areas year after year. Breathing holes occupied by bearded seals are similar to those of ringed seals, but are distinguishable by the presence of bottom soil frozen into the ice dome. Both ringed and bearded seals are found in close association in such situations. Bearded seals open up their holes with the claws of the foreflippers, as do ringed seals, and they are sometimes seen to haul out onto the ice as early as late March. No subnivean lairs of bearded seals have been found and pupping appears to occur only on the surface of the ice in May. In the high arctic, bearded seals are known to overwinter in the fast ice adjacent to polynyas (Stirling, Cleator and Smith 1981). Some of these localities support overwintering populations of walruses, indicating the probable existence of abundant benthic food. The biological productivity of such areas of open water in the winter is not well understood.

Manning (1974), from a study of the craniometry of bearded seals, assigned Alaskan and Canadian arctic specimens to two separate subspecies, E. b. nauticus, and E. b. barbatus. Results from the present study fail to detect any significant size differences between specimens from the two areas, even though it is generally accepted that the Chukchi and western Beaufort seas have much higher benthic productivity than the marine waters of the Canadian arctic.

Female reproductive material examined in this study indicates that first ovulation occurs at 4+ years old, with 100% of animals 7 years and older being sexually mature. A reproductive rate as high as 0.86 is indicated, though the limited number of samples does not permit accurate assessment of this parameter. These results differ from those of McLaren (1958a), who concluded that Canadian eastern arctic bearded seals attained sexual maturity at 6+ years of age and reproduced only every other year. Only one sample in the present series, that of three adult but non-pregnant bearded seals shot together in early May at the same hole in the fast ice of Amundsen Gulf, indicates that reproduction might not occur every year. In such a situation, where resources might be limiting to discrete subpopulations, reproductive control of this sort might be advantageous. The high frequency of underwater vocalization and spatial aggregation of bearded seals probably indicate a highly developed social structure, which could mediate such density dependent adjustments.

While there were significantly more adult females than males in the Hudson Bay sample, the causes are not apparent. Several other studies have indicated that females are more numerous in the catches (Table 6). Burns and Frost (1979) explain this by noting that male mortality rates are higher. Other factors such as increased vulnerability of females at certain times of the year or differential segregation of the sexes might also be involved.

The age structure of bearded seals shot during the open water period appears to be heavily biased toward adults while winter and early spring samples from the floe edge are biased toward adolescent or young of the year. It is possible that the preponderance of adults in the summer harvest reflects a real segregation in the distribution of different age classes. Adults, which apparently feed predominantly on benthic and hyperbenthic organisms, might actively exclude the adolescent bearded seals from nearshore areas in the summer. There is a limited amount of support for this assumption from the observations of Lowry et al. (1980) who indicate that adolescents feed more on pelagic food organisms.

The most important food items of bearded seals in Hudson Bay were decapod crustacea, pelecypod molluscs and fish, mainly the arctic cod, Boreogadus saida. No information was available on seasonal changes in food items, but observation of seals far offshore in the Beaufort Sea (Stirling and Archibald 1977) and in Davis Strait (Koski 1980) probably indicates a shift to fish feeding in the winter months by some or all age classes. This has been documented in some Alaskan studies (Johnson et al.

1966; Lowry et al. 1980). In areas where bearded seals remain in the land-fast ice throughout the winter, it is possible that they continue to exploit a patchy but productive benthic food resource. In Amundsen Gulf bearded seals in such situations appear to feed mainly on Holothuroidea and Cephalopoda.

The bearded seal is one of the least visible of the Canadian arctic phocid seals, but it is the most actively vocal, with a varied underwater repertoire. First described by Dubrovskii (1937) and then by several other authors, (Freuchen 1937; Poulter 1966; Ray, Watkins and Burns 1969), the frequency modulated sounds are often heard where no bearded seals are observed. This is the case in both open water and in areas of land-fast ice. While no systematic studies have yet been conducted on this aspect of their behavior, vocalizations appear to be most frequent in the spring and early summer months. The function of these sounds is not known, but might well be involved in partitioning of feeding and breeding habitats. Because of the patchy distribution of bearded seals and the difficulty in deriving estimates of their numbers by aerial surveys, systematic underwater recordings might be developed into an important tool for population studies. Behavioral studies on the production and function of underwater sounds, both in the wild and on captive bearded seals, might provide important new insights into the ecology of this poorly understood species.

Current offshore developments in such areas as the southeastern Beaufort Sea include plans for removal of large amounts of nearshore bottom deposits near areas where bearded seals are known to overwinter. The patchy distribution of this species and its probable dependence on local areas of high benthic productivity make it liable to severe disturbance by such activities. Studies should be initiated to define the ecological niche of these possibly discrete local populations of bearded seals.

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Table 1. Location and numbers of bearded seal specimens included in this study.

Location	Coordinates	Year	Number of specimens
Barrow Strait		1975	4
Beekman Peninsula	(63°17'N, 64°03'W)	1973	7
Belcher Islands	(56°12'N, 79°19'W)	1960	7
		1974	59
		1975	9
Cape Dorset	(64°14'N, 76°33'W)	1955	6
Coppermine	(67°49'N, 115°05'W)	1973	1
Coral Harbour	(64°09'N, 83°22'W)	1955	9
		1956	6
Cumberland Sound	(64°14'N, 76°33'W)	1966	5
		1969	10
Darnley Bay	(70°03'N, 124°22'W)	1972	3
		1977	3
Herschel Island	(69°35'N, 139°02'W)	1971	1
Holman	(70°39'N, 117°45'W)	1971	13
		1972	1
		1973	1
		1975	3
		1977	1
Igloolik	(69°12'N, 81°18'W)	1961	11
		1968	31
		1969	39
Poste-de-la-Baleine	(55°15'N, 77°45'W)	1978	5
Sachs Harbour	(71°58'N, 125°15'W)	1972	25
Total			260

Table 2. Harvests of bearded seals from the major hunting areas in the Canadian arctic (* are from Anon. 1974, while percentages in parentheses are from the separate studies indicated).

	Number of years with records	Mean number of bearded seals caught	Mean number of bearded seals expressed as a percentage of ringed seals taken or counted
High Arctic			
Alexandra Fiord	2	13	7.98
Grise Fiord	6	25	3.79
Resolute Bay	9	26	6.91
Western Arctic			
Holman	1	16	0.30
Sachs Harbour	7	50	5.00 (5.53; Stirling et al. 1977)
Central Arctic			
Cambridge Bay	2	7	1.21
Coppermine	1	3	0.08
Gjoa Haven	1	6	1.65
Pelley Bay	1	5	1.73
Spence Bay	1	22	3.74
Hudson Bay			
Akudlivik (Cape Smith)	2	151	12.51 *
Chesterfield Inlet	1	12	3.42
Coral Harbour	1	54	4.82
Eskimo Point	3	96	9.73
Inoucdjouac (Port Harrison)	2	167	7.19 *
Poste-de-la-Baleine (Great Whale River)	2	73	6.03 *
Rankin Inlet	2	9	2.04 *
Repulse Bay	2	29	4.33 *
Whale Cove	2	70	8.45 *
Hudson Strait, Foxe Basin, Ungava Bay			
Cape Dorset	6	120	3.91 (4.50; McLaren 1958b)
Fort Chimo	2	255	33.91 *
George River	2	111	17.48 *
Igloolik	6	64	2.79 (18.00; Beaubier 1970)
Koartac	2	49	5.47 *
Lake Harbour	4	93	3.48
Leaf Bay	2	55	25.82 *
Payne Bay	2	277	29.67 *
Port Burwell	2	87	11.03 *
Saglouc	2	251	15.86 *
Wakeham Bay	2	301	6.26 *(18.8; McLaren 1958b)
Eastern Arctic			
Cape Christian	5	22	1.20
Frobisher Bay	6	40	1.84 (7.69; McLaren 1958b)
Pangnirtung	7	54	0.58
Pond Inlet	6	50	1.58

Table 3. Age determined from the claws of the hind flippers of bearded seals compared to ages from the claws of the fore-flippers or teeth of the same seal.

Age from hind claws	Age from front claws	Age from teeth
0+	0+	
5+	7+	7+
5+	7+	
6+	6+	
6+		6+
8+		9+
9+		10+
9+		14+

Table 4. Nose-tail measurements of bearded seals from several different studies.

Study	0+ year old	1+ to 5+ years old	6+ years and older
Present study	153 (15.14, 19)	192.62 (15.49, 26)	230.75 (8.11, 84)
Canadian Arctic			
Eastern Canadian Arctic McLaren (1958a)	141.64 (15.0, 11)	183.92 (16.81, 13)	230.63 (10.27, 35)
Belcher Islands (present study 1975-75)	162.0 (10.21, 10)	196 (14.24, 4)	230.7 (16.71, 22)
Chukchi and Beaufort Seas Foote (1965), Burns (1967)	152 (14.06, 14)	190.0 (17.82, 13)	230.76 (9.58, 21)
Svalbard Benjaminsen (1973)	160.0 (5.5, 4)	190 (15.01, 29)	224.7 (14.02, 155)
Bering Sea Kosygin (1966)	160.5 (---, 11)	193.5 (---, 82)	239.5 (---, 102)

Table 5. Age specific number of female bearded seals bearing corpora lutea and corpora albicantia, with the calculated percentage of sexually mature individuals per age class.

Age	Number	Number with corpora lutea	Number with corpora albicantia	Percentage sexually mature $\left(\frac{CL(n) + CA(n+1)}{n + (n+1)}\right)$
0	14	0	0	0
1	5	0	0	0
2	5	0	0	0
3	1	0	0	0
4	2	0	0	40.0
5	3	3	2	44.4
6	6	6	1	100.00
7	3	2	3	72.7
8	8	8	6	95.4
9	14	13	13	85.7
10	7	7	5	94.4
11	11	10	10	93.3
12	4	3	4	83.3
13	2	2	2	100.0
14 or older	2	2	2	100.0

Table 6. Sex ratios of bearded seals from the western Canadian arctic, Hudson Bay and several other areas.

Area and source	Number of females	Number of males	Chi square	P
Western Canadian arctic (present study)	28	18	2.35	>0.1
Hudson Bay (present study)	117	87	4.41*	<0.05
Kara and Barents seas Chapsky (1938)	53	58	0.23	>0.5
Sea of Okhotsk Pikharev (1940)	138	166	2.58	>0.05
Sea of Okhotsk Sleptsov (1943)	330	213	25.69*	<0.005
Alaska 1962-1966 Burns and Frost (1979)	113	92	7.35*	<0.01
Alaska 1975-1978 Burns and Frost (1979)	400	327	7.54*	<0.01
Sea of Okhotsk Fedoseev (1973)	410	335	7.76*	<0.01

Table 7. Food species and percent occurrence (number of stomachs with species present / total stomachs examined containing food) for the eastern Canadian arctic, Hudson Bay (Belcher Islands and Foxe Basin), and the western Canadian arctic (Amundsen Gulf).

Food species	Percent occurrence: Eastern arctic	Hudson Bay: Foxe Basin	Hudson Bay: Belcher Islands	Western arctic
Nemertinea (unidentified)	13% (1/8)			
Polychaeta (unidentified)	25% (2/8)	8% (5/60)		33% (1/3)
Gastropoda (unidentified)	25% (2/8)	12% (7/60)		33% (1/3)
Buccinum sp.		3% (2/60)		
Pelecypoda (unidentified)	38% (3/8)	27% (16/60)	31% (11/35)	33% (1/3)
Clinocardium ciliatum		3% (2/60)	11% (4/35)	
Serripes sp.		2% (1/60)		
Cephalopoda (unidentified)		5% (3/60)	0.03% (1/35)	
Gonatus fabricii	13% (1/8)			
Rossia sp.				66% (2/3)
Bathypolypus arcticus	13% (1/8)			
Mysidacea				
Mysis oculata	13% (1/8)		3% (1/35)	
Isopoda				
Mesidotea sabini	13% (1/8)			
Arcturus sp.		5% (3/60)		
Amphipoda (unidentified)		2% (1/60)		
Anonyx nugax	13% (1/8)		3% (1/35)	
Atylus carinatus	13% (1/8)			
Rhachotropis aculeata	13% (1/8)			
Stegocephalus inflatus	13% (1/8)			
Euphausiacea (unidentified)		2% (1/60)		
Decapoda (unidentified)		60% (36/60)	31% (11/35)	
Crangonidae				
Argis dentata	13% (1/8)		29% (10/35)	
Sclerocrangon boreas	38% (3/8)	2% (1/60)		
Hippolytidae (unidentified)	13% (1/8)	5% (3/60)	6% (2/35)	
Spirontocaris spinus	13% (1/8)	2% (1/60)	6% (2/35)	33% (1/3)
Lebbeus groenlandicus			3% (1/35)	
Lebbeus polaris	25% (2/8)			33% (1/3)
Brachyura (unidentified)			31% (11/35)	
Majidae				
Hyas coarctatus			6% (2/35)	
Echinoidea				
Strongylocentrotus droebachiensis			3% (1/35)	
Holothuroidea (unidentified)		18% (11/60)		33% (1/3)
Cucumaria frondosa			6% (2/35)	
Fish (unidentified)	25% (2/8)	18% (11/60)	49% (17/35)	66% (2/3)
Boreogadus saida	25% (2/8)	7% (4/60)		
Cottidae (unidentified)	25% (2/8)	3% (2/60)		
Cyclopteridae (unidentified)		3% (2/60)		
Agonidae (unidentified)	13% (1/8)			
Plant material (unidentified)	13% (1/8)		3% (1/35)	

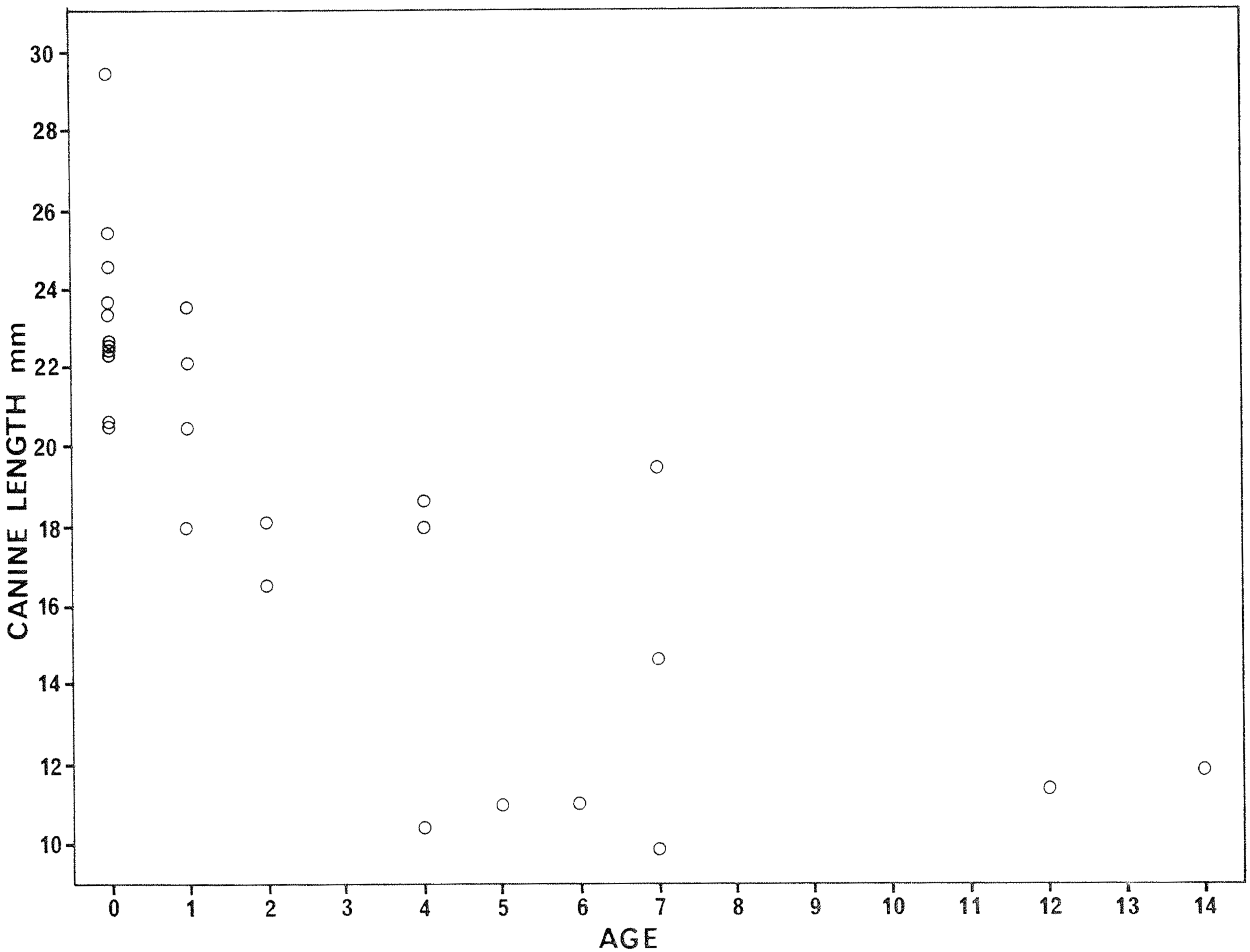

Fig. 1 Length of the lower canine of bearded seals with age.

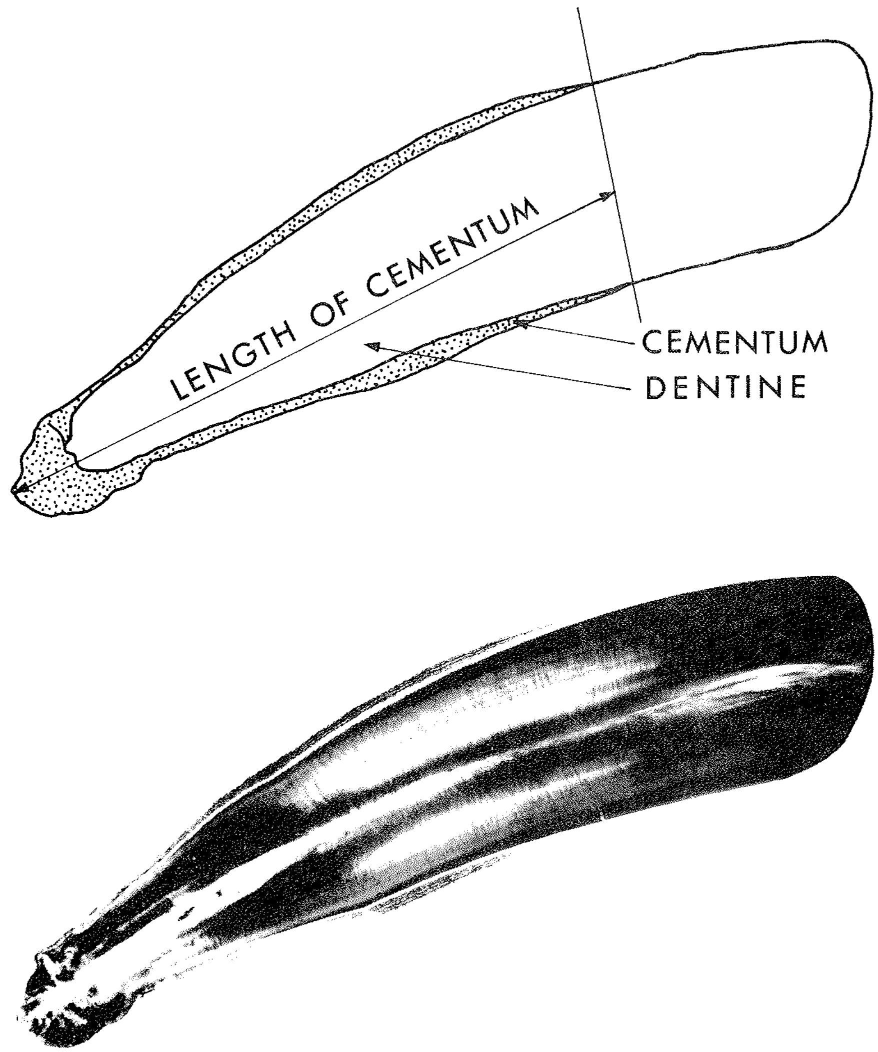

Fig. 2a A diagram and photograph of a long section of the canine tooth of a bearded seal (Erignathus barbatus) showing the main tissues, structures and methods of measurement.

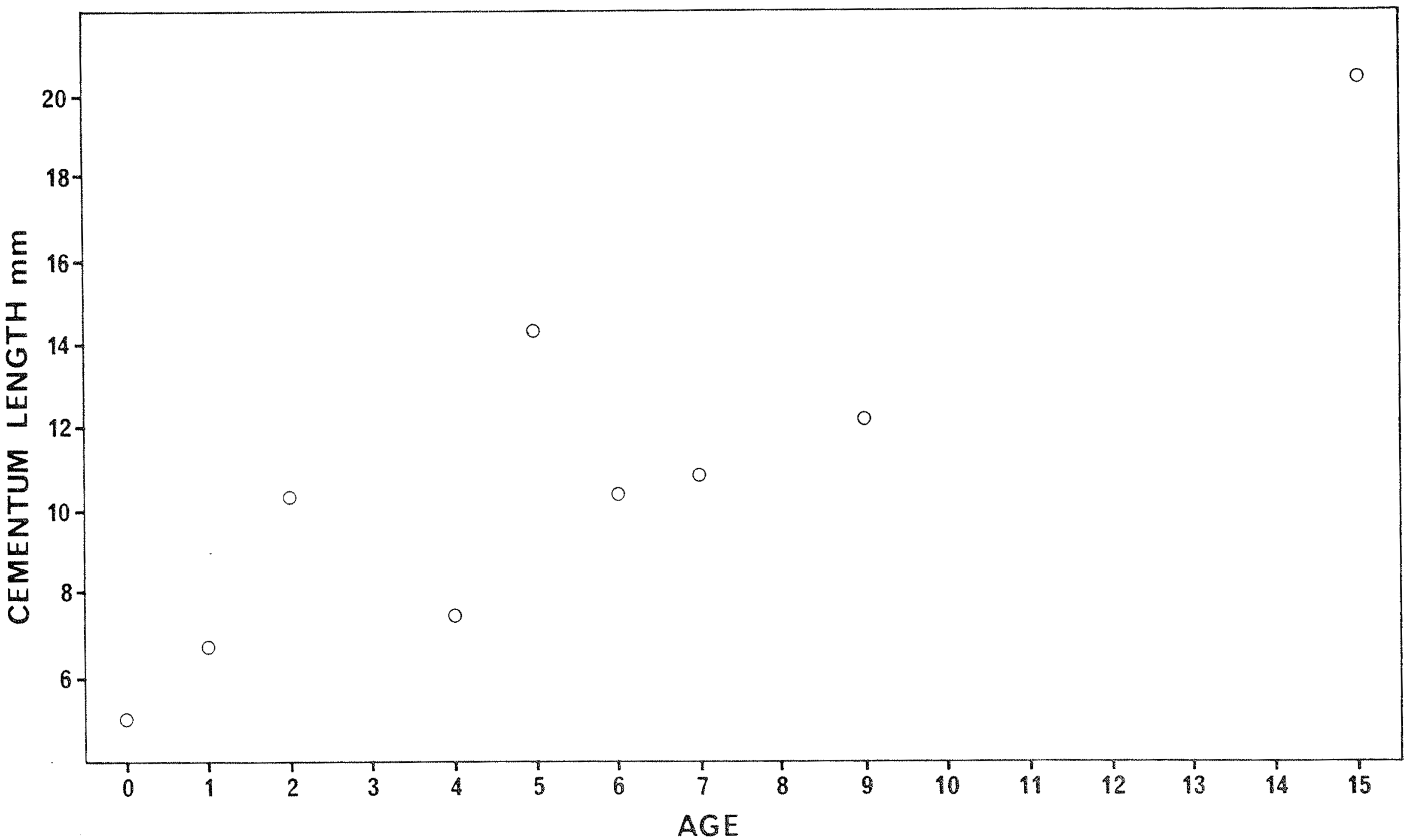

Fig. 2b Increase in length of the lower canine cementum zone with addition of cementum layers.

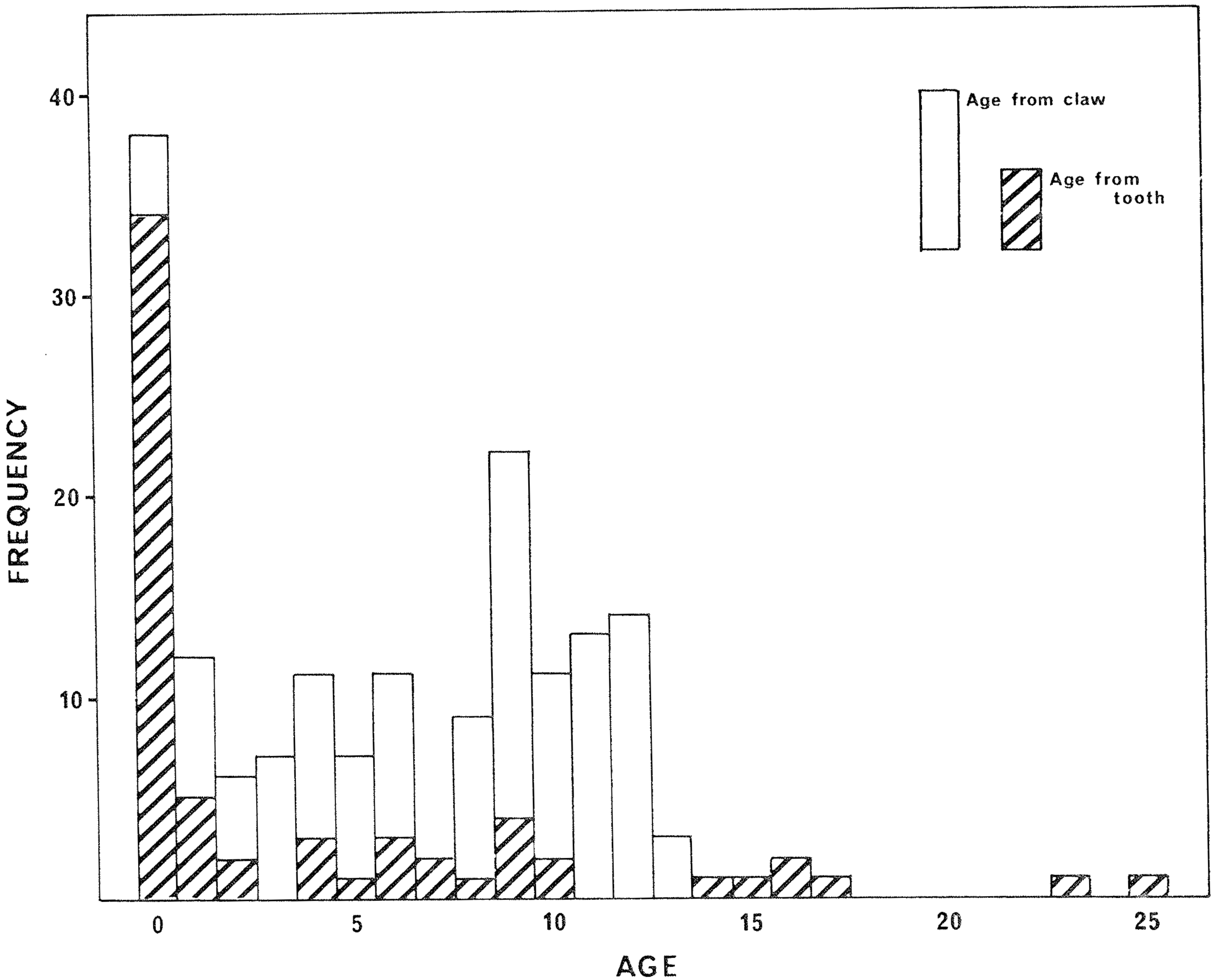

Fig. 3 Frequency of age classes of bearded seals as determined by fore claws and teeth.

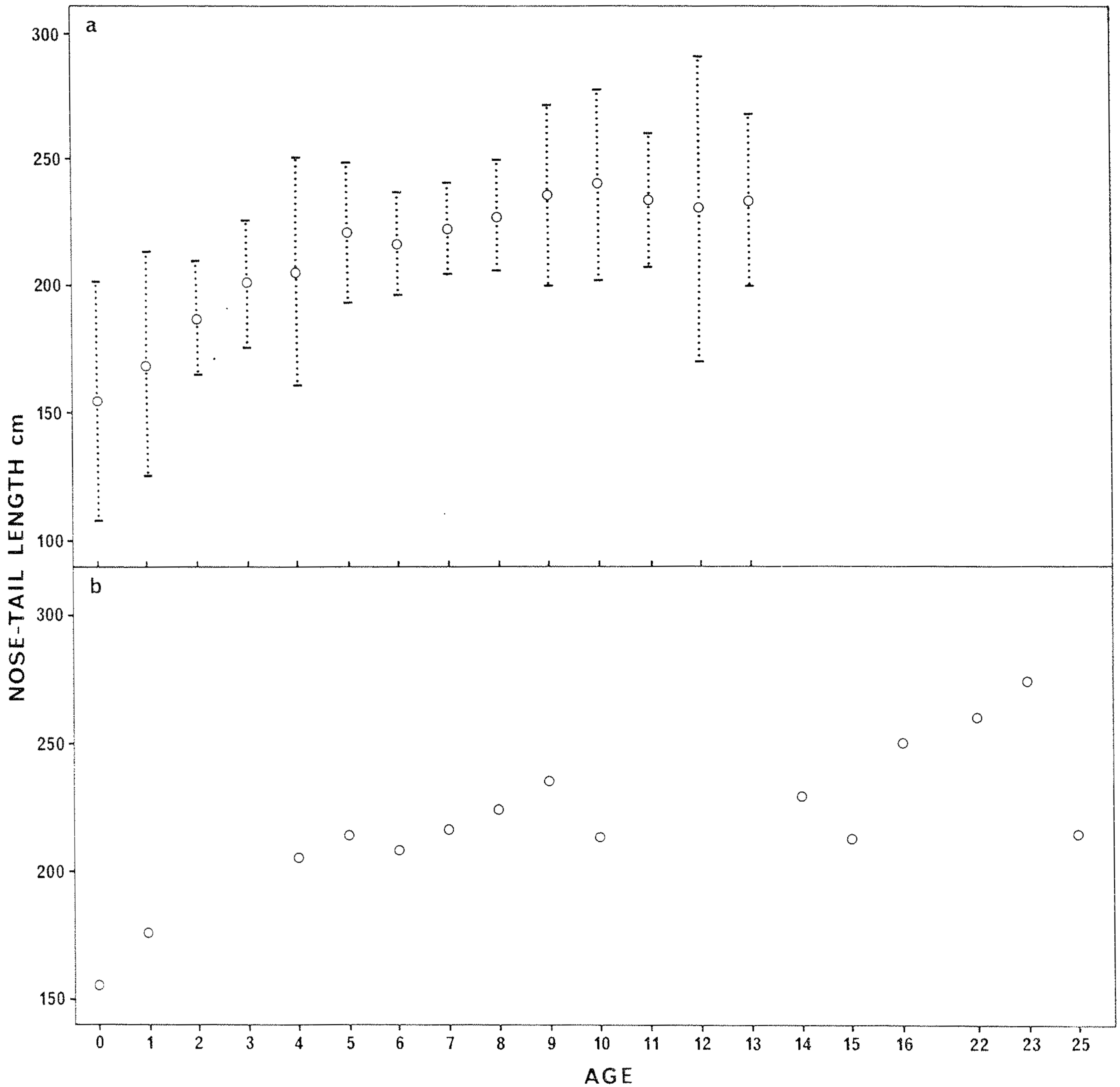

Fig. 4 Relation of nose-tail length of bearded seals to age determined from (a) claws of the foreflipper, and from (b) cementum lines in the teeth. (⊢·········○·········⊣ = 95% confidence interval.)

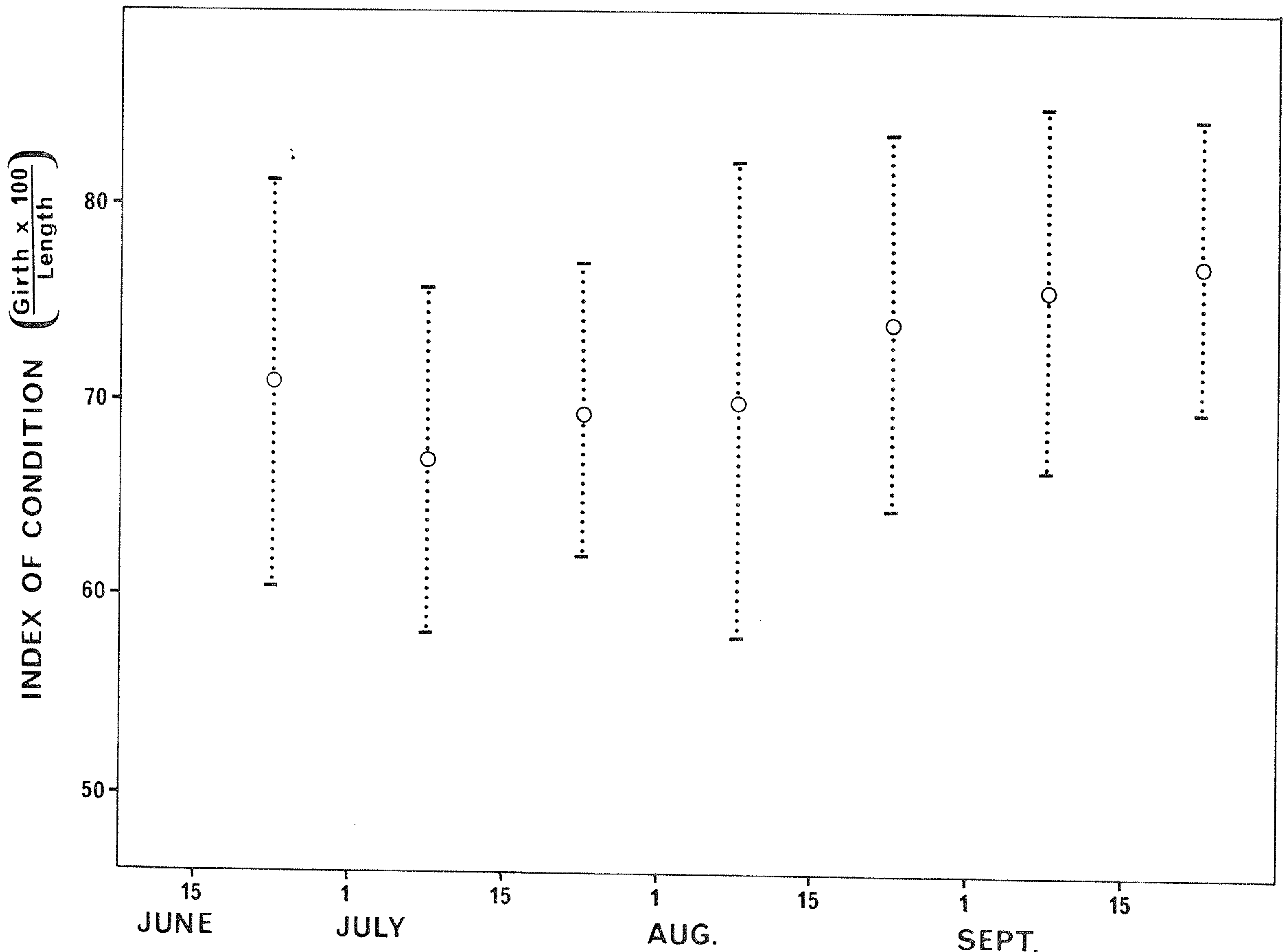

Fig. 5 Seasonal variation in the index of condition of bearded seals in the Canadian arctic.

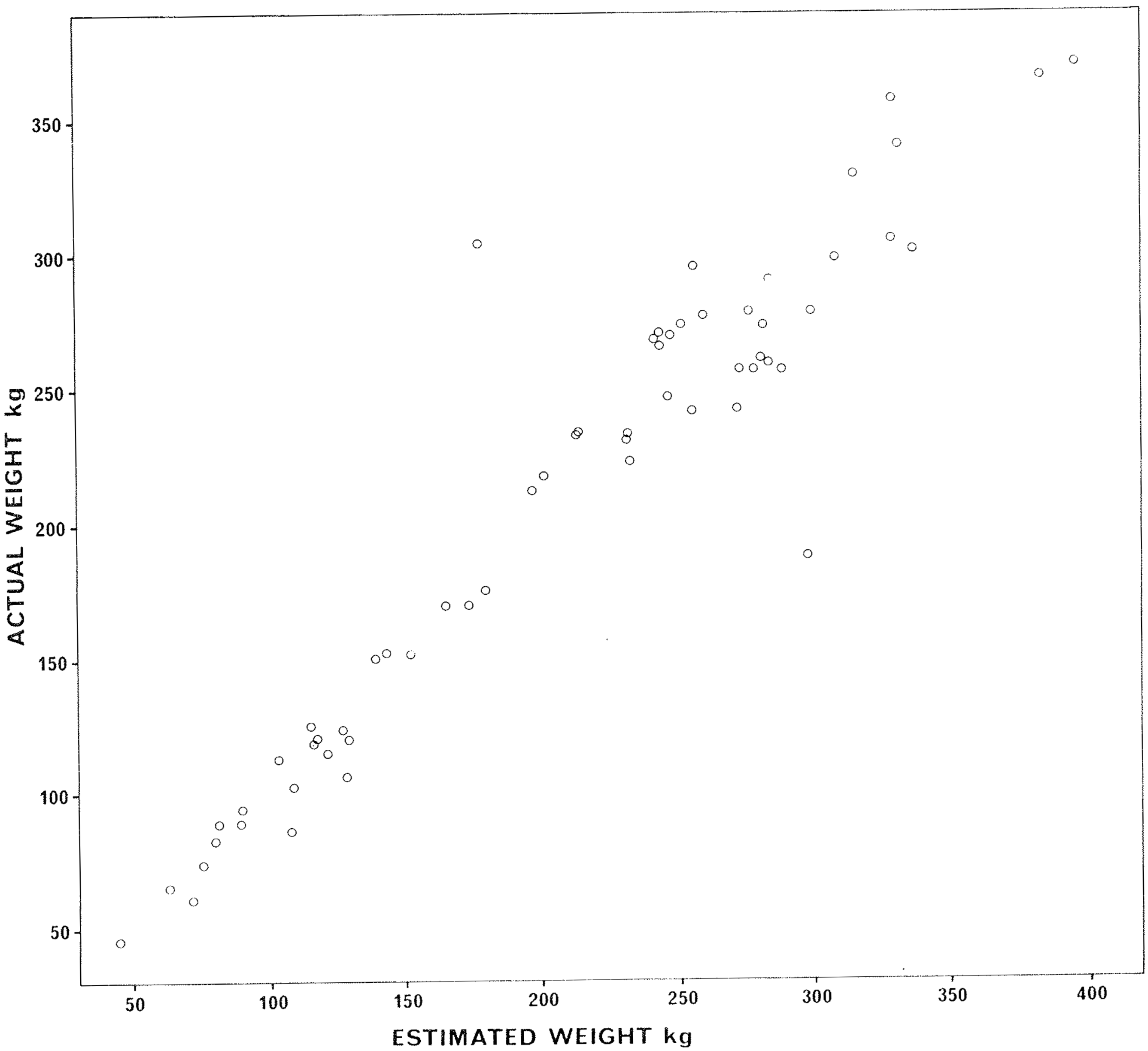

Fig. 6 Actual weights plotted against estimated weights derived from the equation incorporating nose-tail length and girth (log W = 1.4714 log girth + 1.3971 log length - 4.4180).

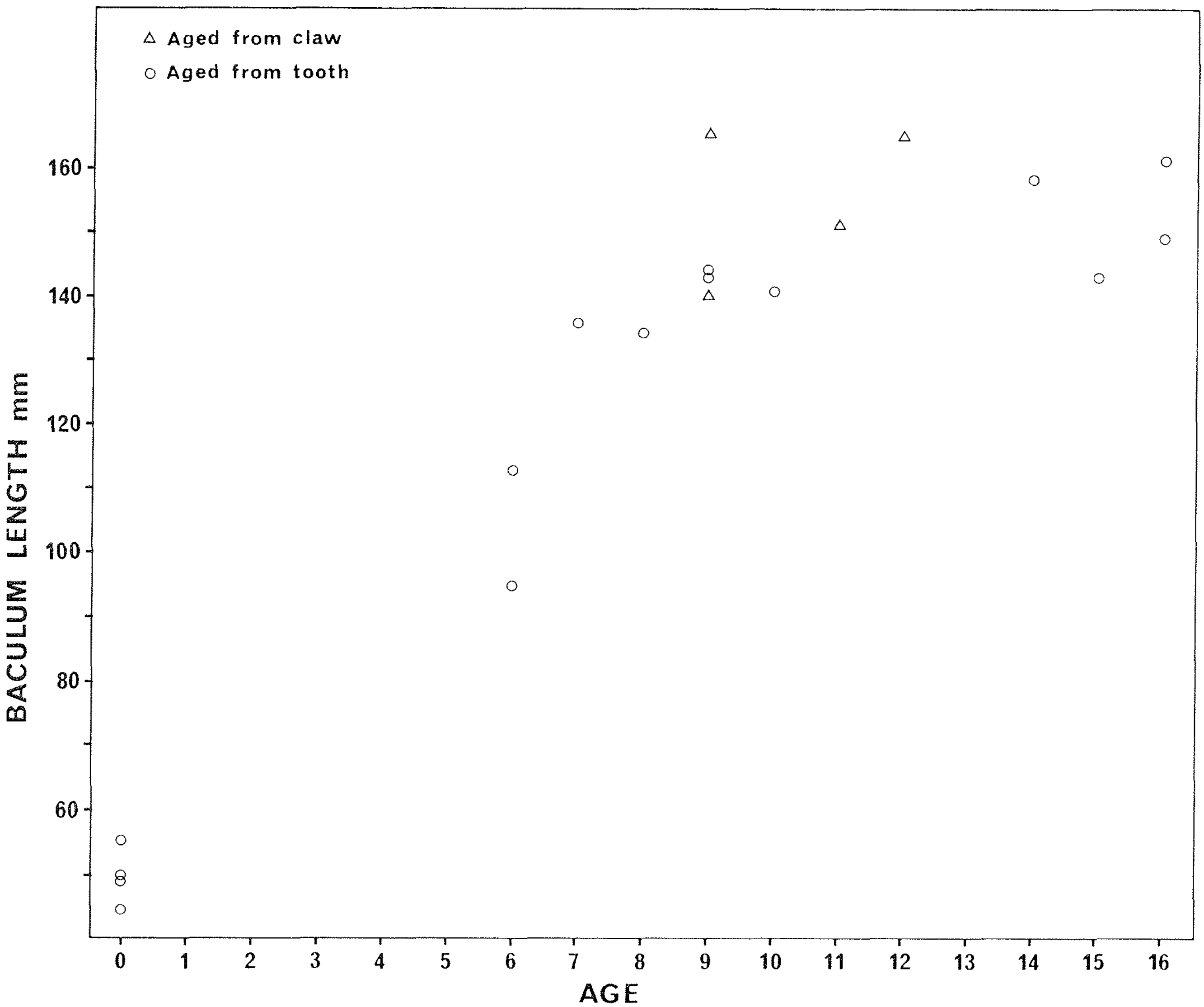

Fig. 7 Lengths of bacula of bearded seals of different ages taken from the Belcher Islands (Hudson Bay) in 1974-75.

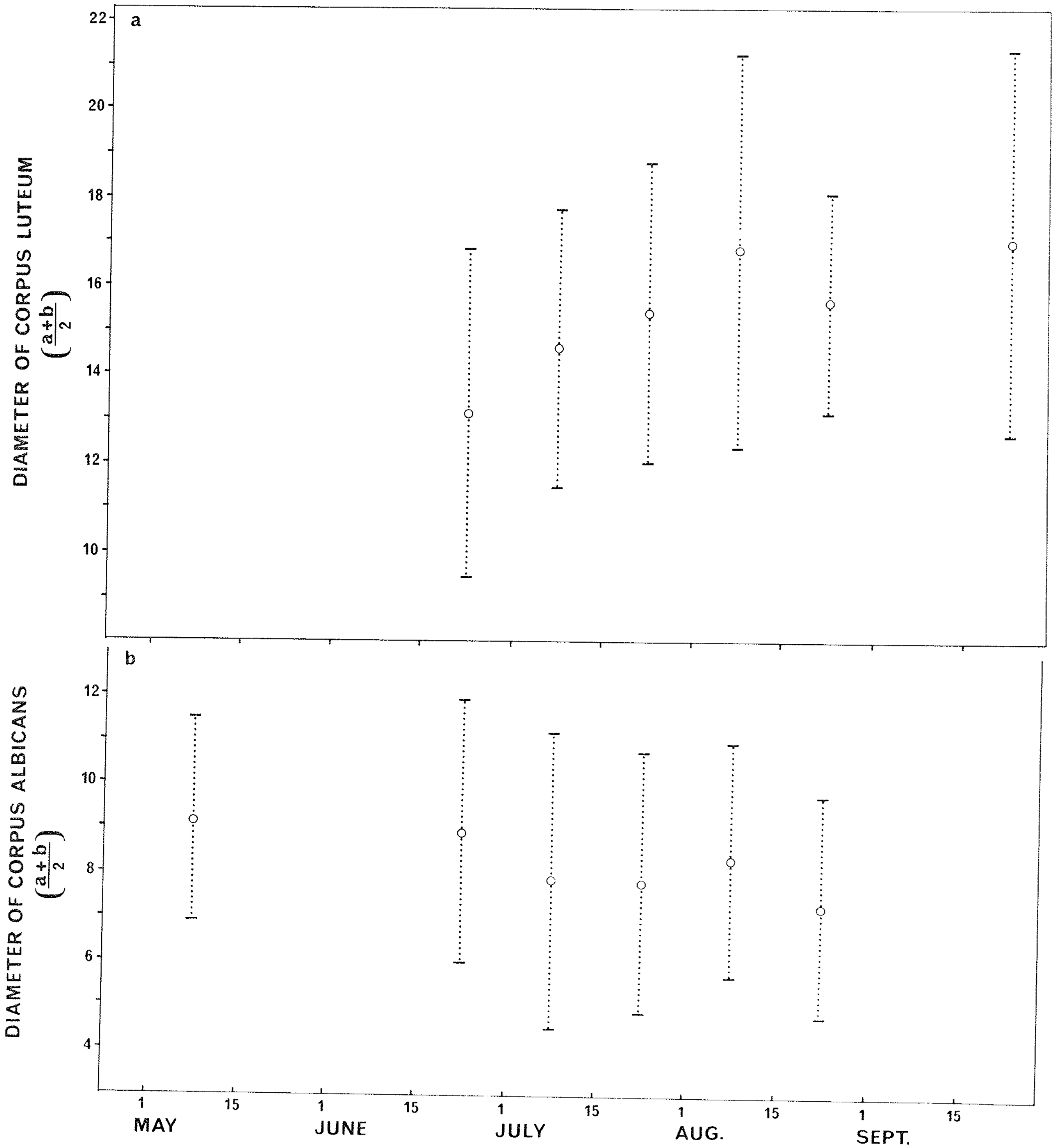

Fig. 8 Seasonal change in the diameter (A + B = two maximum diameters of the corpus) of (a) corpora lutea and (b) corpora albicantia of bearded seals. (I··········O··········I =95% confidence interval).

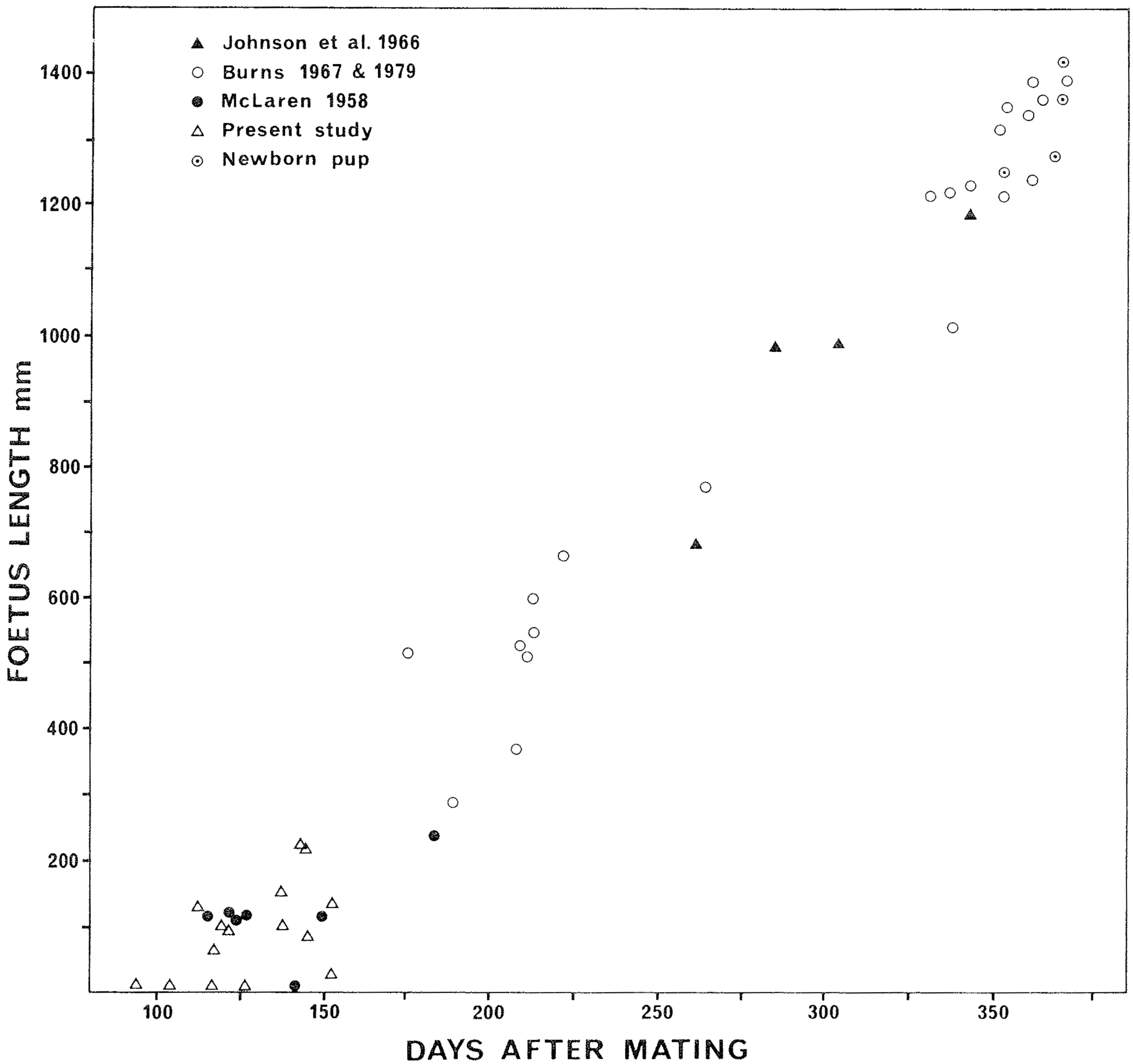

Fig. 9 Regression of foetal length with time. May 1 is considered to be the mean mating date.

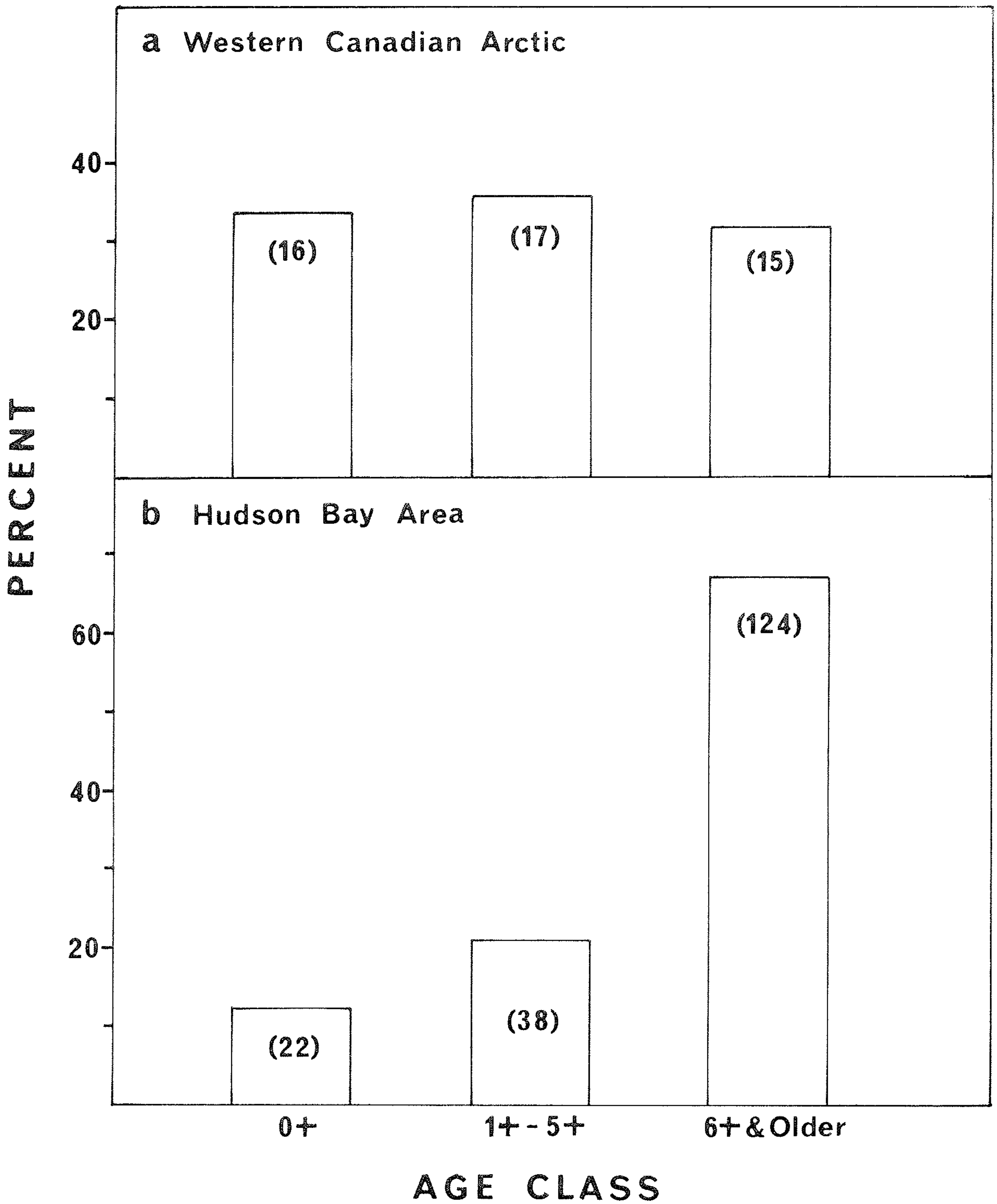

Fig. 10 Percentage of pups (0+), adolescents (1+ to 5+) and adults (6+ and older) taken in the catches of bearded seals from open water during June to November in (a) the western Canadian arctic, and (b) Hudson Bay. ( ) = sample size.

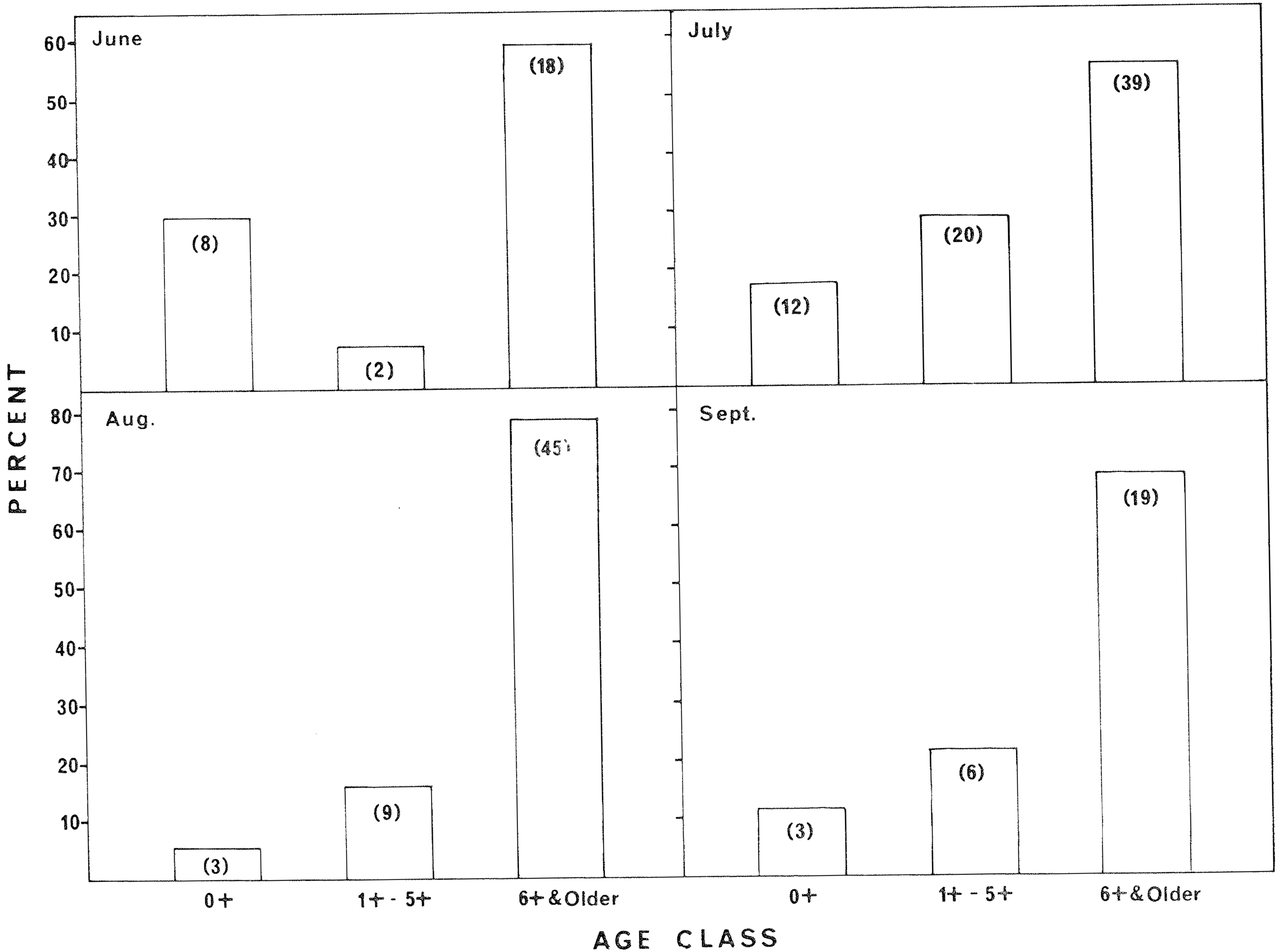

Fig. 11 Seasonal distribution of pups (0+), adolescents (1+ to 5+) and adult (6+ and older) bearded seals in the catches from the Hudson Bay area. ( ) = sample size.