Ph. D. Marine Sciences

by T. G. Smith

Suggested short title:

Ringed Seal Population Dynamics

ABSTRACT

Population Dynamics of the Ringed Seal in the Canadian Eastern Arctic

A total of 10,856 individual ringed seal specimens was obtained from the Home Bay and Cumberland Sound areas, on the east coast of Baffin Island, N.W.T., during a population dynamics study started in 1966. Tooth structure, important in age determination, is described in detail. The reproductive biology was studied and the annual reproductive cycle is described. The seasonal distribution of seals shows an offshore dispersion of young seals in the winter, the fast ice being occupied by breeding adults. An aerial survey combined with behavioral observations gives population estimates of 70,684, 36,376 and 58,782 seals, for Home Bay, Hoare Bay and Cumberland Sound. Best estimates of age-specific survivorship and fertility values were applied to a computer population projection model. Intrinsic rates of $r = 0.016798$, $b = 0.25726$ and $d = 0.188928$ were obtained for the exploited Home Bay population. A hypothetical unexploited population had rates of $r = 0.109007$, $b = 0.197074$, $d = 0.088067$. The best estimate of the sustainable yield was calculated to be 8.84 percent. The Home Bay population was found to be exploited at a level of 7.20 percent, while the Cumberland Sound population is being overexploited, since 15.70 of the population is harvested annually. This however is possible since an estimated minimum of 4,142 seals, produced by the adjacent unexploited coastline, come into Cumberland Sound annually.

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This study has dealt with over 10,000 specimens of ringed seals, the greater proportion of which were bought from local Eskimo hunters. This approach has resulted in the gathering of the largest number of Phocid specimens in any study that the author is aware of, and one of the most complete year-round samples taken of Pinnipeds on the whole. Both the large sample size and the year-round gathering of specimens has permitted the estimation of realistic vital statistics for the population.

The development of seven computer programs have helped greatly in sorting and ordering the large amount of data gathered during this study. The population projection programs SIMI3 and SIMI4 permit the calculation of intrinsic rates for the exploited populations and also allow estimation of intrinsic rates for hypothetical unexploited populations. Various effects of change in survivorship and fertility patterns can also be tested using these programs. Finally, this approach has permitted the calculation of a realistic sustainable yield for a ringed seal population.

Ph.D.

Marine Sciences

McGill University Thomas G. Smith

Population Dynamics of the Ringed Seal in the Canadian Eastern Arctic

by T. G. Smith

A thesis submitted to the Faculty of Graduate Studies
and Research, McGill University, in partial fulfillment
of the requirements for the degree of Doctor of Philosophy
in Marine Sciences

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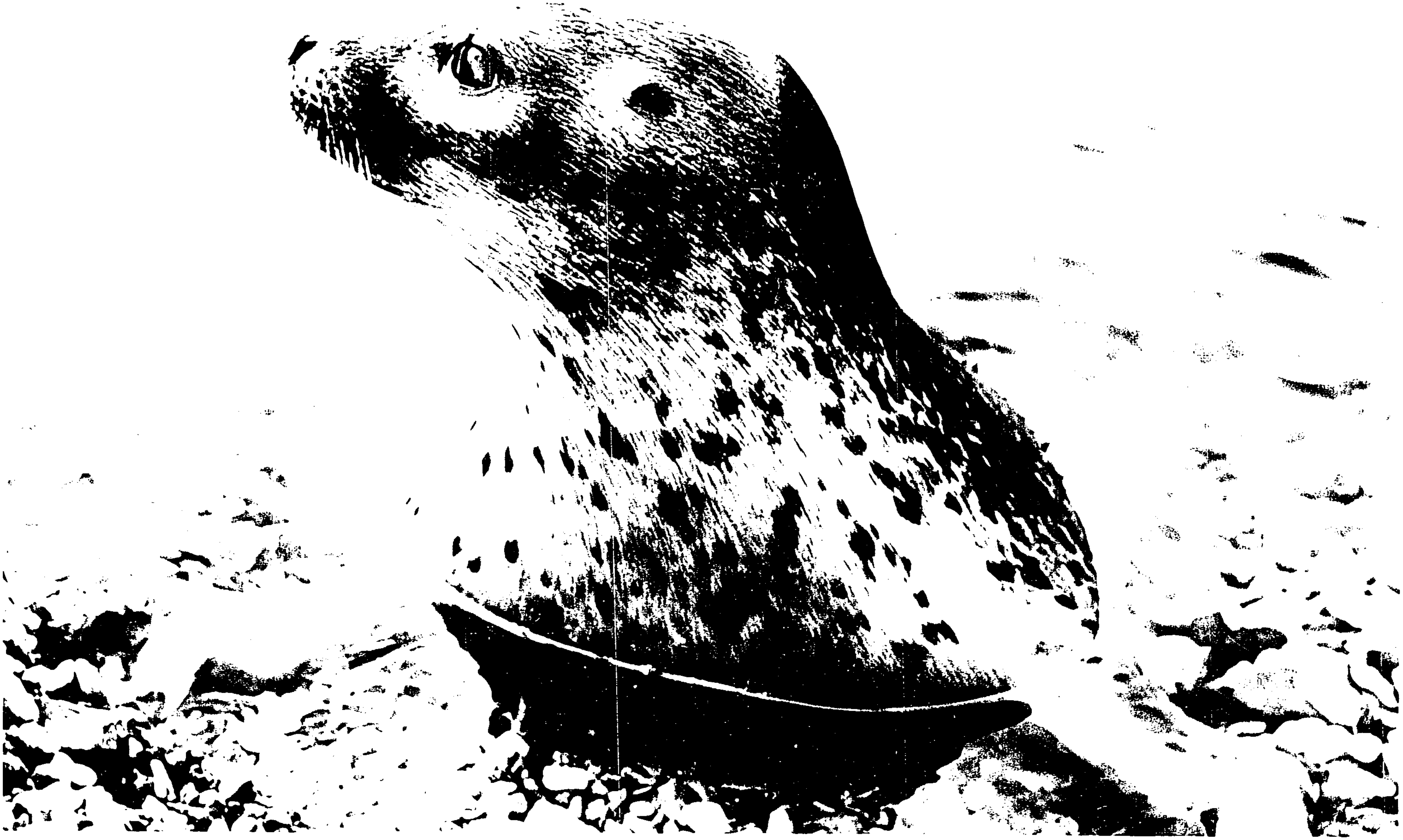
(Frontispiece by Fred Bruemmer)



INTRODUCTION

The ringed seal Phoca hispida (Schreber) is circumpolar in distribution along the arctic coasts (King, 1964). In eastern North America it is reported from the North Pole south to the lower north shore of the St. Lawrence River (Mansfield, 1967) and is sometimes found as far up as the entrance of the Saguenay River (R. Otis, personal communication). McLaren (1958a) has made a comprehensive study of the biology of the ringed seal population in south-western Baffin Island, and reviews the literature on the biology of this species up to that time. Further work by the same author (McLaren, 1958b, 1961a, 1961b, 1967) deals with the economics, availability, density, and population dynamics of the ringed seal in eastern arctic waters. Recent studies on the taxonomy and distribution of the species include Chapski (1955), Scheffer (1958), McLaren (1960a, 1960b, 1966), Rice and Scheffer (1968), Mueller-Willie (1969), and Burns and Fay (1970). A discussion of the biology, density and population dynamics of populations near Point Hope, Alaska is presented by Johnson et al. (1966). Fedoseev (1965) and Nazarenko (1965) give details on the reproductive biology of this species in the Okhotsk and White Seas. Nazarenko (1968) discusses age and sex-specific differences in body size and weight. Usher and Church (1969a, 1969b) present a statistical evaluation of the best estimator of weight from length and girth measurements. Recent papers include the ringed seal in a discussion of methods of age determination (Tikhomirov and Klevezal, 1964; Klevezal and Kleinenberg, 1967) and an account of the distribution of the ringed seal in the northern Bering and Chukchi Seas (Burns, 1970).

The present investigation of the ringed seal was begun in the summer of 1966. Populations of seals from two large areas on the east coast of Baffin Island, Home Bay and Cumberland Sound (Fig. 1) were studied. The seal population in Cumberland Sound is heavily exploited while the Home Bay region, though highly productive is very lightly hunted. It was thought that a comparison of the dynamics of these two populations, if they are discrete stocks, would provide valuable insights into the factors involved in population homeostasis. If, on the other hand, the stocks of the two areas were not separate, the study of a population over such a large geographic area would provide good information on population distribution, dispersion and migration.

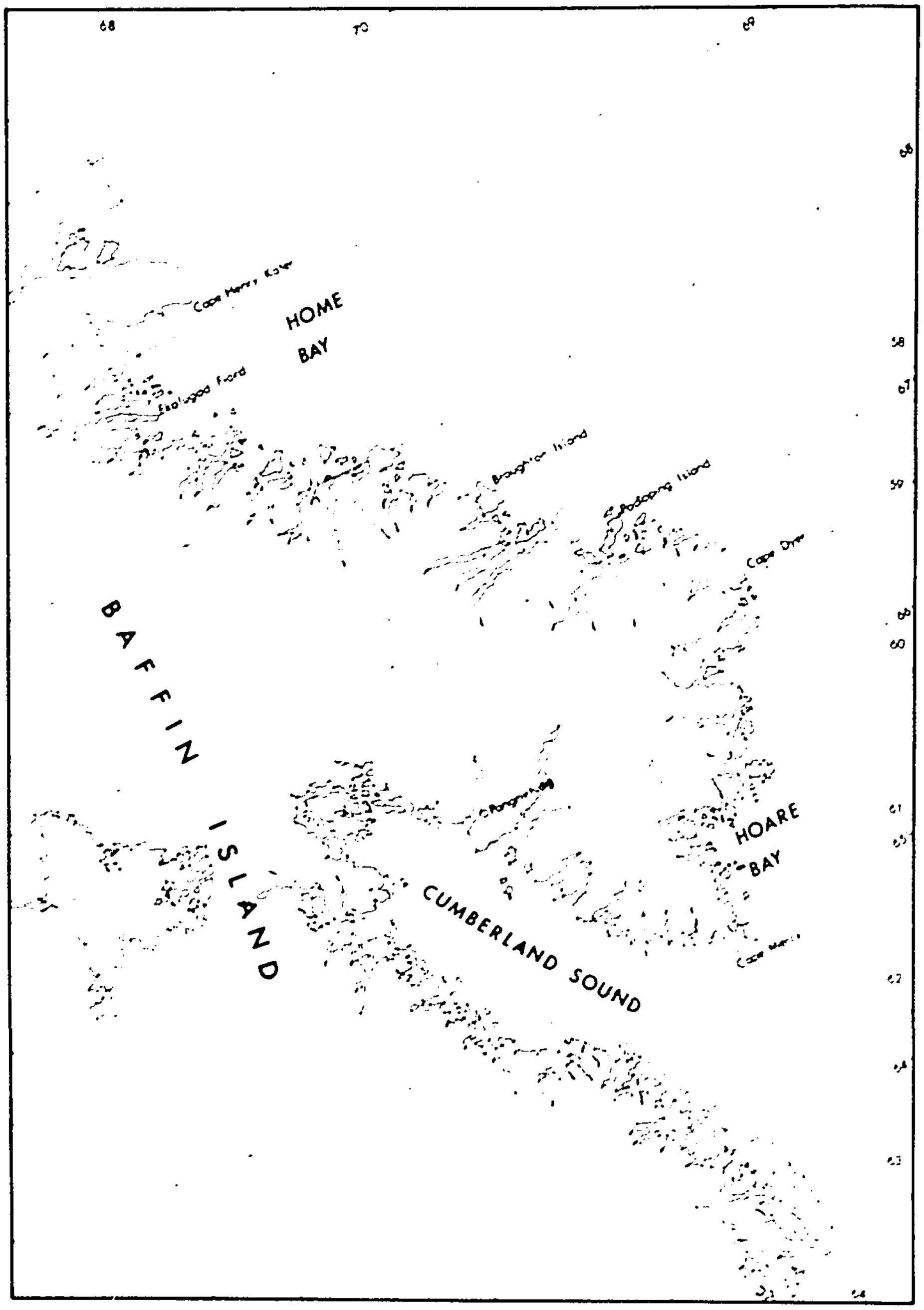


Fig. 1. Map showing the Home Bay and Cumberland Sound study areas, on the east coast of Baffin Island, N. W. T.

THE STUDY AREA

Previous Mammalian Studies in the Area.

The first important work on the mammals of the Home Bay - Cumberland Sound area was made by Ludwig Kumlein (1879). He described the various Eskimo settlements in Cumberland Sound and provided brief notes on the mammals and birds in the area. Low (1906) described the Cetacea of Cumberland Sound during the cruise of the Neptune. Hantzch (1913) worked out from Blacklead Island on the south-eastern shore of Cumberland Sound and also in the Nettilling Lake region. Soper (1924 unpublished, 1928) working from Pangnirtung fiord gave a description of the physical features of Cumberland Sound and an annotated list of the 25 species of animals known to live on Baffin Island at that time. Anderson (1943) worked on ringed seals found in Nettilling Lake. Soper (1944) provided a further annotated list of mammal species inhabiting southern Baffin Island.

Description of the Area.

Haller, Foote and Cove (1967) in a broad study of the economics of the east Baffin coast described the climate, ice distribution, tides, currents, geology, topography and physiography of the Home Bay and Cumberland Sound areas. They also discussed the ancient and recent history of the area and provided information on the development of the various Eskimo villages from Clyde River at the north end of Home Bay to Pangnirtung, the only village in Cumberland Sound at the present time.

MATERIALS AND METHODS

Data Collection.

In order to obtain meaningful figures on the dynamics of the ringed seal population, large numbers of specimens were bought from the Eskimo hunters in Broughton Island for the Home Bay area and from hunters in Pangnirtung for Cumberland Sound. Hunters were paid $1.00 for the lower jaws of the seal together with information on the locality and date on which the animal was shot. A total of 1,932 jaws for age determinations were obtained in 1966 from Cumberland Sound. In 1967, 2,566 jaws from Cumberland Sound and 4,213 jaws from Home Bay were collected. In 1970, 1,000 jaws which also included information on sex were again collected from Home Bay.

Since the greater proportion of the specimens bought from the local hunters did not include any biological information other than age, it was necessary for biologists of the Fisheries Research Board of Canada to hunt their own specimens as well as to process seals killed by local hunters in order to describe the reproductive biology of the ringed seal in Cumberland Sound and Home Bay. A total of 1,145 seals were processed from which reproductive tracts, stomach contents and various tissues for histological studies and pesticide content analysis have been collected. Table 1 summarizes the type of data and number of specimens included in this study.

Narrative of the Field Work.

Work on the ringed seal of east Baffin Island was begun in the summer of 1966. During the period from 20 May to 5 September 1,900

Table 1. Summary of type of data and number of specimens included in this study.

Number of specimens	Area and year collected	Material collected
1932	Cumberland Sound 1966	Jaws for ageing
2566	Cumberland Sound 1970	Jaws for ageing
4213	Home Bay 1967	Jaws for ageing
1000	Home Bay 1970	Jaws for ageing
436	Cumberland Sound 1967	Jaws and reproductive tracts
89	Cumberland Sound 1969	Jaws and reproductive tracts
620	Home Bay 1967	Jaws and reproductive tracts

jaws for age analysis were bought from Eskimo hunters in Cumberland Sound. From 19 May to 7 June A. W. Mansfield, P. Brodie and F. Keith travelled extensively by dog team and "skidoo" on the fast ice of Cumberland Sound hunting ringed seals with the Eskimos. During this period biological specimens were collected and an unsuccessful attempt was made to count birth lairs in the fast ice. Following the breakup of ice, counts were made of seals in the open water from a 22 ft freighter canoe and from the M. V. Calanus during the period 7 to 17 August.

The period 8 May to 3 August 1967 was spent by C. W. Nicol travelling in Cumberland Sound hunting ringed seals and buying jaws and reproductive material from Eskimo hunters. In this way 2,598 jaws and 317 reproductive tracts were collected. A. W. Mansfield and D. Robb spent the period 8 May to 15 September 1967 travelling and collecting ringed seal material in the Home Bay region. Before the return of the field parties from Cumberland Sound and Home Bay, arrangements were made through Eskimo assistants for the collecting program to continue until the end of April 1967.

The period 23 May to 28 June 1968 was spent by the author in Ekalugad fiord at the northern end of Home Bay. During this period, counts were made of the seals on the fast ice of the fiord, in order to determine the date of the peak of the haul-out period and the maximum density of seals at this time. In 1969 the period 30 May to 28 June was spent in the same fiord doing similar studies. In addition to the daily counts of seals on the fiord ice, limited areas of ice were observed for 24 hour periods, on a number of different occasions, in order to study the diurnal peak of seals on the ice and to document the seasonal progression in the number of hours spent out of the water by individual animals.

An aerial and ground census of seals on the fast ice of Home Bay was made from 28 June to 7 July 1969. Ground counts were made during travel by "skidoo" from Ekalugad fiord to Broughton Island from 28 June to 1 July.

The period from 8 July to 13 September 1969 was spent in Cumberland Sound. The purpose of my stay in this area was to collect pregnant ringed seals. Hunting was carried out in the open water from a 22 ft freighter canoe. It was also possible to make a trip out of Cumberland Sound past Cape Mercy, to the Hoare Bay area, in late August and early September, using the 45 ft longliner "Aiviq" belonging to the Department of Indian Affairs and Northern Development.

Treatment of Materials.

Tooth sections. Both cross and long sections were made of the teeth. Sections were then stored in a mixture of alcohol and glycerin. All sections were examined under transmitted light. Cross sections were cut and ground by the method described in Fisher and Mackenzie (1954). Long sections were made by imbedding the teeth in Ward's Bioplastic medium and cutting with a Gillings-Hamco thin-sectioning machine. In this way sections of approximately 100 microns in thickness were obtained.

Reproductive material. Male reproductive material consisted of a transverse slice through the testis and epididymis preserved in

Bouin's solution. The tissue was then imbedded and stained with Harris' haematoxilin and eosin. Mounted sections of the epididymis and testis were examined for evidence of spermatogenic activity under 100 magnification using a compound binocular microscope. The mean diameter of testis and epididymis tubules were calculated from ten tubules chosen at random. The mean percent sperm was also calculated from ten randomly chosen epididymal tubules.

Female reproductive material included the ovaries, and in the case of mature animals, the uterine cornua with the ovaries attached. These were preserved in 10% formalin. Ovaries were sectioned at approximately 3 millimeter intervals with a scalpel and then examined under a magnifying lamp. Counts were made of the number of follicles greater than 5 mm in diameter, and measurements taken of the two greatest diameters in the corpora lutea and most recent corpus albicans.

Other measurements were taken and tissues preserved from specimens collected by the staff of the Fisheries Research Board of Canada. These include measurements of the nose - tail length, maximum girth, blubber thickness over the sternum and total body weight of some animals. Samples of brain, blubber, muscle, and liver were preserved in 10% formalin for pesticide content analysis.

Data Analysis.

All data collected in this study were transferred to IBM punch cards. Six programs were developed to analyse these data. The programs were written in Fortran IV and run on the IBM 360 computers, models 65 and 75, at the McGill University Computing Centre. A complete description of the source decks, input and output, can be found in Smith (1970).

AGE DETERMINATION AND TOOTH STRUCTURE

The determination of the absolute age of Pinnipeds by examination of tooth structure was developed independently by Scheffer (1950) and Laws (1952, 1953a, 1953b). Since then 21 species of seals have been aged by counting annual layers of either dentine or cementum (Klevezal and Kleinenberg, 1967).

McLaren (1958a) showed that the counts of the dentinal annuli from cross sections of teeth in the ringed seal was the most reliable method of ageing this species. He observed that alternating bands of opaque and translucent dentine were observed in thin cross sections of teeth under transmitted light. The annual pattern of dentine deposition was demonstrated by examining the dentine being laid down next to the pulp cavity during two week intervals throughout the year. It was shown conclusively that the ringed seal lays down a translucent band from the end of March to approximately the middle of June and for the rest of the year forms an opaque dentine band. Ages determined from the dentinal annuli compared well with those obtained from counts of ridges on claws and layers in the cementum.

The main purpose of this section is an attempt to describe as clearly as possible the microscopic criteria of the teeth used in ageing, so that different investigators working on the ringed seal will obtain comparable results. Both long sections and cross sections of the teeth have been used in this study.

Tooth Topology.

<u>The sagittal section</u>. Sections of approximately 100 microns in thickness were made in the long axis of the tooth to show the

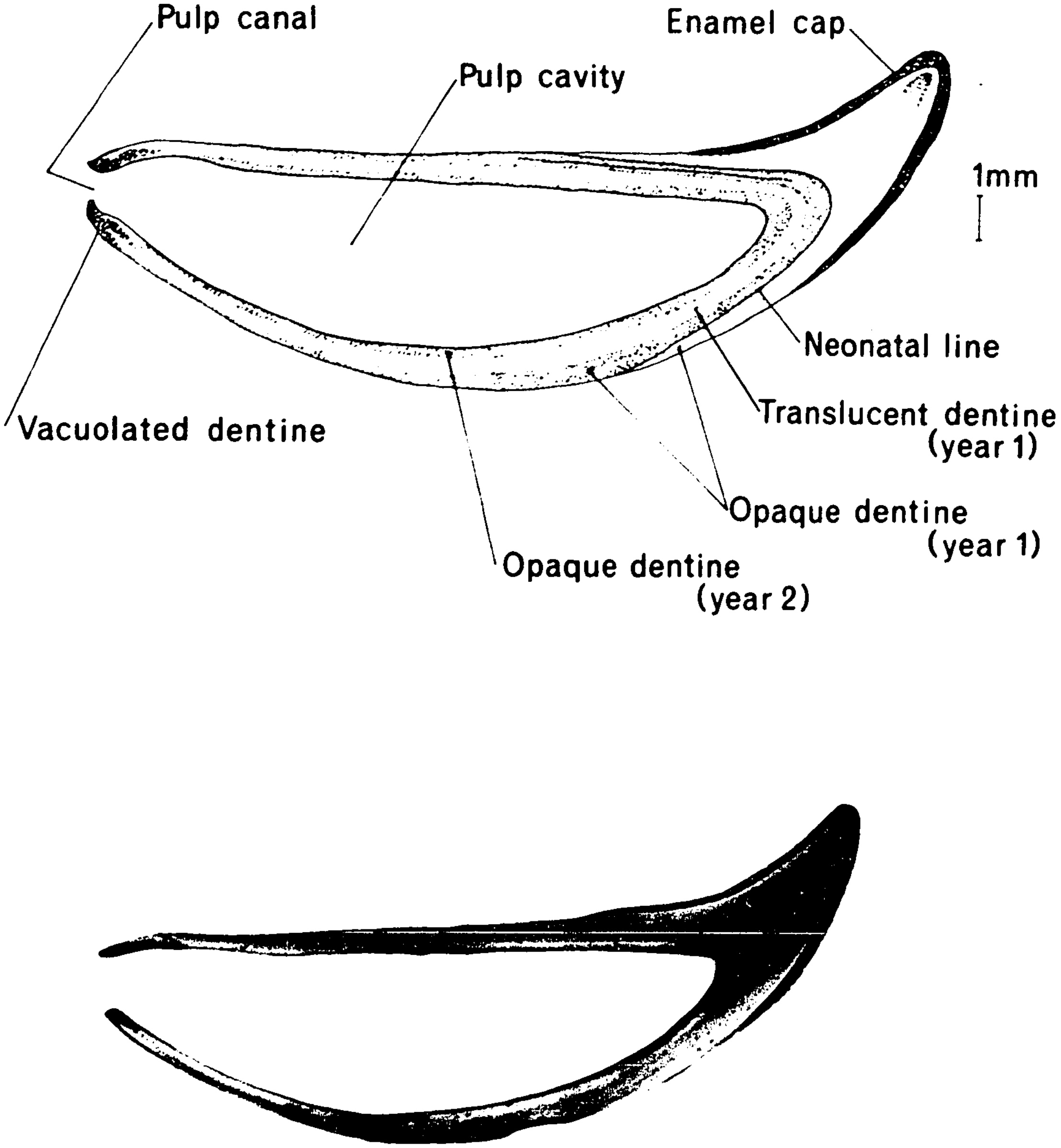


Fig. 2. Drawing and photograph, of a 1+ year old ringed seal tooth, showing the orientation of the main structures used in age determination.

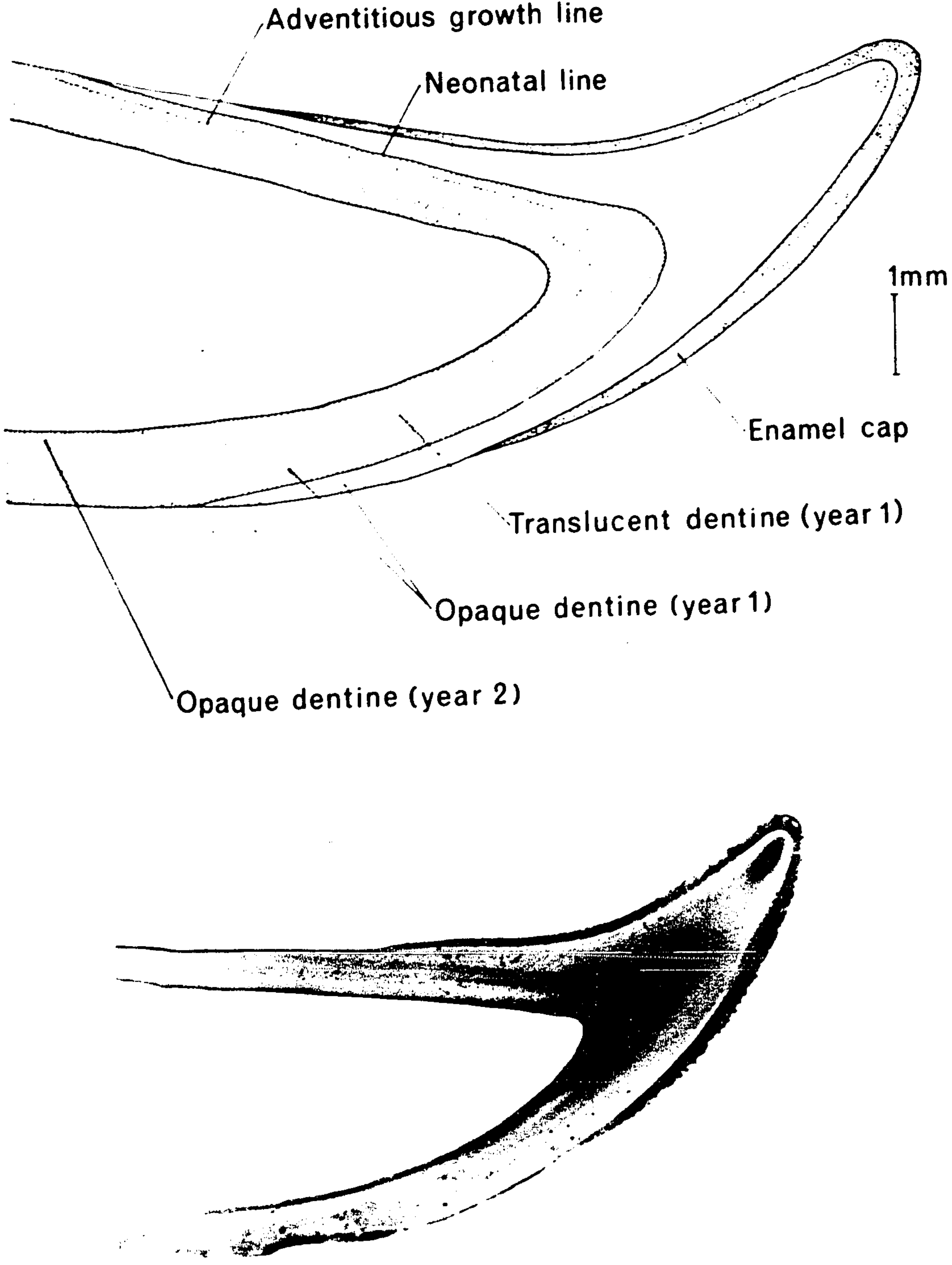


Fig. 3. Drawing and photograph, of part of a sagittal section, from a 1+ year old ringed seal tooth, showing the position of the neonatal line.

orientation of the main structures and tissues. Fig. 2 is a diagram of such a section showing a tooth 1+ years of age. The position of the different measurements taken are shown.

Three different types of tissues are recognized in the sections: the enamel, the cementum and the dentine. The dentine under transmitted light consists typically of opaque followed by translucent bands. In the first year of dentine growth a darker band of dentine is laid down at birth. This neonatal line is usually easily seen in long sections. This line occupies a position half way across the opaque dentine of the first year near the apex of the pulp cavity (Fig. 3). The mean distance from the apex of the tooth to the position at which the neonatal line comes to the surface is 9.36 mm. This is equivalent to the length of the tooth at birth.

The relative positions of the neonatal line, the enamel, and cementum are variable. Measurements concerning this were taken along the buccal side of the long section. The position at which the cement begins to form may be above or below the point at which the neonatal line comes to the surface of the tooth. The distance between the enamel and cement also varies greatly and does not appear to be a function of age. In most cases the enamel and cement do not join each other and often are separated by distances as large as 14.00 mm.

The main increase in length of the canine tooth occurs in the first two years of life. Some time between year 2 and 3 the pulp canal closes (Fig. 4). Thereafter the canine tooth increases very little except for a slight increase caused by the deposition of

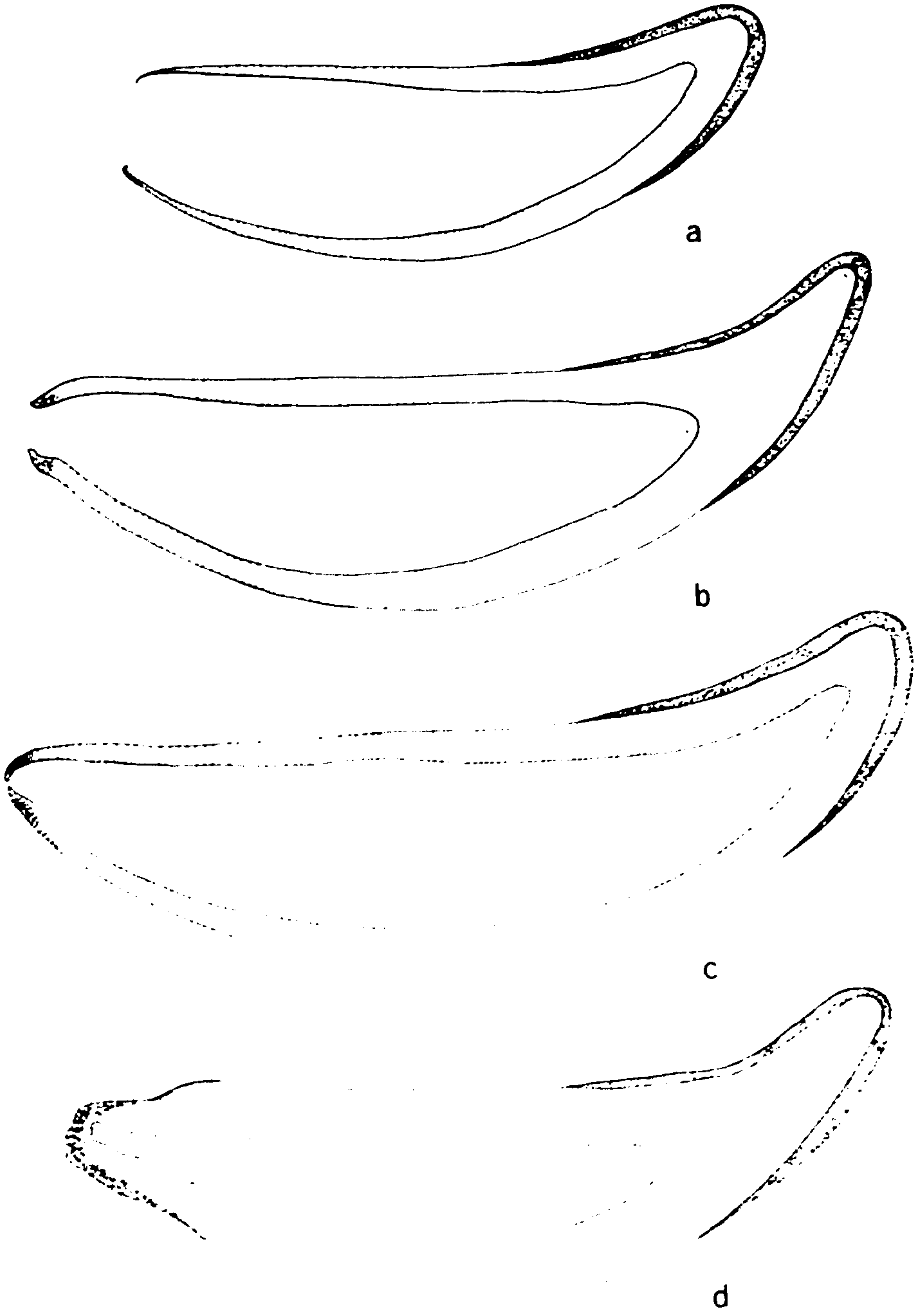


Fig. 4. Sagittal sections, of ringed seal teeth, from animals aged 0+, 1+, 2+ and 5+, showing the closure of the pulp canal.

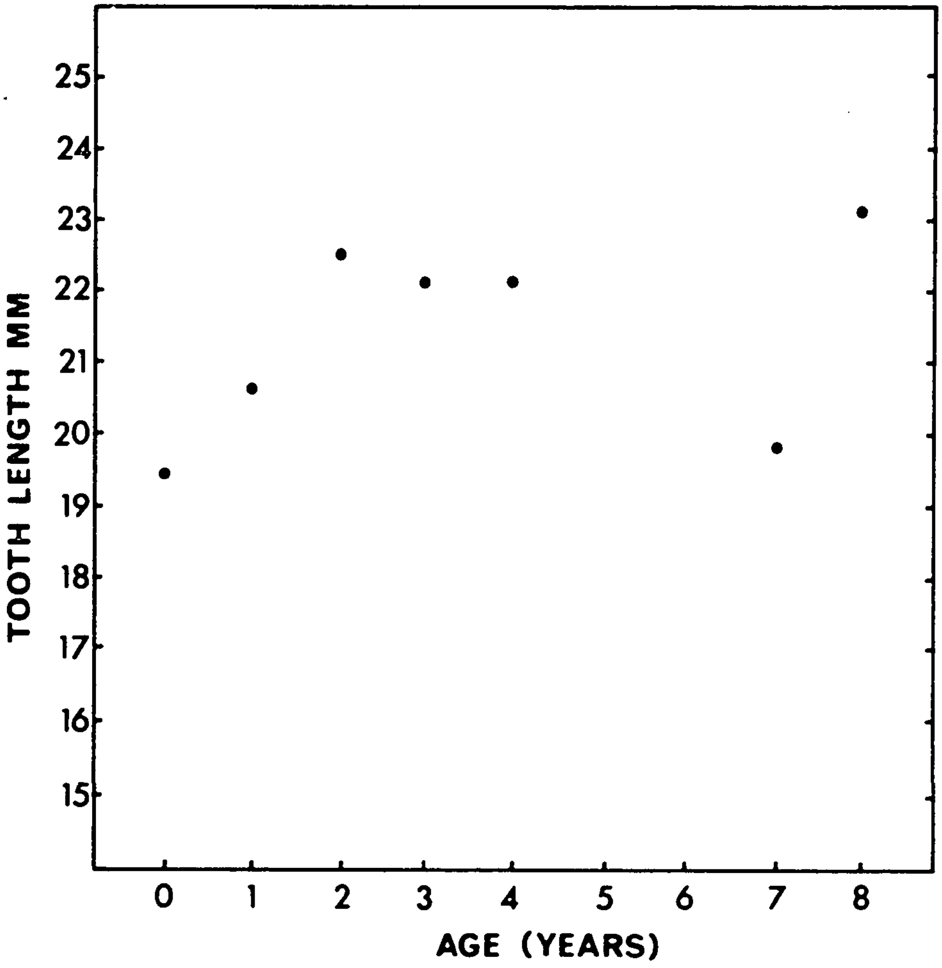


Fig. 5. Increase of total canine tooth length with age.

cementum on the root. Fig. 5 shows the increase of total tooth length from a mean of 14.43 mm in seals less than 1 year of age to a mean of 22.01 mm in animals older than 2 years of age.

The cross section. Since it is much quicker to prepare a cross section than a long section, this is the method most frequently used for ageing large numbers of specimens. In ageing teeth from such sections the most difficult task is to define the extent of the first year of growth. Often the translucent dentine laid down at the end of the first year does not form a very well defined band. Because of this the neonatal line can be used as a useful reference point in making a judgement about thickness of the opaque dentine in the first year. If the cross section is cut high enough, that is, just below the enamel cap, the neonatal line can usually be seen. It appears as a slightly more opaque line which in fact is the junction between two bands of the dentine of slightly different opacity, laid down in the first year.

The widths of the dentinal annuli in a number of cross sections have been measured and are shown in Fig. 6. Since the level of the section varies to a certain extent from tooth to tooth much of the variation in measurements can be attributed directly to this. It can be seen from Fig. 6 that the widest dentinal annulus is formed in the first year (contrary to the statement by Klevezal and Kleinenberg, 1967, p. 124) and decreases through to year 9 where the curve levels off. In very old sections the annuli become extremely crowded and are even narrower. The pulp cavity appears to be filled in animals between the age of 25 and 30 years.

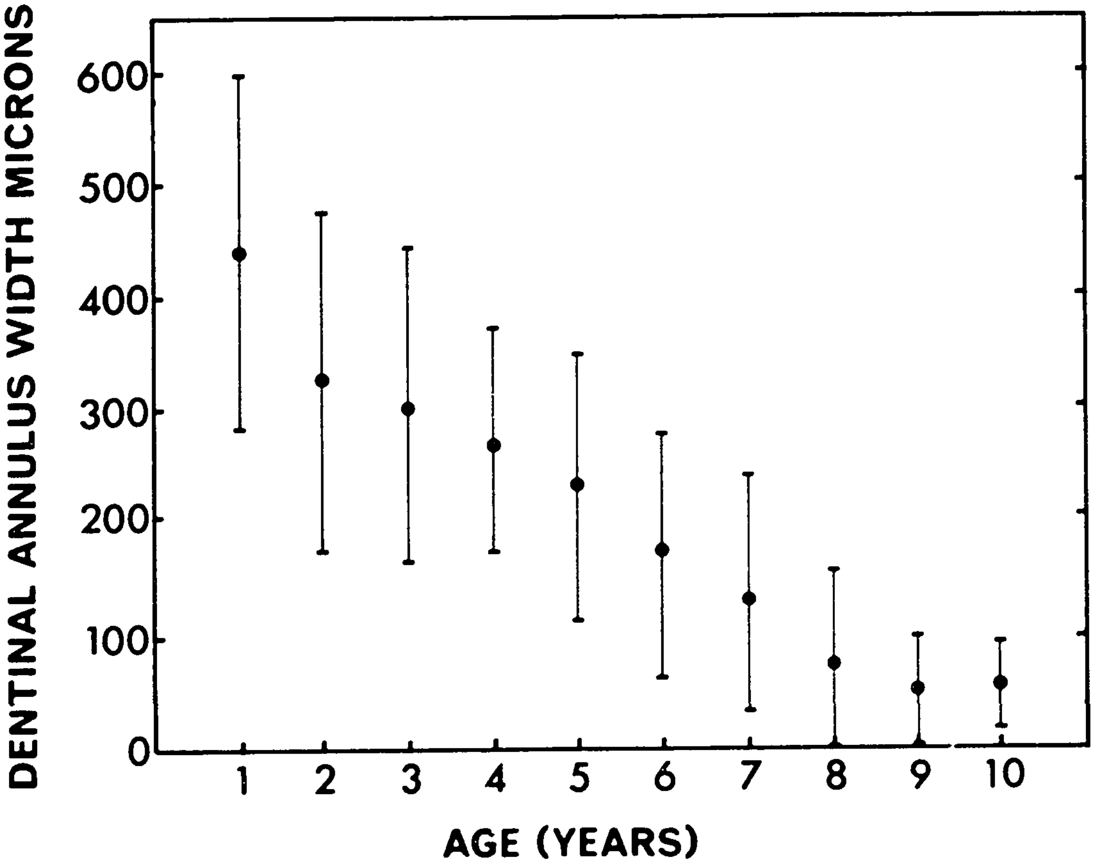


Fig. 6. Decrease in the width of the dentinal annuli with age. Vertical lines = 95% confidence limits; dots = means.

Klevezal and Kleinenberg (1967) suggest that it is possible to determine the age at sexual maturity of the ringed seal by changes in the rate of dentine deposition as seen in the width of dentinal annuli. They maintain that the value of the ratio, of the width of the annual dentine of year (w + 1), to the width of the dentine in year (w), shows a marked reduction in year 4 and concluded that this reflects the age at sexual maturity in the ringed seal. A similar analysis was made in this study but no marked change in the dentine deposition rate was seen (Fig. 7). A gradual decrease in the ratio of dentine width from one year to the preceding year was seen, which appears to reflect a gradual decrease in growth generally. The curve begins to level off around six years of age which agrees with McLaren (1958a) who found that 87.6% of the growth in body length has been achieved when the ringed seal is about six years old.

Tooth Tissues.

The dentine. Three types of dentine appear in examination of teeth under transmitted light. McLaren (1958a) has shown that the normal annual sequence of dentine formation is the laying down of opaque dentine from July to March with the subsequent deposition of translucent dentine from the end of March to the end of June. The present investigation substantiates these findings.

McLaren (1958a) also mentions that occasionally reticulated or vacuolated dentine is seen. He states that the usual sequence of bands consists of dense (opaque) followed by thin (translucent) followed occasionally by reticulated (vacuolated) dentine. Later he goes on to say that the reticulated dentine often is seen at the

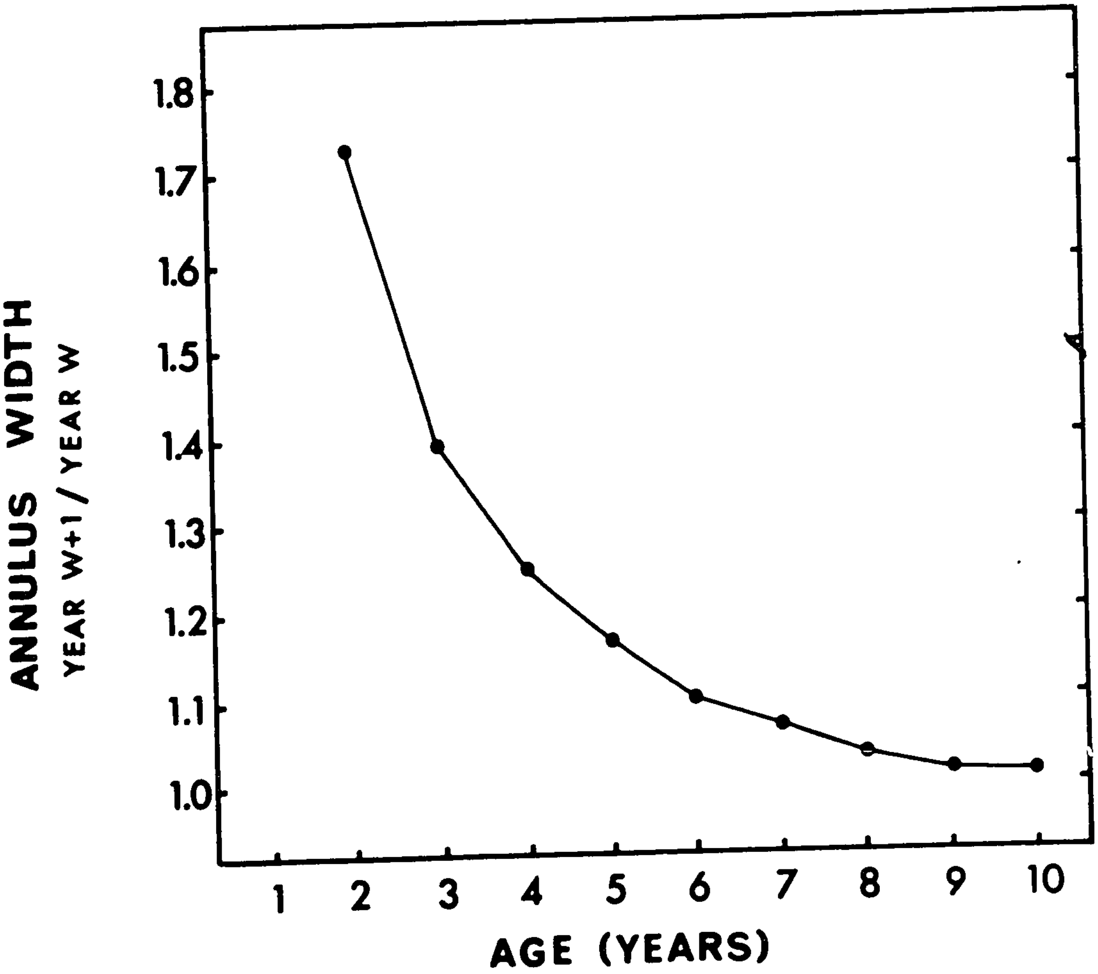


Fig. 7. Decrease in the ratio of the width of the dentinal annulus from one year (w + 1), to the preceeding year (w), with age.

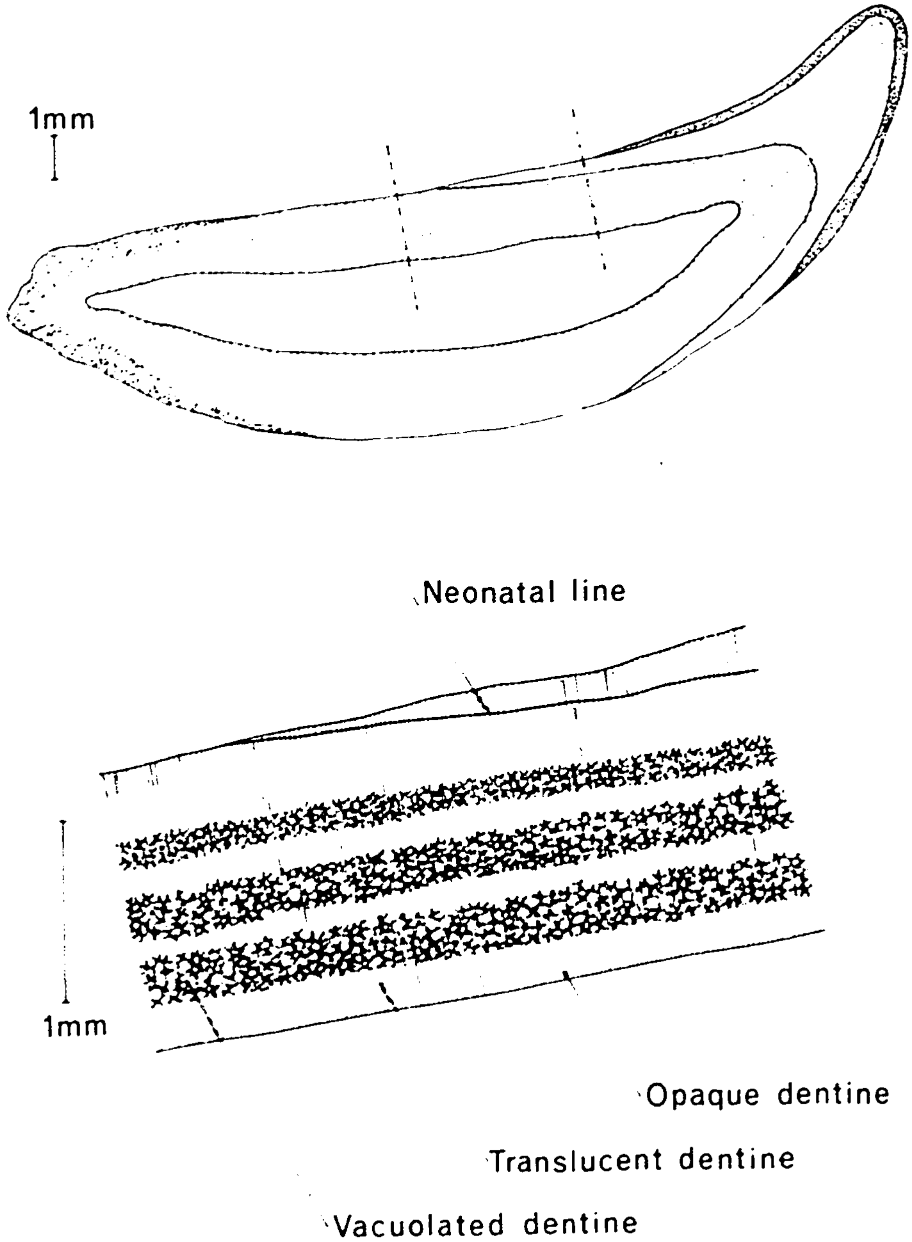


Fig. 8. Drawing and photograph (Fig. 8, continued), of a portion of the sagittal section from a canine tooth, showing the relative positions of opaque, translucent and vacuolated dentine.

Fig. 8. Continued.

beginning of the thin dentine in seals which showed the broadest thin (translucent) bands in the spring. In this study a careful examination of the positioning of the three types of dentine relative to each other was made. It appears that usually opaque dentine is followed by a translucent band at the times of the year described by McLaren (1958a). The formation of vacuolated dentine is not a constant feature. From a sample of 208 teeth, .08 of the animals had vacuolated dentine in the most recently formed dentinal annulus. Most teeth contain some vacuolated dentine in the opaque dentine near the base of the tooth formed shortly after birth (Fig. 2). This might be a result of the changing environment and feeding conditions from the time of birth through suckling and weaning. The position of the vacuolated dentine, with respect to the opaque and translucent dentine, is not easily defined. Often when vacuolated dentine is present it appears to overlie or be formed during the deposition of the opaque band (Fig. 8). In some sections it appears to form the border of the opaque band lying next to the translucent band. In no case is it a definite band as in the case of *Lobodon carcinophagus* reported by Laws (1958) and as implied for the ringed seal by McLaren (1958a).

The cementum. Although there is an annual deposition of cementum in the ringed seal, it is not laid down in clear enough bands to be considered as a reliable method of ageing specimens. It is occasionally used as a method of age determination when the seal is so old that the pulp cavity is completely filled. In these cases long sections should be used, since only a few places along the length

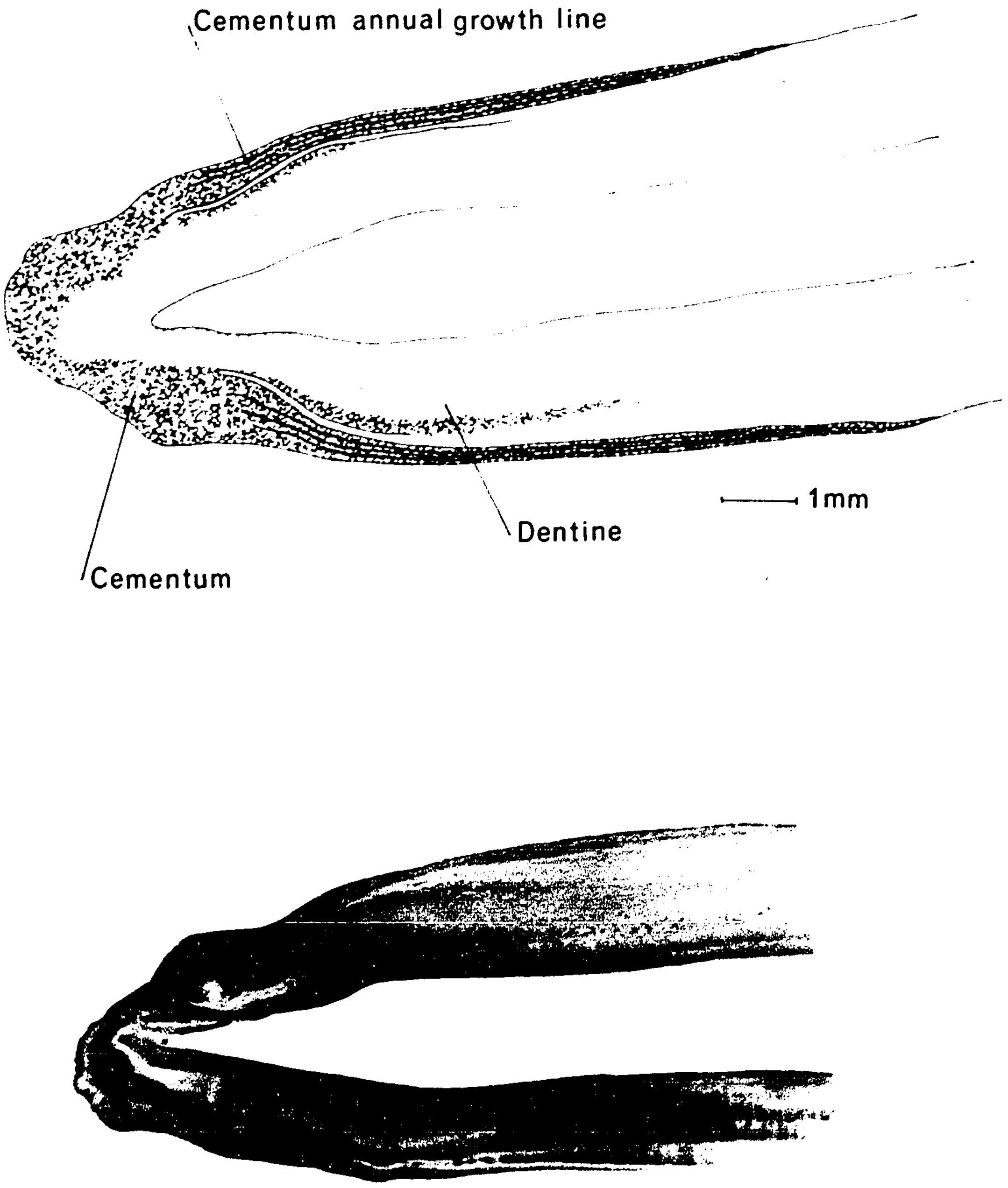


Fig. 9. Drawing and photograph, of a sagittal section, from a five year old canine tooth, showing the position of the cementum and the annual cementum bands.

of the area of cementum formation, are clear enough for age determination.

Fig. 9 shows the position of the cementum in a sagittal section of the tooth. The closure of the pulp canal results from both the inward curving and growth of dentine and the deposition of cementum on the surface of the dentine. Fig. 10 indicates that the increase in the thickness of dentine through the years is fairly constant, averaging a 0.043 mm increase in thickness annually.

Discussion.

A certain amount of confusion has arisen surrounding the terminology applied to the description of the discontinuous growth zones in the dentine. Under transmitted light the dentinal annuli are best described as opaque and translucent. These appear as dark and light bands respectively. In reflected light the opaque and translucent bands take on the opposite appearance of light and dark bands respectively. It is suggested that "opaque" and "translucent" only be used to describe the light reflecting or transmitting qualities of the different bands in order to avoid any possible confusion.

One other point of discussion involving the dentine concerns the relative amounts of calcium in the opaque and translucent annuli. The early workers dealing with this matter (e. g. Laws, 1953b, 1958, 1962; Fisher, 1954; McLaren, 1958a) all assumed that the light-transmitting qualities of the two bands depended on the relative amounts of calcium they contained and that the opaque band was hyper-calcified. More recently other workers (e. g. Klevezal, 1963; Kubota et al., 1961; Ohsumi, Kabuya and Nishiwaki, 1963; Klevezal and Kleinenberg, 1967) have stated that the translucent dentine is

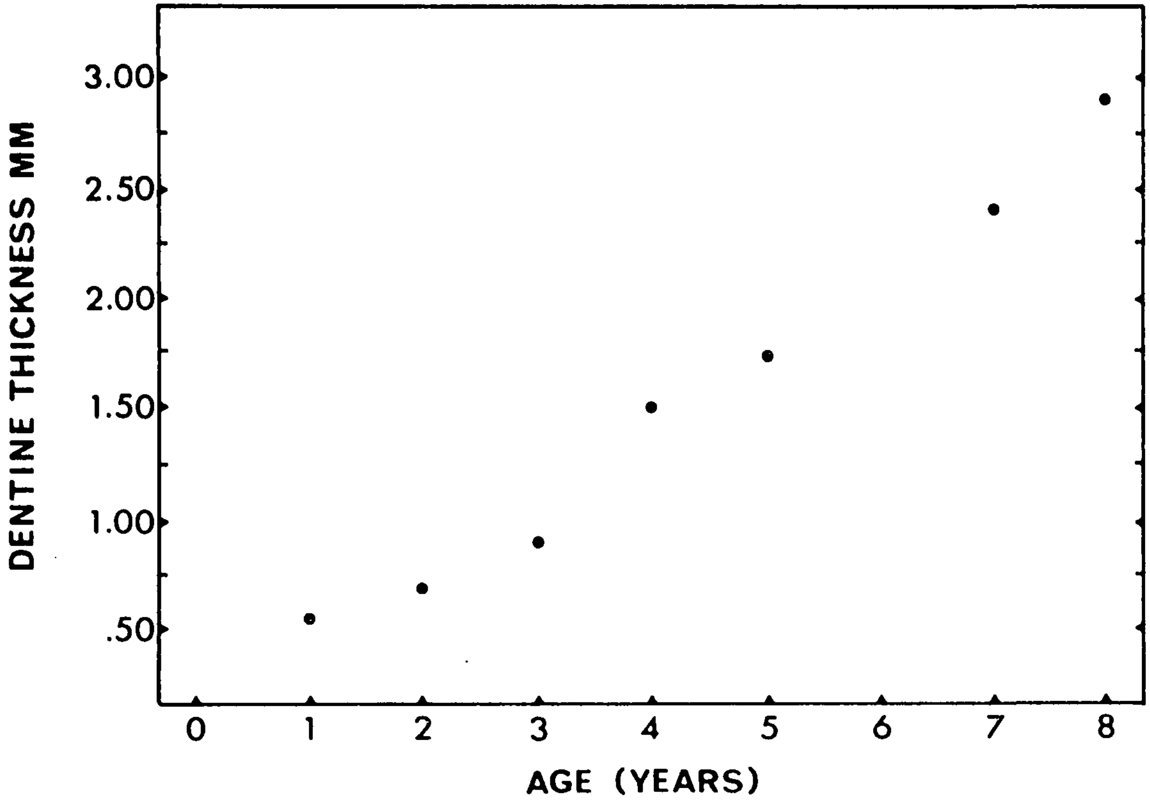


Fig. 10. Increase of dentine thickness with age.

the most heavily calcified. Klevezal and Kleinenberg (1967) explain the hyper-calcification of the translucent band by assuming the rate of calcium deposition to be constant throughout the year. They further explain that since there is less organic stroma to cover in the narrower translucent annulus, which reflects a period of slow-down in growth, the tissue becomes more densely impregnated with calcium. No proof is presented for their assumptions of a constant rate of calcium deposition. As evidence for the theory that translucent dentine is hyper-calcified, they state that haematoxylin and silver nitrate stain the translucent annuli more heavily and that these stains react more intensively to well calcified tissues. Neither of these stains has been shown to be specific for calcium and their use as quantitive indicators of differences in calcium content is quite inconclusive (Best, 1970). Sergeant (1969) gives support to the claim of higher calcium content in the translucent dentine on the basis of microradiography of tooth sections. Contrary evidence has been found by Bevelander, Scott and Nylen (1962) in examining the contour lines of Owen in human teeth by soft roentgen rays. They showed that these bands, which are analogous to the translucent annuli, are hypo-calcified. Evidence for a greater calcium content in the opaque dentine is also inconclusive. Best (1970) states that demineralization of sperm whale teeth by formic acid results in grooves corresponding to the position of the opaque dentinal bands. The suggestion that the optical differences in the dentine might be independent of the mineral content has been put forward by Klevezal (1963) and Best

(1970). This is not unreasonable since no proof has ever been advanced that different calcium contents are the causes of the opaque and translucent qualities of dentine. More work involving chemical analysis and radiographic examination of teeth is needed to resolve this debate.

A number of possible causative factors have been discussed for the discontinuous manner in which dentine and cementum are laid down. Thus Laws (1953b) with reference to the work of Mellanby (1928), suggested vitamin D as the limiting factor in calcium formation, and stated that the elephant seal obtained vitamin D by hauling out and basking in the sun. Fisher (1954) found that the harp seal laid down translucent dentine during the period of haul-out and came to the conclusion that the seals were laying down thin (translucent) dentine during the fasting period because the main source of vitamin D was in their food. McLaren (1958a) linked the formation of translucent dentine to the period of fasting and moult. Carrick and Ingham (1962) suggested that the change in dentine is governed by a change in hormonal activity. Klevezal and Kleinenberg (1967) were of the opinion that the discontinuous growth of dentine reflected a yearly rhythm in the overall growth rate of animals in general. They did not speculate on the specific cause of this although they implied that the period of retardation of growth generally corresponds to the winter season. No definite conclusions about the causes of discontinuous growth of dentine can be made until the structural nature of the different dentinal bands is determined. Even then, it is probable that a number of different factors control the annual dentine cycle and that different species will differ in their causative factors.

GROWTH

Prenatal growth will be described in the section dealing with delayed implantation and foetal development. A comparison of the nose - tail length of a full term foetus of 657 mm (McLaren, 1958a) and the mean nose - tail length of yearlings collected one to three months after achieving nutritional independance shows a 29% increase in length. No comparable data are available on the increase in weight but studies on other pinnipeds have shown that pups often more than double their weight before weaning due to the high fat content of the mother's milk (Sivertsen, 1941; Amoroso and Mathews, 1951; Laws, 1953b; Harrison, 1960).

The largest ringed seal collected in this study was a 14 year old female that measured 151 cm from nose to tail, with a maximum girth of 108 cm and an estimated weight, by the formula of Usher and Church (1969a), of 73.14 kg (161.21 lbs.). McLaren (1958a) recorded a male of 156 cm weighing 222 lbs. The length of adult ringed seals varies greatly and the weight has further variation introduced by the seasonal change in blubber thickness.

Sex-Specific Differences.

Examination of the nose - tail length measurements shows that males are larger than females. Seals were divided into two age groups, yearlings (0+) and adults (7+ and older). The yearling males were 5% larger than the females but the difference was not quite significant when tested with a t-test ($P = .069$). Adult males were found to be 6.59% larger than adult females and the difference was highly significant ($P < .01$).

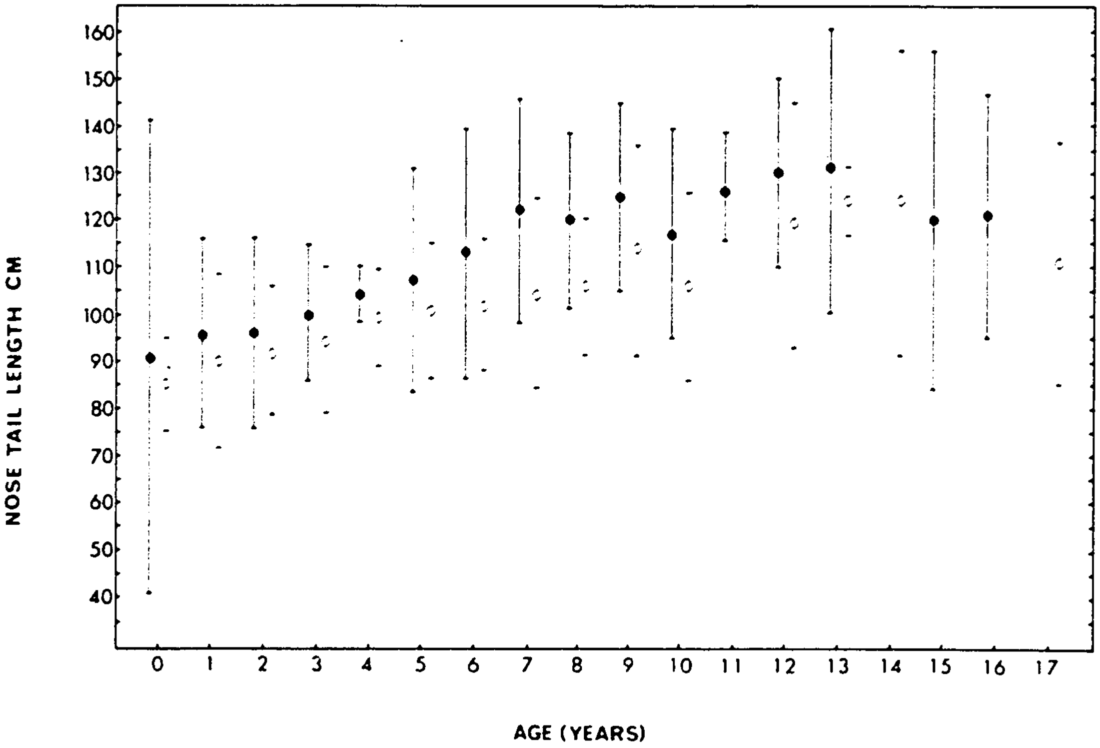


Fig. 11. Increase in length, measured from nose to tail, with age. Solid vertical lines = 95% confidence limit Home Bay seals; solid dot = mean. Broken vertical lines = 95% confidence limit, Cumberland Sound seals; open dot = mean.

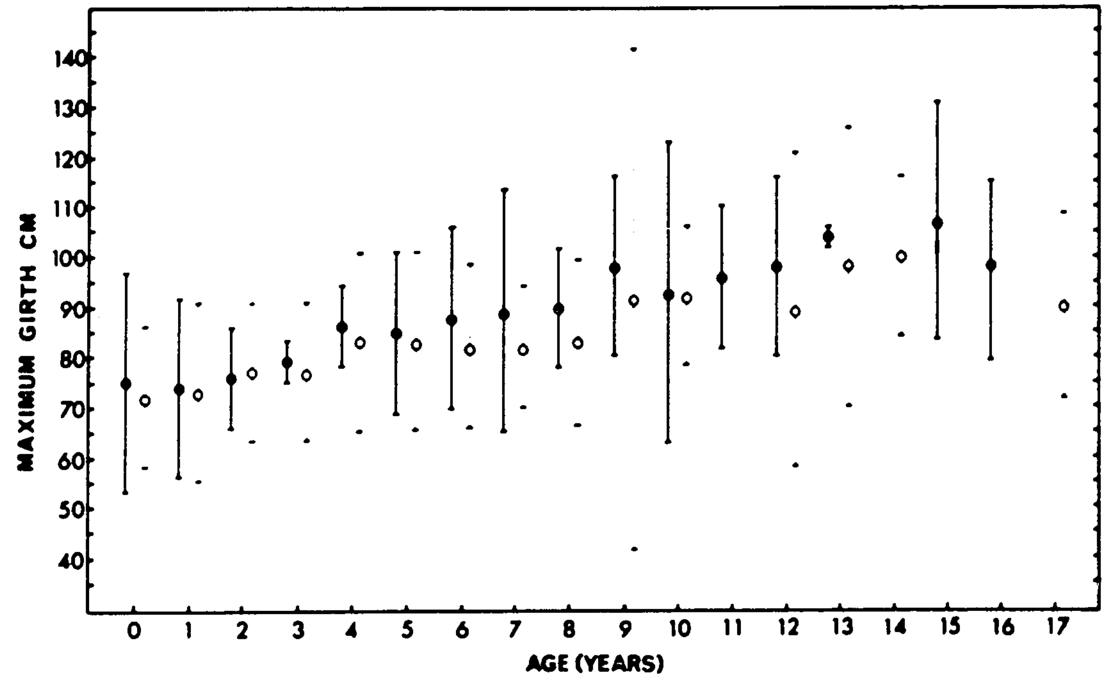


Fig. 12. Maximum girth of ringed seals plotted against age. Solid vertical lines = 95% confidence limits, Home Bay seals; solid dot = mean. Broken vertical lines = 95% confidence limits, Cumberland Sound seals; open dot = mean.

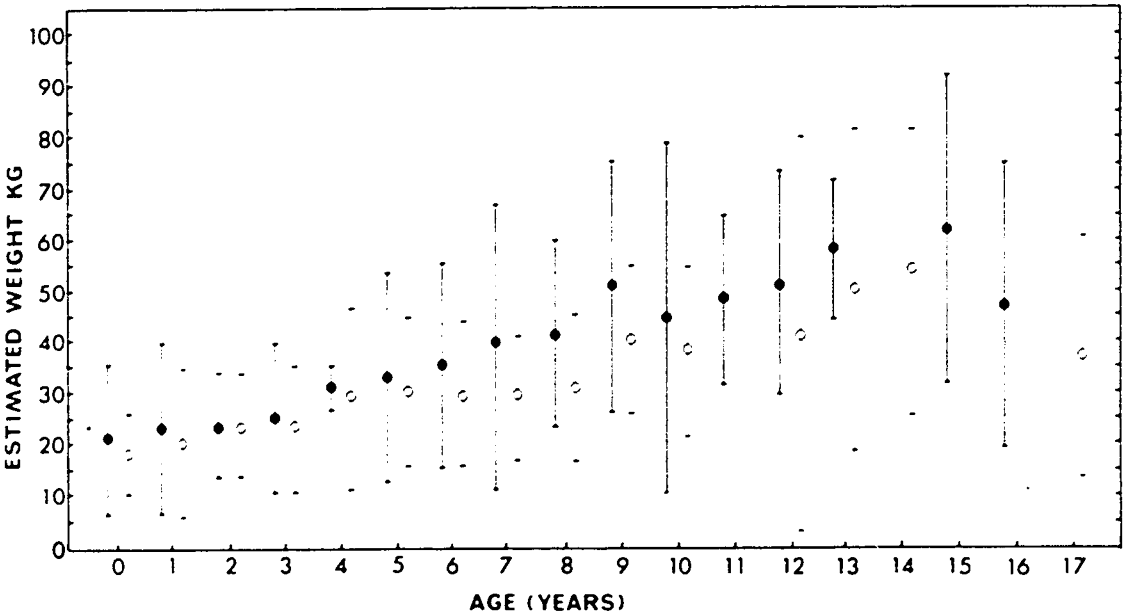


Fig. 13. Increase of estimated weight (by the formula of Usher and Church 1969a) with age. Solid vertical lines = 95% confidence limits, Home Bay seals; solid dot = mean. Broken vertical lines = 95% confidence limits, Cumberland Sound seals; open dot = mean.

Table 2. Comparison of nose-tail length between seals taken in Cumberland Sound and Home Bay.

Comparison	Percent difference in nose-tail length	t-value	Probability of t arising by chance
Home Bay - Cumberland Sound Yearlings	6.58	0.81	$P > .4$
Home Bay - Cumberland Sound Adults	4.00	2.19*	$P < .05$
Hoare Bay - Cumberland Sound Adults	9.10	7.43**	$P < .001$

Comparison of Cumberland Sound and Home Bay Seals.

The nose - tail lengths, maximum girths, and estimated weights (Usher and Church, 1969a), of the Home Bay and Cumberland Sound seals in each age class are shown in Figs. 11, 12, and 13 respectively. In all cases it appears that the Home Bay animals are the largest. The seals were divided into yearling and adult age groups and statistical comparisons of nose - tail lengths made between the animals from Home Bay and Cumberland Sound (Table 2). The yearlings of Home Bay were 6.58% larger than those from Cumberland Sound but the difference was not statistically significant ($P > .4$). The adult age groups in this comparison were significantly different, the Home Bay animals being 4% larger than the Cumberland Sound seals ($P < .05$). A comparison of the Hoare Bay and Cumberland Sound adults showed the Hoare Bay animals to be 9.1% longer and the difference was again significant ($P < .001$, d. f. 33).

The difference in size between animals from Home Bay and Cumberland Sound is probably a function of the stability of ice in the areas used for breeding lairs. McLaren (1958a) comments on this fact and considers ice stability and parental care as the ultimate factors affecting the final size of ringed seals. All evidence in this study suggests that this is the best explanation. Cumberland Sound is known to be an area of unstable fast ice with a large tidal amplitude and a large area of open ice undercut with strong currents. The Home Bay and Hoare Bay areas, on the contrary, have complex coastlines with low tides and extremely stable ice. Evidence shown later in connection with the seasonal movements of seals indicate that a large proportion of the seals in Cumberland Sound have been produced in the Hoare and Home Bay regions. It would seem likely that these dispersing seals were produced in the less stable peripheral ice of these two areas and that they also are of a smaller size therefore contributing to the overall small size of the Cumberland Sound sample.

REPRODUCTION

Sexual Maturity.

The male. The best criterion for establishing sexual maturity in the male is the presence of spermatozoa in the epididymal tubules during the breeding season. In the ringed seal the rut is considered to extend from March to approximately mid-May, although males have been collected with spermatozoa in their ejaculatory ducts as early as December and January (Nazarenko, 1965; Johnson et al., 1966). On the basis of the presence of spermatozoa in the epididymis, McLaren (1958a) concluded that the ringed seal male attains sexual maturity at the age of 7+ years although one specimen of 6+ years, taken in June, had spermatozoa present in the testis tubules. Johnson et al. (1966) report all testes through 6+ years of age to be immature, with an abrupt increase to almost 100% sexually mature animals in the 7+ year class. Nazarenko (1965) dealing with specimens taken in January only, reports spermatozoa in the epididymis of animals 7 years and older.

In the present study very few adult males were collected and all were taken after mid-May, well past the peak of the breeding season. Only one specimen PHC 142, shot on 19 May 1966 in Cumberland Sound, showed small numbers of spermatozoa loosely packed in the testis and the epididymal tubules. All other specimens examined showed no spermatozoa at all, although all the animals 7+ years and older contained cellular detritus in the epididymis, evidence of recent sexual activity. A number of adult males were

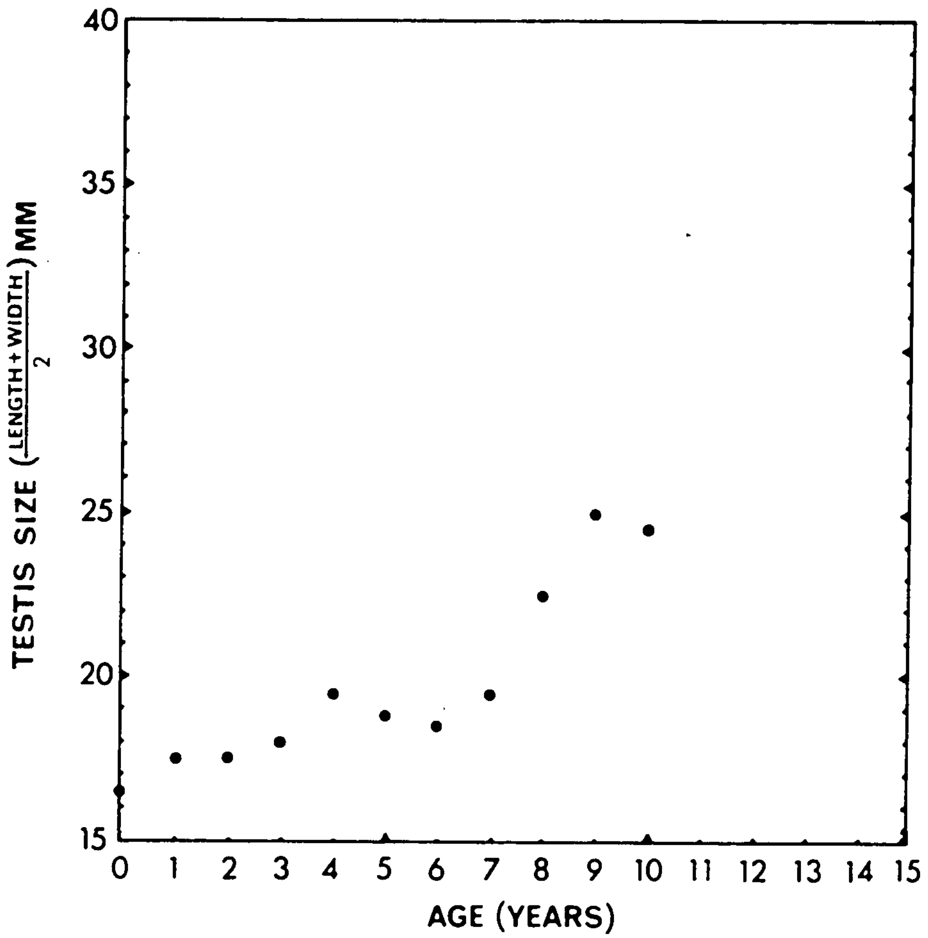


Fig. 14. Increase of testis size, (length + width /2), with age.

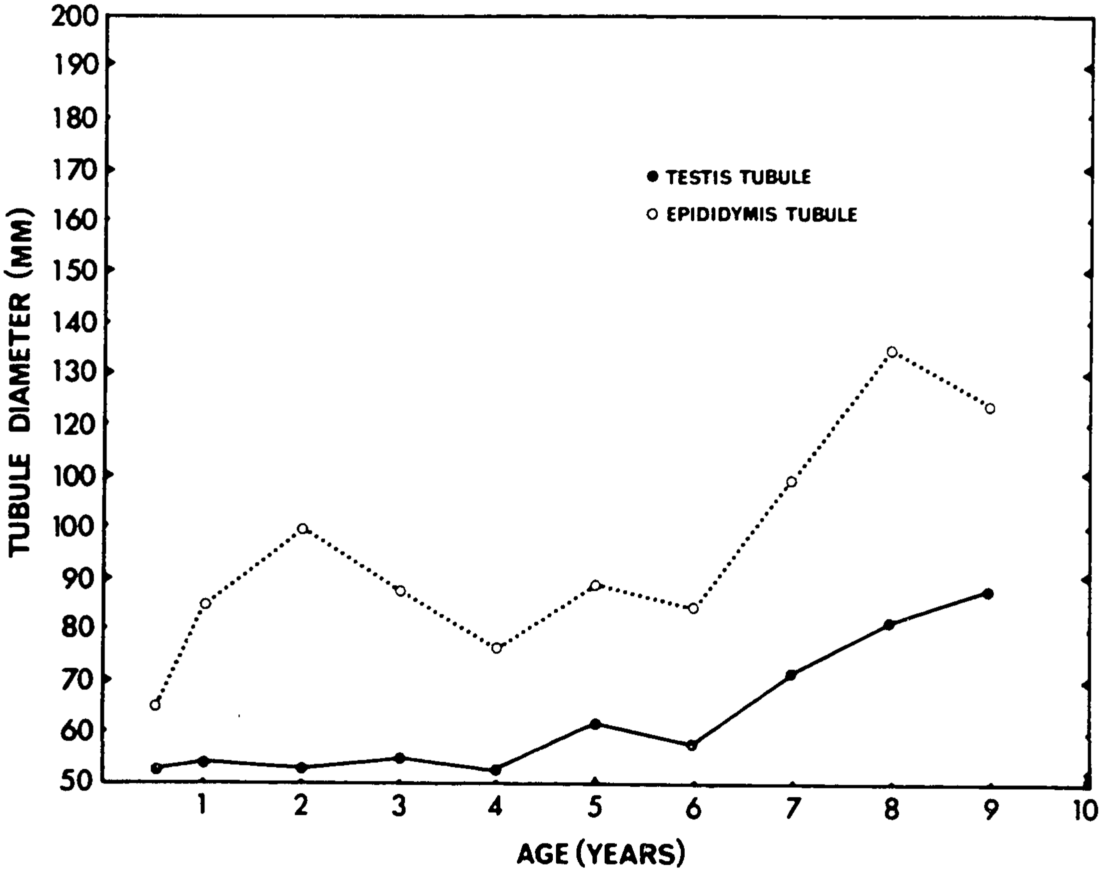


Fig. 15. Increase in the diameters, of the testis and epididymal tubules, with age.

shot as late as mid-June, the testes of which were not collected, but the seals had the strong odor characteristic of males in rut. It is therefore probable that some males are in breeding condition later than mid-May.

Indirect evidence of sexual maturity in the male can be obtained from several different criteria. Fig. 14 shows a graph of the testis size (length + width/2) against age for the material from Pangnirtung. Testis size is seen to increase markedly between the ages of 7+ and 9+ years indicating the attainment of sexual maturity during this period. Fig. 15 shows the increase in diameters of the testis and epididymal tubules with age. Again the most marked increase in diameter is seen in the 7+ year class. It appears from these data that sexual maturity in the male occurs at age 7+ which agrees with the findings of previous studies.

The female. Direct evidence of sexual maturity in the female is obtained by examination of the ovaries for the presence of a corpus luteum of ovulation. In addition to the presence of a corpus luteum, a corpus albicans in an animal of age (n + 1) is taken to indicate an ovulation in the year class (n). Calculations of the percentage of animals sexually mature in each year class were made using the formula $\frac{CL(n) + CA(n + 1)}{n + (n + 1)}$ where CL(n) is the number of animals in the year class n containing corpora lutea and CA(n + 1) is the number of animals in year class n + 1 with a recent corpus albicans.

The percentage of female sexually mature seals in the year classes 0+ to 10+ is shown in Table 3.

Table 3. Age-specific percentages of sexually mature female seals in the Cumberland Sound and Home Bay samples and in three other ringed seal studies.

	Percent sexually mature females									
	(1) Home Bay (1967)		(2) Cumberland (1967)		(3) Hoare Bay (1969)		(4) Johnson et al. (1966)		(5) McLaren (1958a)	
Age	Percent	N	Percent	N	Percent	N	Percent	N	Percent	N
0										
1+										
2+										
3+										
4+	40.0	22	12.5	8	40.0	5	8.0	16	12.0	17
5+	59.2	42	20.0	10	33.0	6	60.0	10	22.0	18
6+	54.8	63	11.8	17	80.0	5	55.0	9	78.0	18
7+	85.7	98	57.9	19	100.00	4	93.0	14	100.	12
8+	91.2	114	92.3	13	75.0	4	100.0	20	100.0	8
9+	100.0	117	100.0	7	100.0	3	100.0	18	100.0	3
10+	100.0	77	100.0	3	100.0	2	100.0	20	100.0	

These data were compared with similar data obtained from specimens collected in Home Bay, Cumberland Sound and Hoare Bay, and earlier data from two other studies: McLaren (1958a) in southeastern Baffin Island, and Johnson et al. (1966) around Point Hope, Alaska.

Examination of 27 pairs of ovaries of animals in age classes 0+ to 3+ from Home Bay, and 107 pairs of ovaries from Cumberland Sound failed to show any follicles greater than 1 mm. in diameter, and no signs of ovulations were detected.

The Home Bay sample reveals that 40.9% of the 4+, 59.2% of the 5+, 84.8% of the 6+, 85.7% of the 7+, 91.2% of the 8+, and 100% of the older age classes are sexually mature. The percentage of sexually mature animals is higher in the Home Bay sample than in the other samples to which it is compared.in Table 3. The main difference lies in the higher percentage of mature animals in age classes 4+ and 5+.

The Home Bay and Hoare Bay samples are most similar in the percentage of sexually mature females per age class, whereas the Cumberland Sound sample differs considerably from both of these. The similarity between the Home Bay and Hoare Bay data might be explained by the fact that both areas have complex coastlines with stable fast ice, ideal for breeding lairs, and that both areas are relatively lightly hunted. Cumberland Sound differs from these areas in having unstable fast ice and being heavily hunted. It is possible however that the difference is not a real one owing to the small number of specimens in the Cumberland Sound sample. The differences between the Home Bay sample and the other two studies lies mainly in

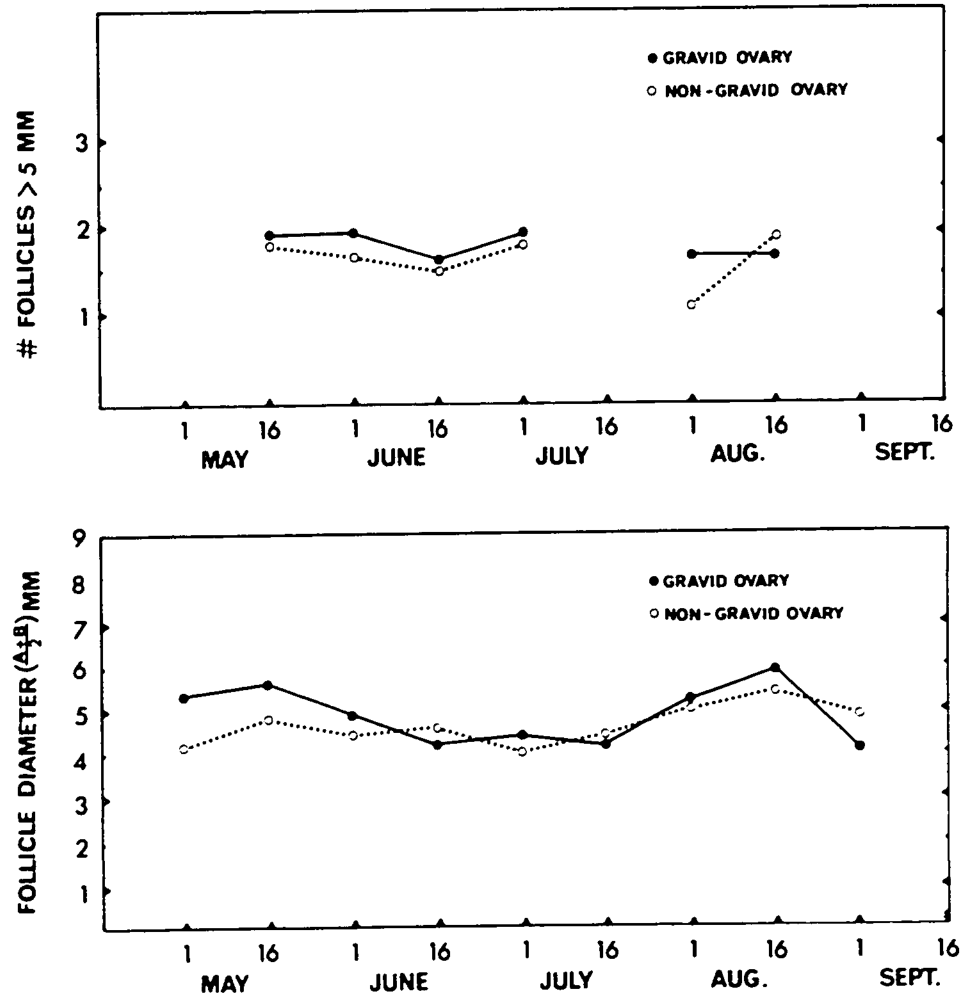


Fig. 16. The mean number of follicles larger than 5 mm in diameter and the mean diameter of the largest follicle, in the ovaries with and without the corpus luteum.

the higher proportion of sexually mature animals in age classes 4+, 5+, 6+ from Home Bay. The difference may not be significant since it could have arisen from the larger number of animals considered in this analysis and the Home Bay sample may therefore be more representative than other reproductive studies made so far.

The Ovarian Cycle and Female Reproductive Structures.

The follicles. The female reproductive material gathered during this study is restricted to the period from mid-May until mid-September and represents only a short portion of the seasonal cycle. In each ovary the number of follicles greater than 5.0 mm in diameter and the size of the largest follicle were recorded. The mean number of follicles greater than 5 mm in diameter and the mean size of the largest follicle in both the ovary with and without the corpus luteum were examined for all age classes. Once the animal is 4+ years old, these do not vary significantly with age.

Fig. 16 shows the mean number of follicles greater than 5 mm in diameter and the mean diameter of the largest follicle at two-week intervals from 1 May 1967 to 15 September 1967. In the ovary without the corpus luteum the number of follicles decline until a slight increase is seen in early September. In the ovary containing the corpus luteum the picture is not at all clear. In both ovaries the size of the largest follicles decline until the end of July, when a marked increase in diameter is noticed which persists until the end of August. In both the elephant seal Mirounga leonina (Laws, 1956) and the ringed seal (McLaren, 1958a) a slight increase in the number of follicles in both ovaries occurs near implantation time.

Table 4. Comparison of the mean size of the largest follicles in ovaries with and without a corpus luteum.

	t value	d.f.	P. of difference arising by chance
Hoare Bay pregnant	2.88*	19	>0.03
Hoare Bay pre-implantation	1.66	4	> 0.10
Home Bay pregnant	1.20	26	>0.44
Home Bay pre-implantation	2.88*	108	<0.05

Table 5. Comparison of the follicle size in ovaries with and without a corpus luteum between pregnant and non-pregnant animals.

(a) Comparison in the ovary with a corpus luteum.

	t value	d.f.	P. of difference arising by chance
Hoare Bay	1.186	16	> 0.46
Home Bay	0.56	68	> 0.54

(b) Comparison in the ovary without a corpus luteum.

	t value	d.f.	P. of difference arising by chance
Hoare Bay	1.84	16	>0.08
Home Bay	1.52	68	>0.15

Comparisons were made between the mean size of the largest follicles in ovaries with and without a corpus luteum. The best sample for making this comparison is made up of 54 females taken from May to the end of July in the Home Bay area. These dates probably exclude any possibility of implantation or preparation for implantation which might affect the follicle sizes differentially in the ovary with or without the corpus luteum. This sample is named "Home Bay pre-implantation" and the comparison of the mean sizes of the largest follicles between ovaries containing the corpus luteum and those without is shown in Table 4. The result of a t-test shows that the ovary not containing a corpus luteum had a significantly larger follicle size ($P < .01$). A significant difference, $P = < .037$, was also found in the "Hoare Bay pregnant" sample. The "Hoare Bay pre-implantation" sample and the "Home Bay pregnant" sample, animals showing an actual implantation, did not show significant differences between the follicle sizes in the two ovaries, since t-tests gave probabilities of 0.107 and 0.44 that the differences could have arisen by chance.

Comparisons of the follicle sizes in ovaries with and without a corpus luteum between pregnant and non-pregnant animals are shown in Table 5. In the ovary containing the corpus luteum there does not appear to be any significant difference in the mean diameter of the largest follicle between pregnant and non-pregnant animals (Table 5a). In the ovary without the corpus luteum there is a more marked difference in the mean size of the largest follicle between pregnant and non-pregnant animals but the differences are still not

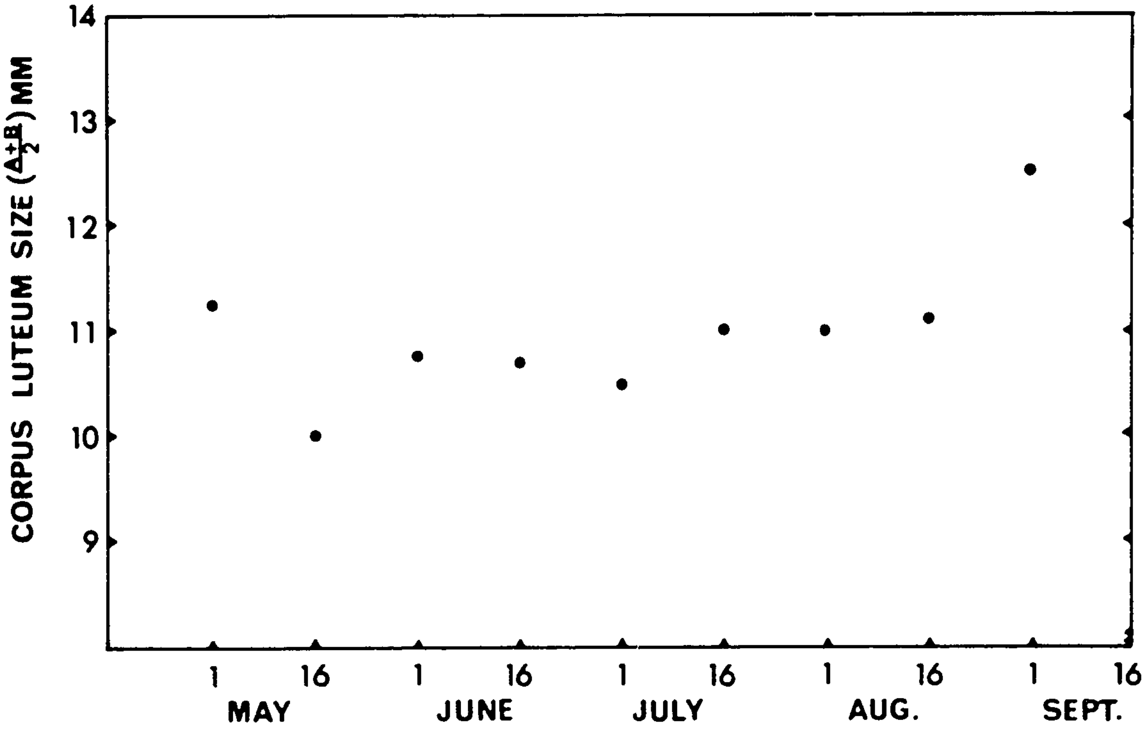


Fig. 17. Seasonal increase in the mean size of the corpus luteum.

significant at the 0.05 level (Table 5b).

A number of different types of degenerating follicles were observed. Haemorraghic follicles (Best, 1967) were occasionally seen. These are usually small blood filled follicles of 1.0 to 2.0 mm. in diameter. A more common type of degenerating follicle was round in cross section and contained the hardened and often orange-colored remains of the liquor folliculi. These follicles are probably analogous to the cystic follicles described in the fur seal _Callorhinus ursinus_ by Pike et al. (1960) and Craig (1964), and similar to the atretic follicles found by Laws (1961) in the fin whale. They range in diameter from 1.0 to 10.0 mm and are generally situated deep in the ovary. They probably are actively growing follicles which are suppressed either at ovulation or some other time during the follicular cycle. These have been found in either ovary whether there was a corpus luteum present or not.

Scars left by atretic follicles such as the corpora abberantia of Laws (1961) were not found by gross examination. It is likely that atretic follicles disappear very quickly, which may be a function of the small size of the ovaries. This is paralleled by the short duration of the corpora albicantia.

The corpus luteum. Examination of the corpus luteum through the age classes 4+ to 21+ failed to show any relation of size with age.

Fig. 17 indicates that there is a gradual increase in size of the corpus luteum from early July to early September. Comparison between corpora lutea of pregnant and non-pregnant seals taken in August failed to reveal any significant differences in mean sizes.

In general the corpora lutea of pregnancy were more highly vascularized, but no obvious signs of regression of corpora lutea not supporting foetuses were seen even as late as September. This is probably due to the fact that many of the specimens not showing a foetus were in fact pregnant, but the blastocyst had not yet implanted.

A small number of corpora lutea were observed which had cavities still filled with liquor folliculi. These resemble the vesicular corpora lutea described in the fin whale by Laws (1961) and in the sperm whale by Best (1967). Thirteen animals showed this type of corpus luteum which represents 2.69% of all specimens examined.

Two specimens were found which contained accessory corpora lutea. In specimen number PH79 the ovary containing a large corpus luteum also contained follicles of less than 5.0 mm in diameter which were all completely luteinized.

In specimen PH532 only two large corpora lutea, each 7.0 X 10.0 mm in diameter were found, both in the left ovary. These corpora lutea could have been formed from the simultaneous rupture of two mature follicles, or more possibly by the rupture of one follicle and the consequent bursting of the wall of the large follicle next to it. Luteinization would then probably occur in both follicles.

One specimen PH321 might in fact show that some accessory corpora in the ringed seal are the result of immature follicles that have erupted. In this animal the ovary opposite the one containing the corpus luteum showed five erupting follicles, none greater than

Table 6. Age-specific size and number of corpora albicantia and the percentage of seals with the corpus albicans in the ovary opposite the one containing the corpus luteum.

	Size of corpus albicans			Percent of seals with corpora albicantia in opposite
Age Class	N	Mean size	Number of corpora albicantia visible (both ovaries)	ovary than corpus luteum
5	5	7.40	1.00	66.6
6	13	6.80	1.00	84.6
7	28	6.80	1.10	85.7
8	48	6.50	1.10	77.1
9	46	6.60	1.10	73.9
10	56	6.50	1.10	76.8
11	40	6.90	1.10	80.0
12	30	6.60	1.10	65.5
13	23	6.70	1.10	87.0
14	11	6.25	1.10	72.7
15	13	6.80	1.40	75.0
16	4	6.15	1.50	50.0
17	2	6.25	1.00	100.0
18	2	7.75	1.10	100.0
19				
20	3	6.70	1.10	0
21	3	6.20	1.10	100.00
26-				
31-				
36-				
Mean		6.67	1.10	85.2

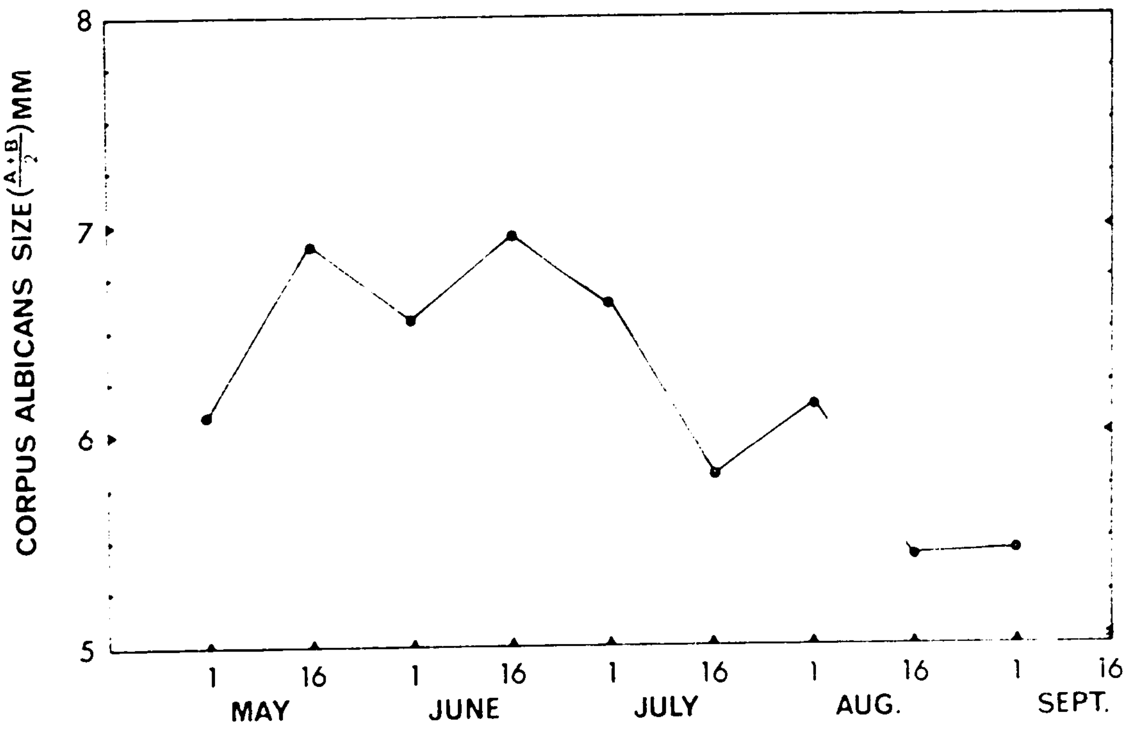


Fig. 18. Seasonal variation in the mean size of the most recently formed corpus albicans.

5.0 mm in diameter. The follicles were empty of liquor folliculi and did not have any luteal elements, indicating that they had probably erupted a short time before the animal was collected. What the eventual appearance of the follicles would be is not known, but it is possible that they would have luteinized and formed accessory corpora lutea.

The corpus albicans. The relationship between age of the seal and the number and size of the corpora albicantia is shown in Table 6. The mean diameter of corpora albicantia visible in both ovaries is 6.67 mm and the mean number is 1.10. There are no apparent correlations between age of the specimen and number or size of corpora albicantia.

The variation in the diameter of the most recently formed corpus albicans with time is shown in Fig. 18. Mean diameters at two-week intervals from May to September show the diameter to decrease from a maximum of 6.8 mm to 5.43 mm. No samples were taken past mid-September, but the continuous decrease in the size of the corpus albicans results in its almost total disappearance after two years. This is shown by the count of the total number of corpora albicantia which gives a mean of 1.1 per set of ovaries.

A definite alternation of ovulation from one ovary to the other exists in the ringed seal. Table 6 gives the percentage of animals with the corpus albicans and the corpus luteum in the opposite ovary for each age class. An average of 85% of the animals show an alternation of ovulation from one year to the next.

Missed ovulations. Animals can fail to reproduce by not ovulating; or by ovulating and not being fertilized; or by the blastocyst failing to implant; or by abortion or resorption of the embryo.

Four seals PH63, PH184, PH186, PH524 aged 11+, 9+, 14+ and 9+ respectively, did not contain corpora lutea although they had all previously borne young, as shown by their reproductive tracts. The medulla and cortex of the ovaries of the four specimens appeared to be more highly vascularized than ovaries containing corpora lutea. All the follicles of both ovaries of PH186 were filled with blood while a large proportion of the follicles of PH184 were also haemorraghic. Although this might be interpreted as a further indication of an abnormality preventing ovulation, small numbers of haemorraghic follicles were occasionally found in ovaries containing a functional corpus luteum.

Four corpora lutea were found which were smaller than the average size indicating a possible missed fertilization. It is not definitely known if these animals were fertilized since none of the specimens were taken later than mid-July. All their corpora lutea appeared to be normal with no vascularization or development of connective tissue. Three of the four animals PH296, PHC433, and PH556 were nulliparous aged 5+, 5+, and 7+ respectively. These seals had corpora lutea of 6.0 X 5.0 mm, 7.0 X 7.0 mm, and 6.0 X 5.0 mm, in cross section. The fourth specimen PH38 was a nulliparous female 9+ years old. The corpus luteum was 6.0 X 4.0 mm in cross section and was identical in appearance to the others.

No evidence was found of failure to implant a blastocyst owing

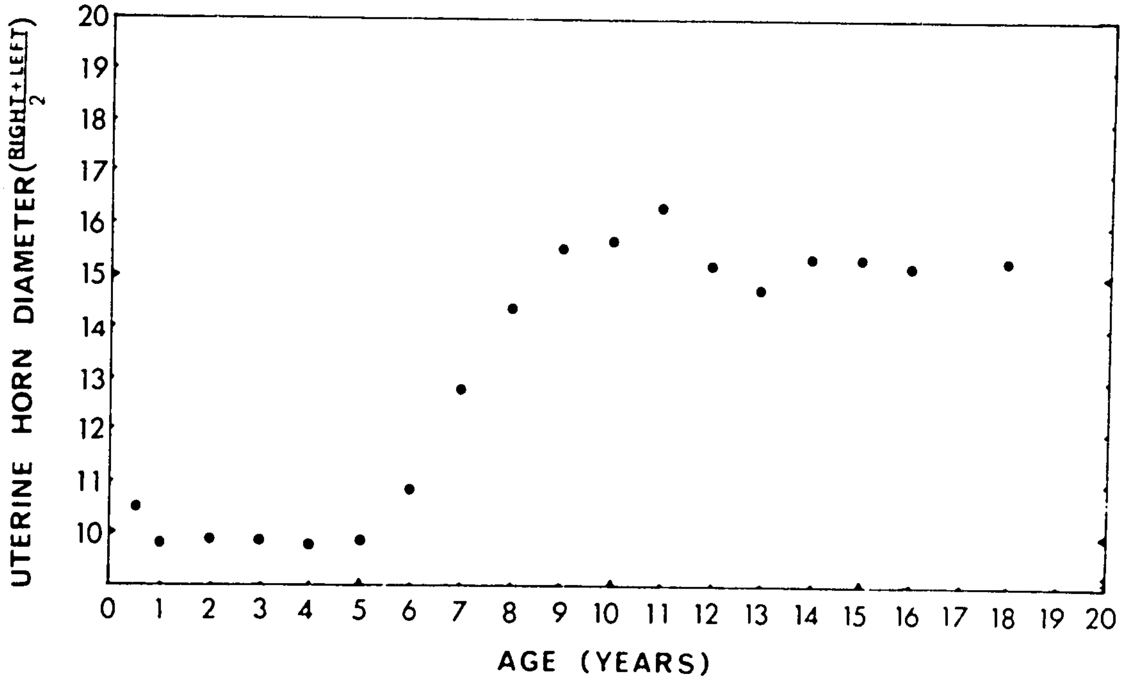


Fig. 19. Increase in the mean diameter, of the uterine cornua, with age.

to luteal malfunction. All specimens taken in August and September had normal functional corpora lutea. Examination of the reproductive tracts failed to show any evidence of prenatal mortality from abortion or resorption of the conceptus, but it must be mentioned that only a limited number of whole reproductive tracts were examined.

The uterine cornua. Measurements were made of the diameter of the uterine cornua, sectioned halfway along their length. A sharp increase in diameter is seen at the 6+ age class with a levelling of the curve at the 9+ age class (Fig. 19). If it is assumed that the increase in the cornua size is caused by the bearing of young, then the graph shows the age at first conception to be one year later than it actually is. The graph supports the previous evidence from ovarian and reproductive tract examination that reproduction is first seen in animals of 5+ years and that 100% of the 9+ year animals are sexually mature.

The diameter of the cornua in 0+ age animals is larger than in adolescent seals. Harrison, Matthews and Roberts (1952) observed the same phenomenon in *Halichoerus grypus* and *Phoca vitulina*. In both these species the uteri resembled those of the bitch in oestrus, and they concluded that the uterus had been subject to some hormonal stimulation causing proliferation of the epithelium and active secretion from the glands.

Suspended Development, Implantation of the Embryo and Development of the Foetus.

The phenomenon of suspended development, or delayed implantation,

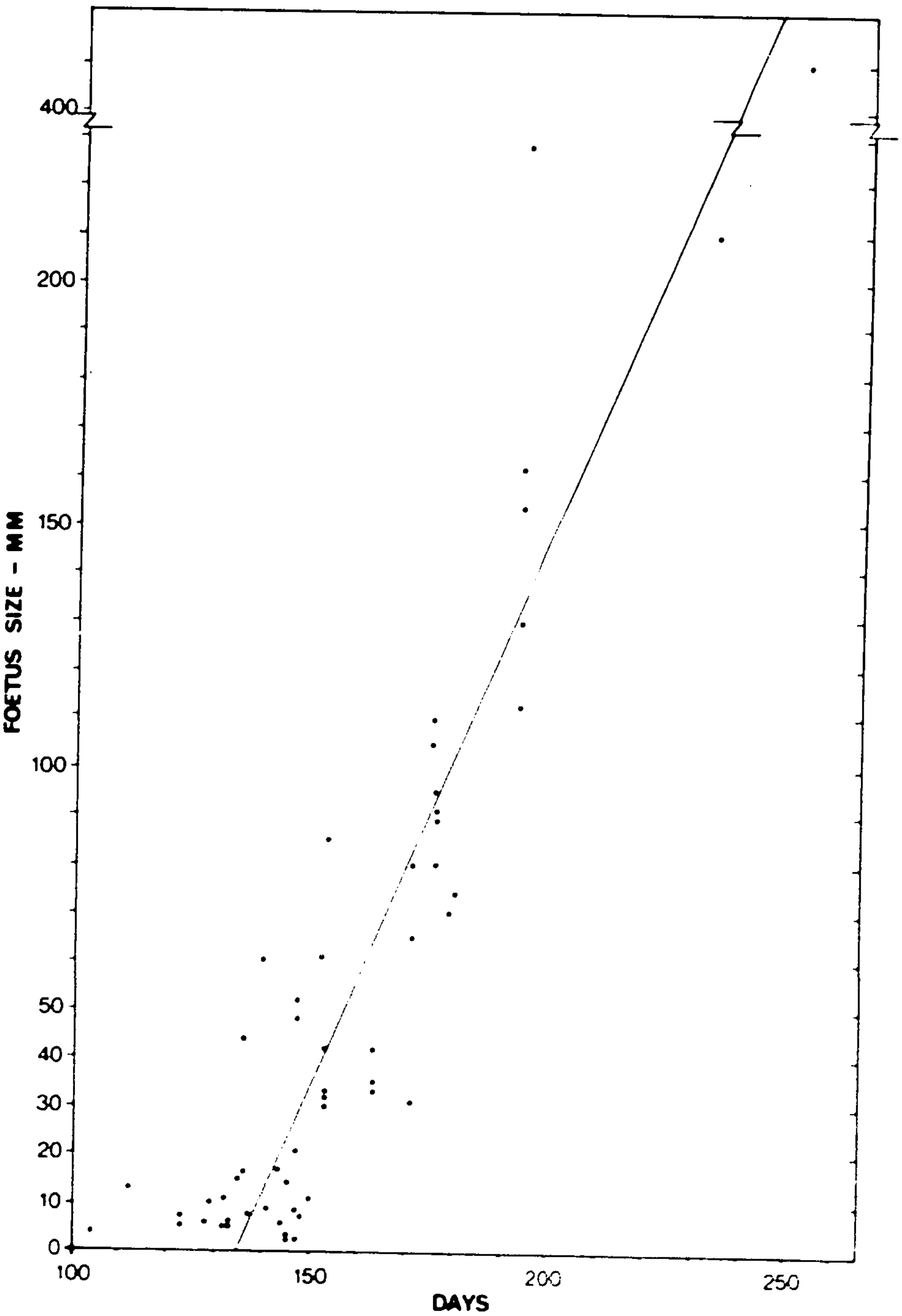


Fig. 20. Regression of foetal length on time.

is known to be widespread in the Pinnipedia (Harrison, 1969). McLaren (1958a) calculated that the period of suspended growth was in the order of 3.5 months in the ringed seal.

The earliest foetus measured in this study was 4.0 mm in length and taken from an animal shot on 12 July 1969 in Cumberland Sound. The latest implanting blastocyst was seen as a swelling in the uterine horn of a specimen shot on 7 September 1967. Allowing a maximum of two weeks for the growth of the early specimen to the size of 4.00 mm, this gives a spread of implantation dates of approximately 71 days. McLaren (1958a) and Johnson et al. (1966) state that the male rut ends about mid-May. In this study a number of males were collected in mid-June which were still in breeding condition, as evidenced by their strong rutting odor. Such seals are known as <u>tiggak</u> by the Eskimos. Since moulting white coats which average about two weeks old, are occasionally seen as late as the third week in June, the last births probably occur during the first week in June. This evidence suggests that the breeding season begins around the middle of March and extends as late as the second week in June. Johnson et al. (1966) state that no pregnant females were taken past April 8; therefore it is probable that the peak of pupping is in late March and the peak of mating in early April.

A linear regression of length of foetus on time was made, using 1 April as the nominal birth date. Fig. 20 shows the regression line plotted through all the data from this study, as well as the foetal lengths taken from McLaren (1958a). Regression lines were also

Table 7. Statistical evaluation of regressions of foetal length on time for all the data available, for data from Home Bay and for data from Cumberland Sound.

Sample	F value	d.f.	P. of arising by chance
All data (Fig. 20)	179.587**	1,58	< 0.001
Home Bay	3.127	1,9	> 0.076
Cumberland Sound	0.922	1,13	> 0.65

calculated separately for the sets of data from Home Bay and Cumberland Sound. A statistical evaluation of the regression lines is given in Table 7. The variance ratio of the explained and unexplained variance using all lengths shows that the regression of foetal size on time has removed a significant portion of the variation in the foetal lengths. Both the Home Bay and Cumberland Sound regressions contain a large amount of unexplained variance, with probabilities of .07 and .65 respectively of the regression lines having arisen by chance.

Calculations of the period of suspended development and the length of active growth of the embryo were made using the regression of all the foetal lengths according to the method of Huggett and Widdas (1951), as modified by Hewer and Backhouse (1968). These calculations result in a period of suspended development of 81 days with an active gestation of 270 days. These values differ from those given by McLaren (1958a), who calculated a period of suspended development of 3.5 months and assumed a period of active growth of 240 days. Fig. 21 summarizes the reproductive cycle for the ringed seal.

Discussion.

Follicles in both ovaries are seen to increase in size around implantation time. Hansson (1947) showed that a decrease in estrogen secretion at implantation which controls follicle growth by suppressing production of FSH (follicular stimulating hormone) by the anterior pituitary, results in a wave of follicular development. After implantation, the corpus luteum secretes progesterone. It is

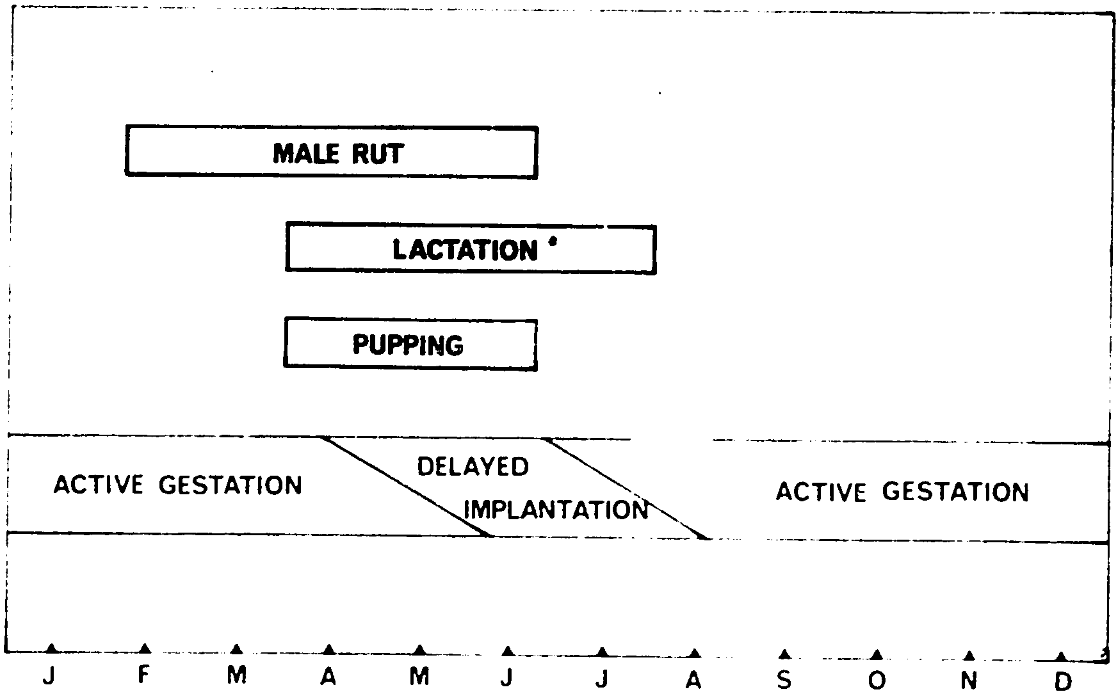


Fig. 21. Summary of the seasonal events, in the reproductive cycle, of the ringed seal.

possible that progesterone also stimulates follicle growth and this would explain the significantly larger follicles found in the ovaries containing the corpus luteum (Laws 1953b). During pregnancy the placenta secretes estrogens which keep the level of follicular activity down in both ovaries (Marshall and Moir, 1952).

No significant differences were found between the sizes of corpora lutea of pregnant and non-pregnant animals taken in August and September. McLaren (1958a) described the change in the histological structure of the gland from May through to implantation. Initially the gland is pale yellow with little connective tissue or vascularization. Near implantation the corpus luteum becomes noticeably vascularized and finally nearly all the luteal cells are separated by fibrous trabeculae. It appears therefore that the histological appearance of the gland and not the size is the best indication of the state of the corpus luteum. Pike et al. (1960) found that resorbing corpora lutea in the fur seal, Callorhinus ursinus decrease little in overall size since regressive elements of connective tissue replace luteal tissue.

Evidence from the present study suggests that there are a number of possible ways of forming accessory corpora lutea. They may be formed from unruptured follicles, from erupting immature follicles, from the simultaneous eruption of two large follicles, or from the rupturing of the wall between two large follicles one of which has ovulated.

Macroscopic traces of the corpus albicans appear to be completely absent after two years. In the ringed seal McLaren

(1958a) found that animals up to 10 years old retained a maximum of four corpora albicantia. In both the ringed seal and the harp seal (Fisher, 1954) a balance appears to be attained between the number of corpora albicantia gained and lost after 10 years of age. In *Otaria byronia* (Hamilton, 1939) and the elephant seal (Laws, 1953b) corpora albicantia are resorbed completely within a year. It is likely that in the ringed seal detailed microscopic examination would reveal more than one corpus albicans. However since error can be introduced by confusion of small corpora albicantia with remnants of more recent atretic follicles, only the most recent corpus albicans has been considered in all calculations of reproductive rates.

A definite alternation of ovulation was seen by comparing the frequency of occurrence of the corpus albicans in the ovary other than the one containing the active corpus luteum. This is caused by the fact that the oestrogens secreted by the placenta have a greater effect on the ovary containing the corpus luteum which is usually on the side of the pregnant uterine horn. It is possible that one of the reasons for failure of alternation of ovulation is caused by transmigration of the blastocyst to the other uterine horn as was shown to occur by McLaren (1958a).

A number of factors can affect the length of total gestation in an animal having suspended development (delayed implantation). In the ringed seal ovulation appears to occur shortly after parturition. Lactation, which is estimated to be in the order of two months, does not appear to delay ovulation if the calculated period of delay of implantation of 81 days is correct, since the earliest implantation in this study occured at the beginning of July.

Harrison (1969) states that in some seals there is an interval of about 2 months between conception and suspension of development of the embryonic blastocyst, and infers that this might also occur in the ringed seal. Evidence in this study contradicts this view since blastocysts in a very early developmental stage were seen as late as 7 September indicating that the suspension of development of the blastocyst begins almost immediately after fertilization.

The causes of delayed implantation in the Pinnipedia are not well understood. Laws (1956) suggests that in the elephant seal the delay is caused by secretion of oestrogen by the ovaries, which inhibits the release of luteo-trophine by the anterior pituitary. Other investigators have found that oestrogens administered to ovariectomized rats can overcome the delay in implantation (Cochrane and Meyer, 1957). This however applies only to animals having the facultative type of delayed implantation. The administration of oestrogens or progesterones to animals with obligate delayed implantation has never stimulated growth in the blastocyst (Daniel, 1970). It is probable that the delay in implantation in pinnipeds is a combination of inhibiting and stimulating factors. It is also probable that hormones interact with other tissues to produce substances that are necessary for the growth of the blastocyst. Daniel (1968) and Daniel and Krishnan (1970) have found that the uterine fluids collected during delayed implantation in several mammalian species show a lower protein content than in animals in active gestation. They also identified a protein called "blastokinin" in the uterus of rabbits which is shown to stimulate blastocyst growth in vitro.

Delayed implantation in pinnipeds is exclusively obligate and does not seem to be a secondary effect caused by external, physiological, or behavioral factors such as day-length, temperature, moulting, lactation or migration (Harrison 1963, 1969). It appears to be a definite reproductive feature which must impart some selective advantage to the animal possessing it.

SEASONAL MOVEMENT OF SEALS

Seasonal Distribution and Dispersal of Age Classes.

The distribution of seals at different times of the year was investigated by examination of age-frequency distributions obtained from the Home Bay and Cumberland Sound catches.

The Home Bay area. The histograms in Fig. 22 show a semilogarithmic plot of the percentage-age-frequency distribution of seals taken in the Home Bay region during four periods in 1967. In May, the adolescent animals (age 1+ to 6+) represent .19 of the population sample. In June this proportion rises to .34, a significant increase (chi square = 40.21 $P < .005$). During the period of 1 July to 31 October, which represents the open water season, the adolescents show a further significant increase to .42 of the population (chi square = 16.43 $P = .005$). The period 1 November 1967 to 31 March 1968 has the highest proportion of adolescent seals (.67) with very few adults present. Proportions of the yearling, adolescent and adult seals are shown in Table 8.

In the Home Bay region the highest proportion of yearlings (0+ seals) occurs in the month of June on the fast ice. As the season progresses this percentage decreases because the seals become decreasingly catchable as they grow older. The adolescent year classes are lowest in the May catches. They increase in proportion in the June, July to October and November to March samples. The increase in the June and the following open water period reflects the movement into coastal areas by the adolescent animals. This supports McLaren's (1958a) assertion, that, during

Table 8. Proportions and frequencies ( ) of yearlings, adolescents and adults from catches taken at different times through the year from Home Bay and Cumberland Sound.

	Yearlings	Adolescents	Adults
(a) Home Bay			
1 - 31 May 1967	.39 (159)	.19 (79)	.42 (175)
1 - 30 June 1967	.39 (737)	.33 (660)	.28 (552)
1 July to 31 Oct. 1967	.27 (195)	.42 (307)	.31 (227)
1 Nov. 1967 to 31 March 1968	.20 (46)	.68 (157)	.12 (29)
(b) Cumberland Sound			
1 - 31 May 1967	.27 (144)	.61 (319)	.12 (65)
1 - 30 June 1967	.37 (425)	.52 (592)	.11 (126)
1 July to 30 Sept. 1966	.25 (288)	.59 (536)	.16 (147)
5 Nov. 1966 to 30 April 1967	.22 (37)	.64 (108)	.14 (24)

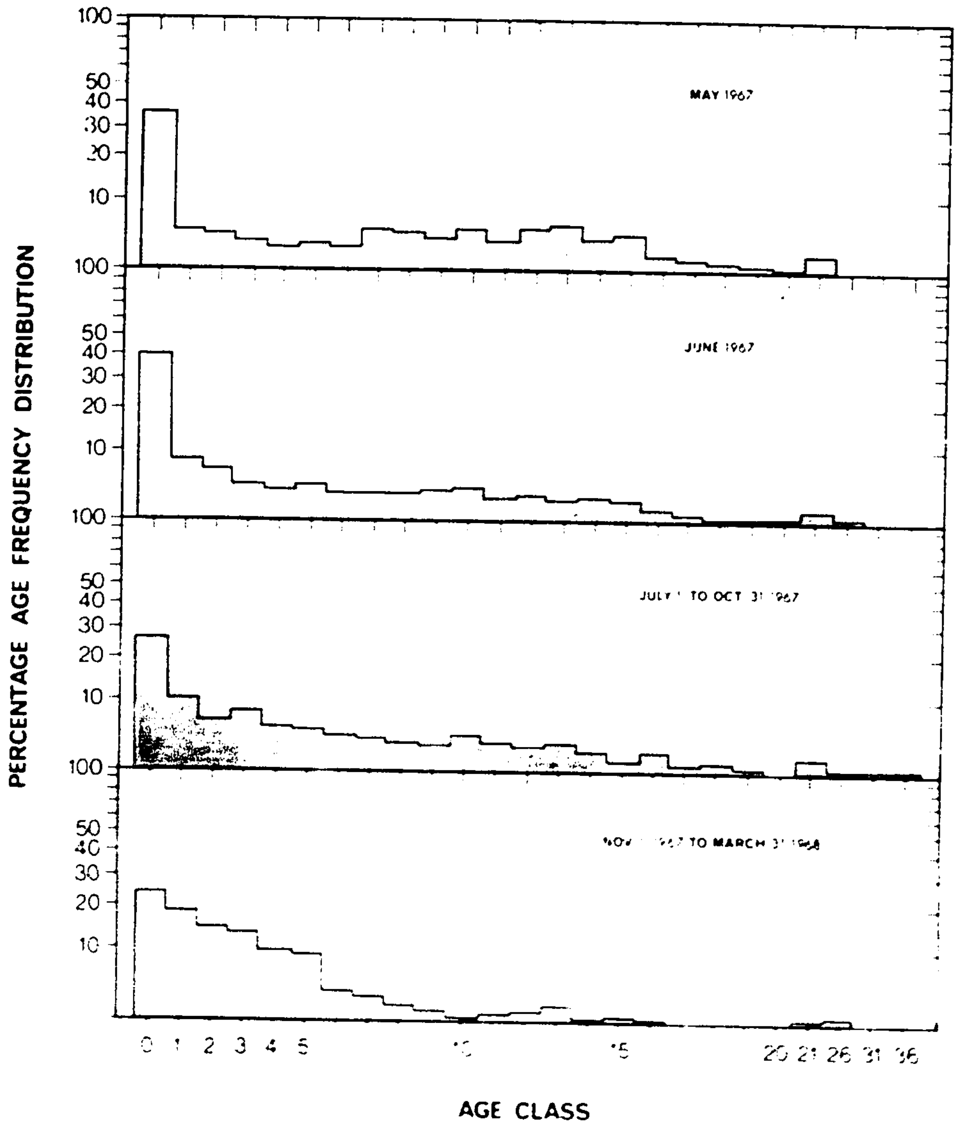


Fig. 22. Seasonal change in the age composition of the catch from the Home Bay area.

the winter fast ice season, the adolescent animals are excluded from breeding ice by the adult seals. During the period 1 November 1967 to 31 March 1968 the adolescent seals form the largest proportion of the catch, adult seals being almost completely absent. Most of the hunting during this period is done at the floe edge, during the period when the ice is beginning to freeze up. This area is occupied exclusively by adolescent seals. Very little hunting in this part of the Canadian Arctic is done at the breathing holes, and the adult animals, which during this period are distributed under the fast ice, are largely inaccessible to the hunters. The highest proportion of adults is taken in the May period although there are probably as many adults present in June. This is due to a combination of factors. The area hunted at this time of the year is the fast ice which is still occupied mainly by adult animals and the pups which have just been born. The adolescents are still, to a large extent, absent from these areas, but gradually move in through the month of June. In May the adult females are still suckling their newborn pups making them vulnerable to being shot whereas in June most of the pups have been weaned. In May the hunters willfully hunt the adults but in June they avoid doing so because they know the animals are in full moult and the pelts are almost worthless. Because of the number of factors affecting the age-frequency distributions, i. e. seasonal segregation of age classes and availability of seals to the hunter, hunter selection, and decreasing catchability of the yearling seals, it is difficult to obtain a representative age-frequency distribution for the population. The age distribution obtained for the open water season (1 July to 31 October) is judged to be the most representative with some qualifications. It is evident that the 0+ animals in this sample are over-represented because they are naive and therefore more easily killed. It is also possible that the adolescent seals may be slightly over-represented in the younger age classes and become decreasingly catchable as they grow older. For this reason the first two or three age classes may always be biased to a small extent. It is felt that the older adolescent age classes and the adult animals are equally catchable and therefore show a representative age structure.

The Cumberland Sound area. In Cumberland Sound the seasonal distribution of the different age classes does not appear to follow the same pattern as in Home Bay. The histograms in Fig. 23 reveal that a high proportion (mean = .59) of the animals in Cumberland Sound are adolescents in all the date periods considered.

Comparison of the histograms from the four periods does not give as clear-cut a picture of seasonal movement as in the Home Bay sample. It does appear however that there is a higher proportion of yearling seals in the June catch than in either the May or open water catch. The difference was tested and found to be significant in both cases (chi square = 11.58 and 15.78 respectively, $P < .005$ in both cases). This higher proportion of yearlings in June might be interpreted as a movement into Cumberland Sound by yearling seals produced in adjacent areas such as Hoare Bay.

Indications are that there is never any great concentration of adult seals in the Cumberland Sound hunting areas. The maximum

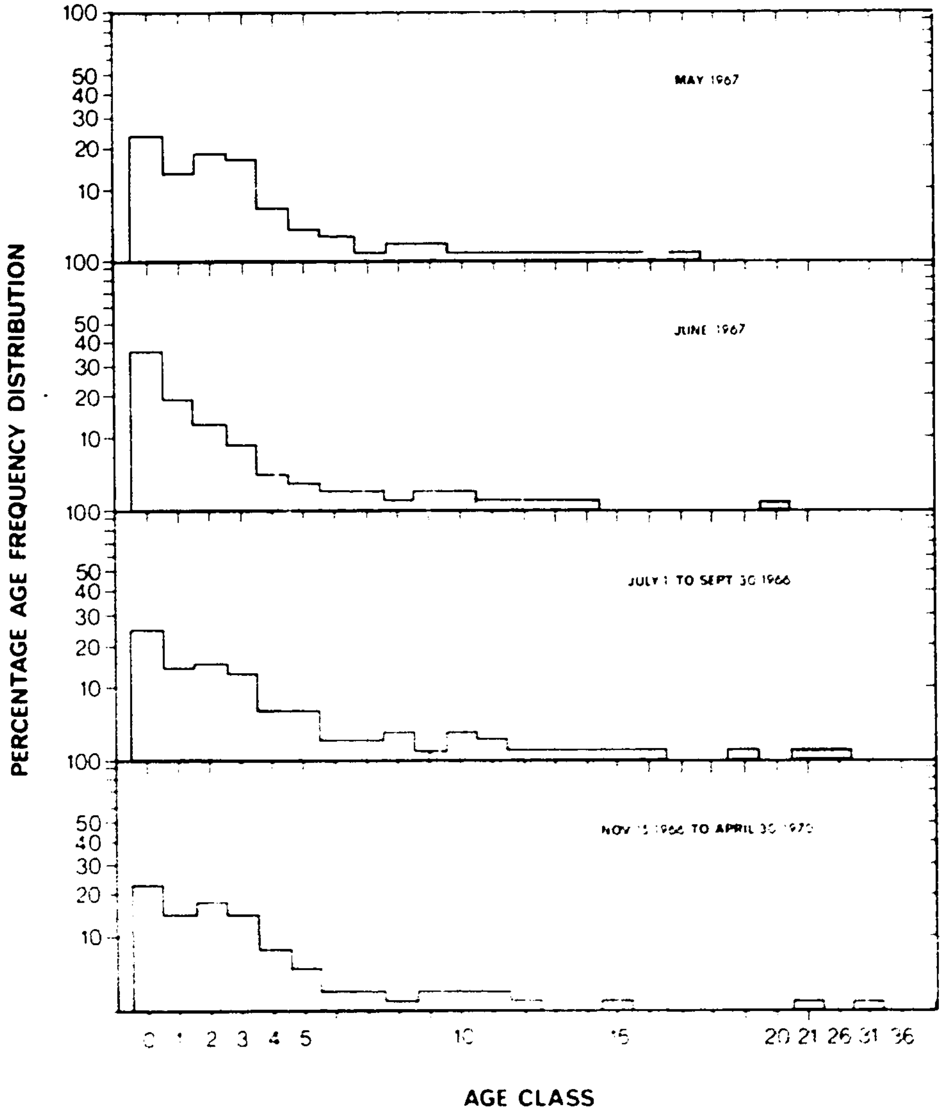


Fig. 23. Seasonal change in the age composition of the catch from the Cumberland Sound area.

proportion was .16 which was seen in the open water period of 1 July to 30 September. It is possible that the ice instability due to a large tidal amplitude of 19.5 feet (Pilot of Arctic Canada, 1959) and strong currents, cause the area to be largely unsuitable for breeding purposes, and this would explain the low number of adults. It is very likely that the hunters of this region are exploiting the seals that are born in unexploited, highly productive areas outside Cumberland Sound. This is supported by a definite indication that yearling seals move into Cumberland Sound from outside areas in June.

Discussion.

One of the most likely areas to be supplying Cumberland Sound with young seals is the unexploited coast line between Cape Dyer and Cape Mercy, which includes the Hoare Bay region. One sample of ringed seal obtained there in the open water during September 1969 showed .54 (13/22) of the animals to be sexually mature. Although this is a small sample the higher proportion of adults is significantly greater than in the open water sample taken in Cumberland Sound (chi square = 2.60 P = .05). The proportion of adult seals in the Hoare Bay unexploited population was observed to be even greater than in the Home Bay samples although not quite significantly so (chi square = 2.31 P = .193). This difference might indicate that the unexploited population in Hoare Bay contains a maximum number of adult animals and this would support the theory that such a population could act as a supply center of young seals for a highly exploited area such as Cumberland Sound, immediately adjacent to it.

An important factor which likely promotes this dispersal is the Canadian Current which sweeps along the coast from Cape Dyer past Hoare Bay and into Cumberland Sound, crossing over to Nuvuyen on the southeast side of the Sound from Leopold Island near Cape Mercy (Pilot of Arctic Canada, 1959). The adolescent seals, which occupy the peripheral areas of ice just prior to breakup are likely to follow this current into Cumberland Sound where the fast ice breaks up usually about two weeks earlier (around mid-June) than the fast ice along the outer coast. The yearling seals which appear to come into Cumberland Sound during the month of June are also likely influenced in the same way by the current and the earlier breakup of ice at the mouth of the Sound. The southeast coast outside Cumberland Sound also probably contributes a quantity of seals to the annual hunting returns, but perhaps to a lesser extent than the Hoare Bay area because of the direction of the current. No age samples have been obtained from this area but the complexity of the coastline indicates that it is probably quite productive.

COUNTS AND BEHAVIORAL OBSERVATIONS ON THE FAST ICE

Counts of seals on the fast ice and a study of their diurnal behavior patterns were made in Ekalugad fiord during May and June of 1968 and 1969. Ekalugad fiord, which is situated at the northern extent of the Broughton Island hunting area, was ideal for these purposes because it was subject to very little hunting disturbance and had a high density of seals. The fiord is 36 miles long, 5 miles across at the widest part, narrowing to approximately 1.5 miles in the arms at the landward end. The surrounding terrain is high, sometimes up to 2000 feet usually rising steeply from the sea level. The fast ice is very stable and smooth due to the low tidal amplitude of approximately 3.5 feet. Cracks in the ice appear in late June but these are relatively few and are formed all the way across the fiord near the seaward end. One river enters the fiord in its northern landward arm causing the ice for approximately one mile from its mouth to be unreliable for travel.

Counts During the Haul-out Period.

The period from 26 May to 29 June 1968 was spent making counts of seals on the fast ice in the fiord. In 1969 the period 5 June to 26 June was spent making similar counts and observing the diurnal behavior patterns of the seals on the fast ice. Fig. 24 shows the location of the observation points, the census area and the diurnal study area in Ekalugad fiord. Counts were made using a pair of 7 X 35 binoculars from observation points above the ice. The total area censused in this manner was 38.58 square nautical

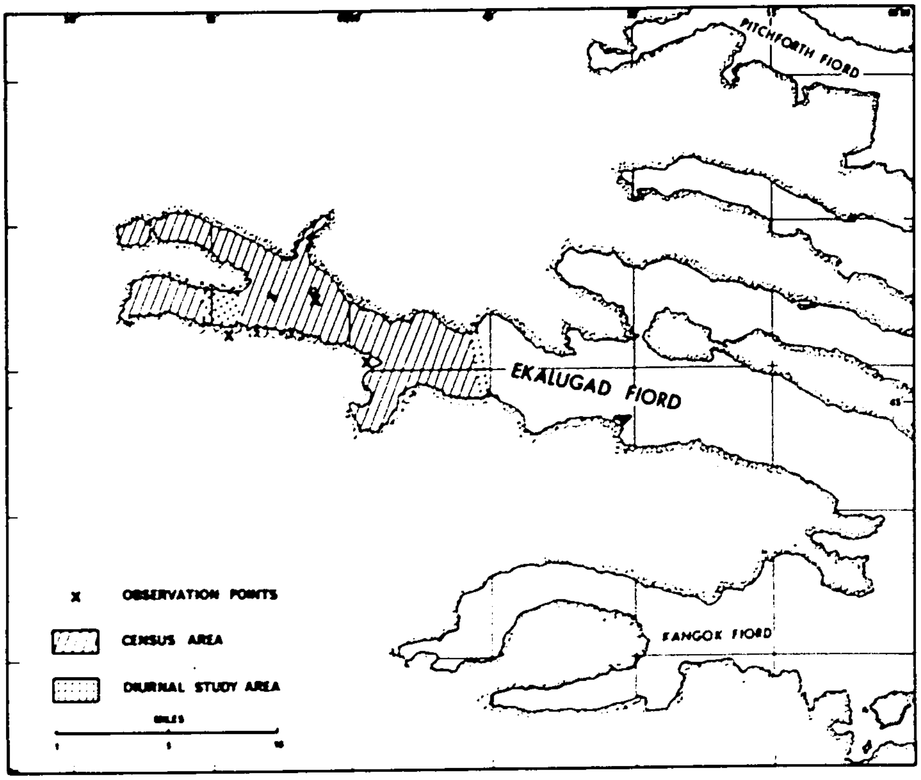


Fig. 24. A map of Ekalugad fiord, at the north end of the Home Bay area, showing the observation points, the census area and the diurnal study area.

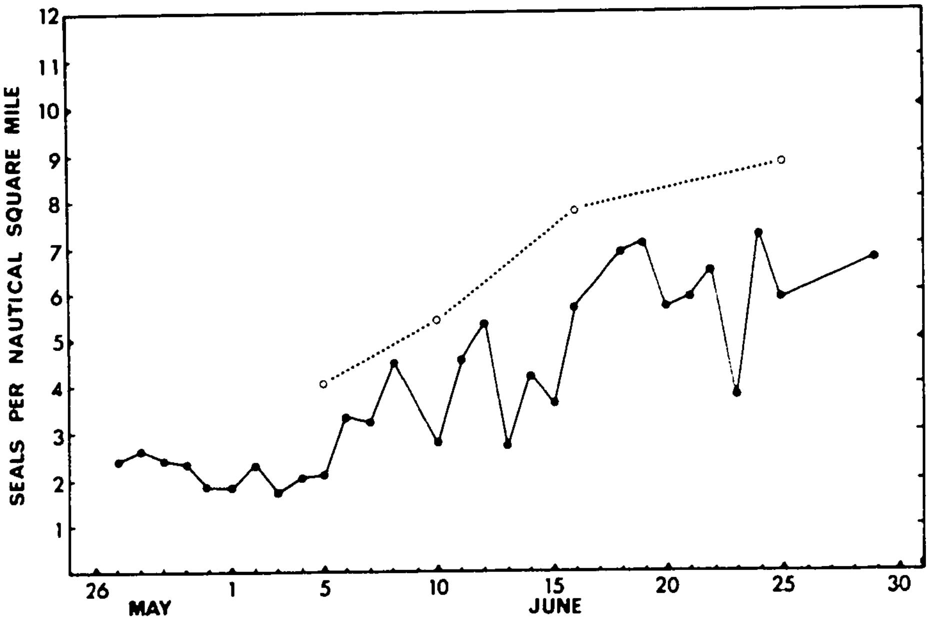


Fig. 25. Numbers of seals hauled out per square nautical mile of fast ice, during May and June of 1968 (solid dots, solid line) and 1969 (open dots, broken line).

miles. In 1968 a peak density of 7.12 seals per square nautical mile was recorded on 25 June. In 1969 a slightly higher peak density of 8.49 seals per square nautical mile was observed again on 25 June (Fig. 25). In both years counts terminated near the end of June because it was necessary to return to Broughton Island before travelling on the fast ice became impossible. In 1969 counts of seals in Ekalugad fiord were made on 7 July during the aerial survey, indicating that the peak number of seals in this area occurs later than had been shown by the previous ground counts. On this date 15.73 seals per square nautical mile were counted.

During the census of 1969 a record was kept of the number of nursing pairs observed during the counts. Nursing pairs are presented as a percent of the total number of seals counted during May and June (Fig. 26). A general increase in the number of suckling pups was seen until 9 June, after which a gradual decrease in their numbers was observed. If mid-April is considered the mean birth date these observations imply a 1.5 to 2 month lactation period. This is supported by the fact that only one post partum female, shot 9 June, was lactating, whereas six other post partum females collected between 10 June and 1 July had no milk in their mammaries.

It is not clear whether or not the increase in the number of seals, between the end of June and those counted from the air on 7 July, was due to the continued haul-out of seals resident in Ekalugad fiord, or to an influx of seals from the outside which were moving into the remaining fast ice. It appears that the latter explanation is the more likely since densities recorded in Ekalugad

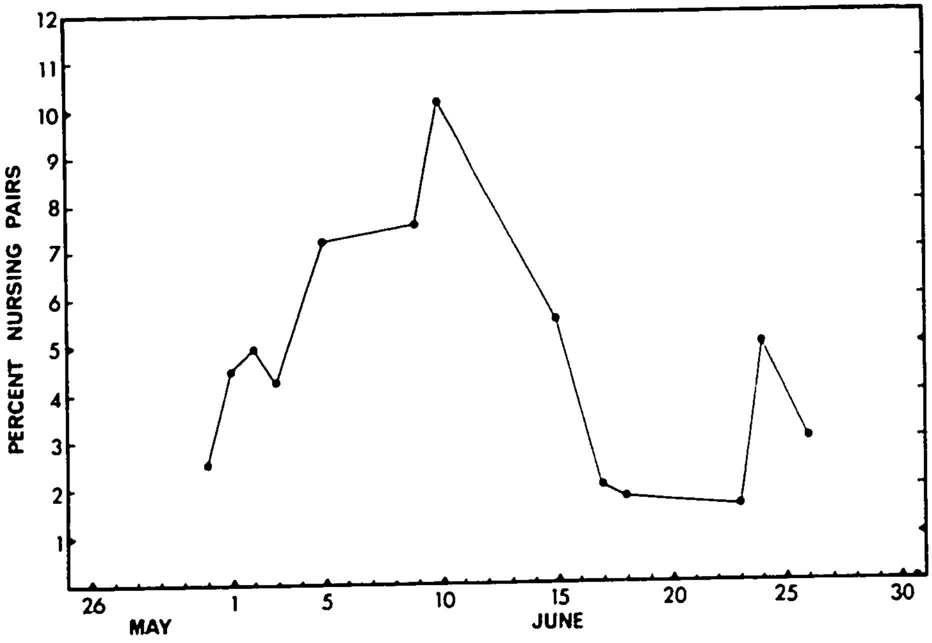


Fig. 26. Seasonal counts of nursing pairs, i. e. mother and newborn pup, expressed as a percentage of the total daily counts, during May and June 1969.

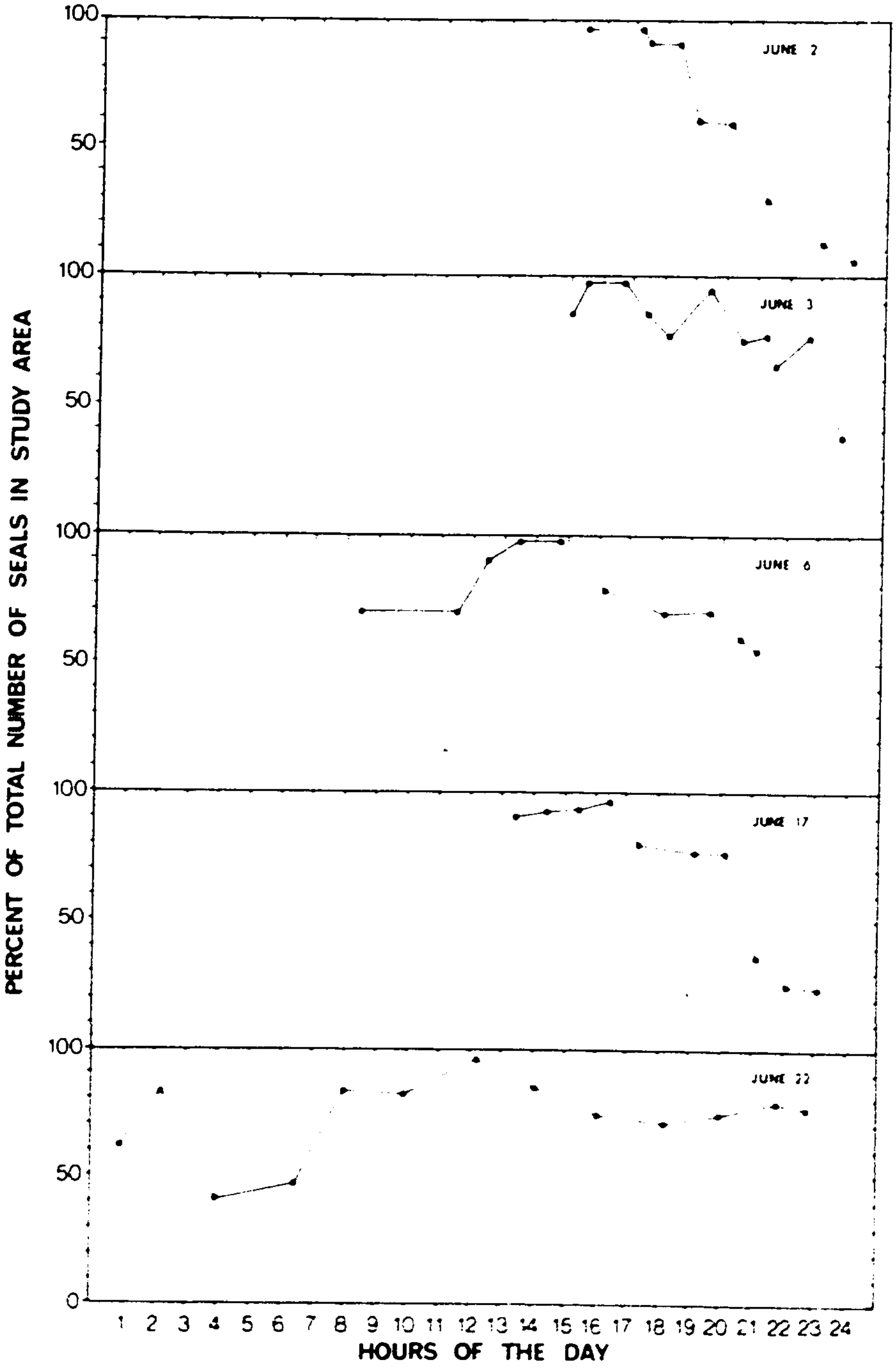


Fig. 27. Diurnal density regime of seals, on the fast ice, in the Ekalugad fiord study area, on five seperate days, during June 1969.

appeared to have almost stabilized around 15 June. The maximum density recorded in Ekalugad fiord during the ground counts on 25 June in both years also corresponds well with the mean fiord density calculated from the aerial surveys. It is possible that, since Ekalugad fiord is wider and straighter than most of the other fiords in the Home Bay area, it is especially prone to earlier invasion by seals from the outside at the breakup of the ice.

Diurnal Behavior Patterns.

In order to study the diurnal regime of seal density, the time spent by individual animals on the ice, and obtain an estimate of the number of seals under the ice, the area immediately in front of the camp, in Ekalugad fiord, was observed for varying lengths of time of up to 24 hours' duration, on 2, 3, 6, 7, 22 June 1969. Observations were made using a spotting telescope and binoculars. The maximum size of the observation area, about 2 square miles, was decided by the number of individual seal positions on the ice that could be plotted and observed without possibility of confusion. The actual positions of the seals were drawn on a map of the area and the total number showing on the ice within the area, which was delimited by a known angle using a fixed tripod position for the telescope, was recorded at each observation.

Counts of the numbers of seals on the ice during the day were made at one- and two-hour intervals (Fig. 27). In early June, at the beginning of the haul-out period, the peak numbers of seals were observed between 1400 and 1900 hours (-4 hours G.M.T.). As the season progressed the greatest number of seals were observed from

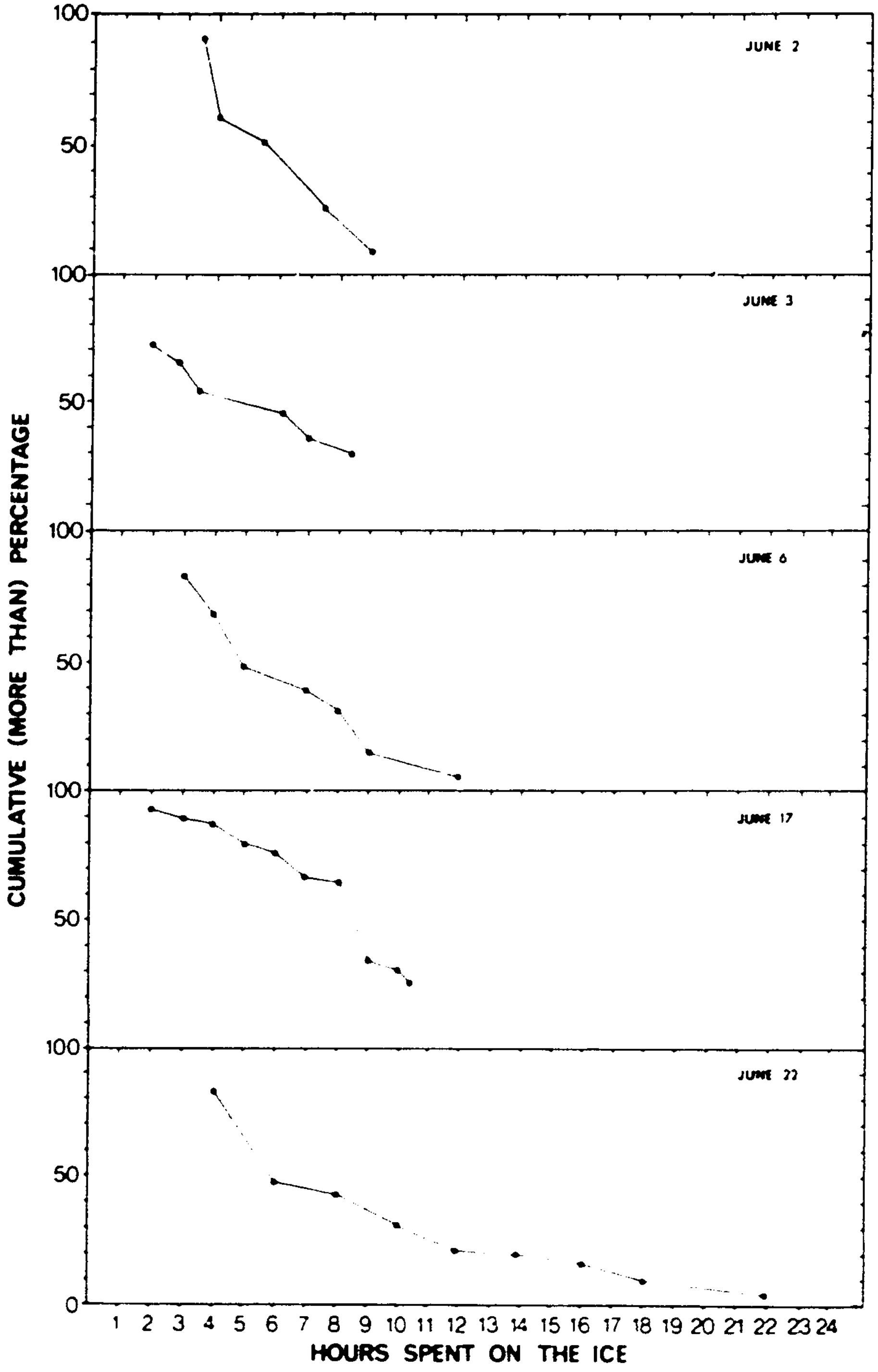


Fig. 28. Mean minimum number of hours spent on the ice, during one "sitting", by seals, on five different dates in June 1969.

1200 to 1400 hours. It was also noticed that there was a very marked reduction of seals during the night hours in early June whereas in late June the number of seals remaining on the ice during the night was much higher (Fig. 27).

The number of hours spent on the ice by individual seals without re-entering the water is shown in Fig. 28. The mean minimum number of hours increases from 5.2 at the beginning of June to 7.6 on 22 June. This was observed to be true for the adult seals but the small number of pups observed during this time appeared to spend much shorter intervals on the ice. Often a pup would be seen on the ice for a short time then it would disappear and presumably the same pup would reappear at the same hole. This often went on at several different breathing holes during the observations for periods covering 4 to 8 hours.

Only indirect means could be used to estimate the number of seals under the ice at a given time since it was not possible to identify individual animals during the observations. If the simplifying assumptions hold (i) that seals used the same breathing holes and did not haul out at other breathing holes in or outside the study area and (ii) that counts of seals were made at the diurnal peak of haul-out, then an estimate of the number of seals, missed in the counts made at this time can be made. Using the figures from the 24-hour observation period made on 22 June 1969, the number of seals at the peak of haul-out was 19 and the total number of seals (different positions = different individuals) seen during the day in the area was 38. This indicates that 50 percent of the seals, at the peak of haul-out during the day, are under the ice. No other means of estimating this parameter were available. The observation that a seal sits out a mean minimum of 7.6 hours at a sitting would indicate that a seal hauls out for approximately 2 long periods in the day if the estimate of 50 percent of time spent under the ice is correct. It is realized that the simplifying assumptions used to obtain this estimate are not entirely realistic and the figure of 50 percent of seals under the ice should be considered a maximum estimate only. More observations coupled with a means of marking and identifying individual animals are needed to provide an accurate estimate of this factor which is of great importance when knowledge of the absolute size of the seal populations is needed.

Discussion.

A number of factors are likely involved in the changing pattern of diurnal behavior as the season progresses. Increases in the amount of daylight hours and changes in the angle of solar radiation, which are quite marked at these latitudes during this time of the year, might explain the advance in the day of the peak seal numbers, and the decrease in the drop off of numbers during the night hours, from the beginning to the end of June. A corresponding rise in the mean daily temperatures might also be involved, although this is not a very marked increase. Perhaps the most likely explanation for the increased amount of time spent by the seals on the ice near the end of June, is the fact that they are in full moult and are very reluctant to go into the water in this condition. It is possible that the yearling seals spend much less time on the ice because they have finished their moult which occurs normally within two weeks of birth.

ESTIMATES OF POPULATION SIZE

Aerial and Ground Census of Seals on the Fast Ice of Home Bay.

An aerial and ground census of seals on the fast ice of Home Bay was conducted from 29 June to 7 July 1969. Ground counts were made during travel by "skidoo" from Ekalugad fiord to Broughton Island from 28 June to 1 July. Some areas counted from the ground were also counted from the air on the same days. Aerial counts were made from a Piper Apache on charter to the Fisheries Research Board of Canada from Atlas Aviation, Resolute Bay, N.W.T. The survey lasted five days during which a total of 32.25 hours were logged. An area of 1,192 square nautical miles was covered in which a total of 7,020 ringed seals were counted.

<u>High and low altitude counts</u>. At the beginning of the survey, counts were made from an altitude of 1,000 - 1,200 feet. When I joined the aerial survey crew on 3 July, counts appeared to me to be consistently low due to the difficulty of picking out seals from a background of mottled ice. A comparison of the ground counts and counts made in the same areas from the air (Table 9) showed that there was a consistent significantly lower number of seals (chi square = 56.51 $P < .005$) in the aerial estimates. In addition to this evidence, a flight on 2 July was made over the end of Ekalugad fiord where I had been camped and where I knew there was a large number of seals. On the first pass over the diurnal study area (Fig. 24) at 1,000 feet, three seals were counted. The second pass was made at 200 feet during which 73 seals were observed. It was thus positively determined that high altitude counts were grossly inaccurate.

Table 9. Comparison of seal counts on the fast ice made from the ground and from the air (1,000 feet) in Home Bay at the end of June, 1969.

Location	Area of ice	Ground Count	Air Count	Ground Density	Air Density
9	17.25	87	28	5.04	1.62
10	12.93	23	11	1.77	0.85
11	7.37	50	15	6.78	2.03
19	4.08	85	103	20.83	25.24
23	7.03	22	15	3.12	2.13
24	3.40	54	20	15.88	5.88
32	9.53	3	1	0.31	0.10
33	3.63	16	4	4.40	1.10

In the remaining days of the surveys (3 and 7 July) all counts were made at heights of 40 - 100 feet, flying at a speed of 135 - 140 mph. From this height the silhouette of the seal could be seen clearly which makes it very much easier to pick out. The forward speed of the aircraft was great enough that seals were not scared down until the plane was directly over or past them. With two observers counting well ahead and out to the side, it is felt that all seals up to a distance of three miles on either side of the plane were counted without significant error. One test run up and down the same flight path in a long narrow fiord revealed that .74 (124/168) of the seals up to a distance of 0.25 miles from the side of the plane dive down into the water after the plane has passed.

Seal densities in different categories of fast ice. Three types of fast ice areas were censused during the survey: ice in deep fiords; areas at the mouth of fiords and around islands; transects of one mile in width, flying out toward the floe edge (offshore ice). Ice areas in deep fiords are easily delimited since the boundaries are quite definite. It is also relatively easy to delimit areas between islands or between islands and the mainland. Defining boundaries in strip counts out toward the floe edge was more difficult. Two strips were flown with each observer estimating ½ mile from his side of the aircraft and counting all seals in that area. Both strips were flown on headings of 30° starting in the vicinity of a DEW Line site. Counts were made at an altitude of 100 - 200 feet to increase visibility which is somewhat limited at very low levels by pressure ice and icebergs. Distance flown was estimated by calculations

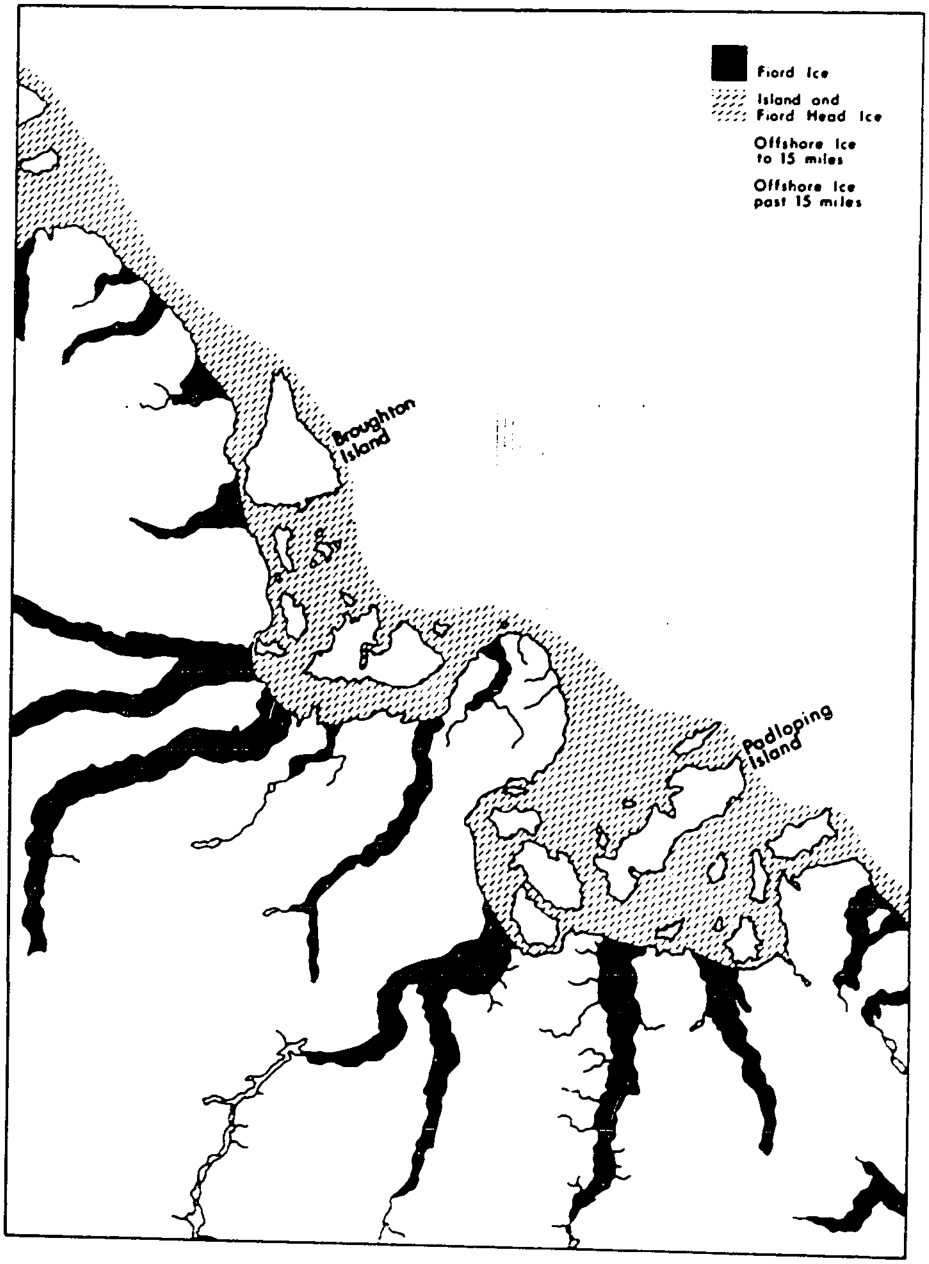


Fig. 29. A portion of the Home Bay area near Broughton Island, showing the type of area censused and the categories of fast ice used, in making estimates of the population size.

Table 10. Densities of seals recorded on various flights from different categories of fast ice.

Date	Altitude	Type of ice	Mean density	S.D.	S.E.
June 29, 30 and July 2	1000 feet	Fiords	3.78	3.28	0.94
		Heads of fiords and around islands	4.93	9.67	2.06
July 3	less than 100 feet	Fiords	8.42	4.60	1.16
		Heads of fiords and around islands	5.89	4.88	1.18
July 7	less than 100 feet	Fiords	8.83	12.24	3.39
		Heads of fiords and around islands	6.53	3.38	0.87
	100 feet	Cape Hooper transect			
		(0 to 18 miles)	5.02		
		(18 to 33 miles)	1.02		
	100 feet	Cape Broughton transect			
		(0 to 27 miles)	7.98		
		(27 to 33 miles)	0.19		

involving time and air speed as well as radar fixes, at the end of a strip, from the DEW Line stations.

Fig. 29 shows a portion of the Home Bay survey area and the categories of ice censused. Although small areas in fiords appeared to have considerably higher numbers of seals than others, the overall distribution of seals in the fiords and ice areas around islands was random. This was tested using the coefficient of dispersion $s^2 /\overline{X}$ and a test to determine the significance of the departure of this ratio from unity. The value of the standard error, $SE = (2/n-1)$, was used (Greig-Smith, 1964). Critical values of Student's t-distribution of $P > .9$ and $P > .2$ were obtained for fiords and ice around islands, indicating no significant departure from a random distribution.

Table 10 lists the densities calculated from the three different types of ice areas on the different days of the aerial survey. No significant differences were found between the mean densities in fiords or around islands between counts made from a low altitude on 3 and 7 July ($P = .9$ and $P = .5$ respectively). Final estimates of density were taken from the counts made on 7 July. This yields an average density of 8.83 seals per square nautical mile of fiord ice and 6.53 per square nautical mile of ice at the head of the fiords and around the islands. The estimate of density from the strip count out from Cape Hooper is judged to be the most representative. Counts were high from the other transect since the beginning of the strip lay within a bay near islands and the ice here is not representative of the "offshore type" of ice area, being much more densely occupied. Also the Cape Hooper strip is more reliable since it was divided at 18 miles, shortly after the density of seals dropped off noticeably. A density of 5.02 seals per square nautical mile for ice up to 15 miles outside the outlying islands thus appears to be a realistic estimate. Ice past this point appears to contain less than one seal per square nautical mile.

Estimates of Population Size.

Estimates of the size of the populations were made from densities of seals counted in the 3 different categories of fast ice using information from the Ice Summary and Analysis (1964, 1965, 1966, 1967) to determine the area of ice involved.

A consideration of the seasonal distribution of age classes and the behavior of the seals indicates that the figures for seal densities obtained from the aerial counts alone are much too low.

A comparison of the Home Bay age-frequency distribution for the open water period, which can be considered as representative of the population age structure, and the age-frequency distribution for seals taken from 15 June to 10 July, the period around the time of the aerial survey, reveals that the adolescent age classes are under-represented. The open water period contains .57 of adolescent to adult in the population whereas the period immediately around the time of the aerial survey has .46 adolescent, a significantly lower proportion (chi square = 15.06 $P < .005$). In order to correct the estimates for the under-represented adolescents in the aerial survey the difference in proportion of adolescents from the unbiased

Table 11. Population sizes calculated from densities obtained from the Home Bay aerial survey for the Home Bay, Hoare Bay, and Cumberland Sound areas, and the final corrected population size estimates.

Area	Total density from aerial survey	Corrected estimates
Home Bay	33,028	70,684
Hoare Bay	16,931	36,376
Cumberland Sound	27,466	58,782

and biased age frequencies (.1149) was used as a correction factor and added to each original total number of seals estimated in each area.

Perhaps the most important factor contributing to the underestimation of the population size is the number of seals under the ice at the time during which the counts are made. Preliminary estimates of this proportion indicate that it could be as high as .50. Table 11 gives the total number of seals calculated from the densities in the three categories of fast ice as determined from the aerial survey in Home Bay, for the Home Bay, Hoare Bay and Cumberland Sound areas. These estimates are then corrected by applying the two factors mentioned above and the final figures are shown in Table 11.

McLaren (1958b) gave estimates of 74,000, 28,000 and 68,600 for the number of seals in Home Bay, Hoare Bay and Cumberland Sound. Estimates from the present study are 70,684, 36,376 and 58,782 which are in line with his estimates but were not derived in the same way. McLaren's (1958b) estimates were based on counts from Ney Harbour, an area of 3.6 square miles of fast ice, and on his division of the sea ice into three categories of ice containing different densities of seals. An aerial survey conducted by the same investigator in 1964 over a limited number of areas in the Frobisher Bay region showed a mean density of 7.5 seals per square mile, a figure comparable to the densities in this study. These figures were not accepted as the true density, and calculations were done to raise the estimates which were considered low because of the seals that were assumed to have been missed by the observers (McLaren,1966). Evidence in the present investigation indicates that aerial surveys are reliable in giving the number of seals present on the ice, but that the population size would be underestimated based solely on these counts because of the significant proportion of seals that are in the water and hidden from view.

Estimates of population sizes using the factor of 50 percent for the proportion of the population under the ice might be slightly high because this figure is a maximum estimate. However this is probably balanced out by other factors which would cause the population size to be underestimated and which have not been corrected for because no quantitative evaluation of their effect is available. One such source of error involves the yearling age class. During the behavioral observations it was noticed that the young of the year appeared to spend much less time on the ice than the adults. This is to be expected since it has been shown that most pups are fully weaned by mid-June and that they also moulted their foetal coat shortly after birth. Since the age frequency at the time of the aerial survey shows that .39 of the population are yearlings, the fact that a significant proportion of the pups are not on the ice would lead to a further underestimation of the population size.

The estimates of population numbers arrived at in this investigation only indicate the approximate size of the real populations. Density estimates derived from the aerial survey in

Home Bay have been applied to Hoare Bay and Cumberland Sound to make the population estimates. This is probably valid for the Hoare Bay area which is quite similar to Home Bay in having a complex coastline with stable fast ice. Calculation of the population size of Cumberland Sound using densities obtained in Home Bay might not be realistic since there are many indications that Cumberland Sound is much less productive. Age frequencies from Cumberland Sound catches at all times of the year show a low proportion of adults, while age frequencies from Hoare Bay, an area of stable fast ice immediately adjacent to Cumberland Sound, shows a significantly greater proportion of mature seals. This indicates that the fast ice of Cumberland Sound is not suitable for breeding purposes, probably mainly because of the high tidal amplitude in the Sound, 19.5 feet as compared to 3.5 feet in Home Bay, which causes the ice to be very unstable. The strong currents caused by the tide under the ice are also a likely source of danger for any young born in these areas.

VITAL STATISTICS OF THE POPULATION

The Sex Ratio.

Table 12 lists the sex ratios obtained in this study and in two other investigations of the ringed seal. The sex ratios of pups obtained in 1967 and 1970 in the present study, do not depart significantly from unity. This was also the case in the pup sex ratio obtained by McLaren (1958a) and in the foetal sex ratio of Johnson et al.(1966).

In the present study information on the sex of all animals caught in 1970 was recorded. The sex ratios of the yearlings, adolescents and adults in the catch were examined for the months of May, June, and the open water season from July to October. All age groupings at all times except the adults in the month of May, showed a 1:1 ratio and no significant departure from this ratio was noted (Table 12). In May, even though the sample size was small there was a significantly greater number of adult females than adult males in the catch. This is probably not indicative of absence of males in the fast ice area but merely indicates that females are more vulnerable at this time since they spend more of their time lying out on the ice while suckling their newborn pups. This is confirmed by a return to a 1:1 sex ratio in the adults in June when the fast ice conditions still prevail but after most of the pups have been weaned.

Reproductive Rates.

Age-specific-reproductive rates were determined by examination of the uterine cornua for the presence of a blastocyst or foetus.

Table 12. Sex ratios obtained in this study and in two other investigations of the ringed seal.

Sample	Sex ratio (male : female)	Chi square	Probability of chi square value arising by chance
McLaren (1958)	259 : 229	1.84	P>.1
Johnson et al (1963)	108: 112	0.042	P>.5
Home Bay (1967)	117 : 112	0.108	P>.5
Home Bay (1970)			
Adults (May)	6 : 21	8.32**	P<.005
Yearling (June)	33 : 38	0.352	P>.5
Adolescents (June)	7 : 13	1.80	P>.1
Adults (June)	37 : 25	2.32	P>.1
Yearling (July-October)	149 : 142	0.028	P>.5
Adolescent (July-October)	92 : 92		
Adults (July-October)	99 : 108	0.390	P>.5

Table 13. Mean age-specific reproductive rates from the present study and three other ringed seal studies, as well as from a large harp seal sample from the Gulf of the St. Lawrence River.

Age	Home Bay (1967)	McLaren (1958b)	Johnson et al (1966)	Nagarenko (1968)	Harp seals Sergeant (1970) unpublished
0					
1					
2					
3					.025
4	.30	.10			.219
5	.44	.50			.625
6	.63	.75			.844
7	.64	.93			.846
8	.67	.93			.911
9	.74	.93			.926
10	.74	.93			.896
Mean of ages 11 to 40:	.74	.77			.881
Overall mean:	.73	.73	.85	.62	.88

The youngest animals seen to be pregnant were 4+ years old and the oldest age class used in the calculation of mean reproductive rates was 40+. Table 13 shows the age-specific mean reproductive rates for animals taken in Home Bay and Hoare Bay areas in this study and the reproductive rates found in two other studies of ringed seal as well as the age-specific rates from another pagophilic species, the harp seal in the Gulf of St. Lawrence (Sergeant, 1970, unpublished data).

The combined mean reproductive rate from the Home Bay and Hoare Bay samples is .74. Other workers on ringed seal have reported rates as low as .62 (Nazarenko, 1965) and as high as .85 (Johnson et al., 1966). The rate obtained in the present study is considered an underestimate. This results from the fact that reproductive tracts were only collected to mid-September, and since it has been shown that the delay in implantation can last until the first week of October, a considerable number of animals that were pregnant were probably classed as non-pregnant. The data of Johnson et al. (1966), although not age specific, comes from a large sample taken from November to April and is probably quite representative of a true reproductive rate for ringed seals. Sergeant's (1970) unpublished data (Table 13), which is age-specific, probably gives a realistic representation of the age-specific reproductive rates in the ringed seal population if the reproductive rate in the 3+ age class is eliminated. The mean reproductive rate calculated from these data over 40 age classes is .88 which is quite close to the value obtained in Johnson's et al. (1966) investigation. These values are therefore considered representative for the ringed seal population and will be used later in calculations involving life table construction and population dynamics. McLaren (1958b) arbitrarily reduced the fertilities assuming that the ringed seal displays sexual senility. The work of Sergeant (personal communication) on the harp seal, Mansfield (personal communication) on the grey seal, and evidence from the present study fails to detect any indication of such a phenomenon, therefore the fertilities are held constant in the adult year classes from 11+ to 40+ for all calculation of average reproductive rates.

The Stationary and Stable Age Population.

The age-frequency distributions used in this study form a kl_x series, that is, they are samples of the age structure of the population observed at a given time, and the survivorship rates are inferred from the shrinkage between successive age classes. In order for these values to be meaningful two conditions must be met. First, the initial size of each age class must be equal, in order that the drop in frequency from one year class to the next, can be used to estimate survivorship. Secondly the age-specific mortality and reproductive rates must have remained constant long enough (at least over the range of age groups present) to produce a stable-age distribution. It should be pointed out that the stationary age distribution just described is a special case of the stable-age distribution and that a stable-age structure can be found in populations that are increasing or decreasing at a constant rate.

It has been assumed that the populations of ringed seals

Table 14. Number of ringed seal skins traded per year in the Cumberland Sound and Home Bay areas.

Year	Cumberland Sound	Home Bay
1961	8,242	
1962	5,391	
1963	9,296	
1964	10,103	
1965	12,490	4,292
1966	7,601	4,545
1967	4,931	4,510
1968	5,787	3,837
1969	10,190	5,937
Average number:	8,226	4,624
Average per household	121	119

harvested in Home Bay and Cumberland Sound are stationary. Table 14 shows the total number per year of ringed seal pelts bought at the Home Bay and Cumberland Sound trading posts. No quantitative date are available on catch-effort therefore these data do not directly reflect the stability of the seal stocks of the areas. Examination of the total pelts traded however do positively show that a low catch can be followed by a high catch therefore indicating that the maximum yield has not been exceeded. Fluctuations in the total take are greater in the Cumberland Sound catches. This can be explained by the rapid changes taking place in the way of life of the Eskimos in this area. In 1967 almost all the hunting camps distributed throughout Cumberland Sound moved into the village of Pangnirtung. Subsequent to this, with the various construction projects going on in the town, less people depended on hunting as a livelihood. The Broughton Island community that hunts Home Bay has been more consistent in its hunting effort and this is reflected by the catches. A good part of the fluctuation in the catches can be explained by the fluctutation in the market prices of the skins since there is a strong correlation (r = .923) between prices and number of skins traded. It appears therefore that the fluctuations in catches can be mostly explained by socio-economic factors and that the total catch is quite uniform apart from this. It is interesting to note that the mean number of pelts per household, as calculated from data in Haller et al. (1966) is almost identical for Cumberland Sound and Home Bay (Table 14). In the future an effort should be made to gather catch-effort data in order to be able to check on the stationarity of the seal stocks.

A comparison was made between the representative age frequency samples from 1967 and 1970 to see if the population had a stable-age structure. A comparison of the proportion of adults in the 1967 and 1970 data showed that they did not differ significantly (chi square = 0.70, $P > .5$). A comparison of the individual frequencies in the adult age classes of 7 to 19 years using a 2 X 13 contingency table showed that there were no significant differences, (chi square = 13.67, $P > .36$). This indicates that the age-frequency distributions have remained stable through the period 1967 - 1970, which is a further indication that the population is stationary.

Preliminary Analysis of the Catch Curves.

A number of difficulties are involved in deriving estimates of total survivorship and mortality from any catch curve. These arise from the fact that some age classes are more vulnerable to being caught and also that mortality is not constant throughout all age classes. In the ringed seal catch curves, it is probable that the yearling animals are more likely to be caught and are thus overrepresented. It is also likely that the yearling natural mortality is slightly higher. This might also apply to a lesser degree to other early adolescent age classes. It is also reasonable to assume that the older age classes have a higher natural mortality but it is difficult to get a realistic idea of what this might be because of the low numbers of old seals in the catch.

The usual assumption in most methods of estimating population survivorship and mortality from age frequencies is that the population age distribution is geometric. This assumption of constant survivorship through the age classes leads to error when the method used does not have built into it a means of testing the variance in the survivorship factor. The method of Chapman and Robson (1960) described more fully in Robson and Chapman (1961) uses such a test by comparing its best survivorship estimate,

$$\bar{X}\left[(1 + \bar{X} - (1/n)\right]^{-1}$$

to the estimate obtained from Heinke's (1913) formula,

$$(n - N_0)/n$$

by the use of a chi square formula.

When the survival estimate calculated by the Chapman and Robson method is significantly larger than that calculated by Heinke's method it implies that there is an overabundance in the 0 group relative to the older groups. The chi square comparison of these two values tests the hypothesis that these two estimates differ only by sampling error. This test establishes whether or not there is good agreement between the observed frequency in the 0+ age class, expected on the basis of the data in the older age groups. The catch curve can be tested in this way for the representativeness of the frequency of the next age group by simply eliminating age group 0 from the data, recoding the age groups and testing again with the chi square formula.

Although the survivorship estimates derived from the Chapman and Robson (1960) formula are dependent on a constant survivorship which does not strictly hold for the youngest and oldest age classes in the present data, the analysis was used, since it allowed for testing of the representativeness of the younger age classes with respect to the older age classes and permitted statistical comparisons to be made of survivorship values that were of relative validity between segments of the catch curves from different sets of data. Actual survivorship values are derived from a number of different sources and what are considered to be the best estimates will be presented later in a composite life table.

The overall Chapman and Robson (1960) best estimate of survival with 95% confidence intervals from the 1967 and 1970 catch curves are .8477 ± .0316 and .8792 ± .0112 which are not significantly different ($t = .785$, $P > .4$). Ricker (1958) points out that moderate fluctuations in recruitment from year to year cause irregularities in a catch curve but do not destroy its general form. He suggests that such curves can be combined to increase the regularity of the curve. The age frequencies of the 1967 and 1970 data were combined which yielded a survival estimate of .8542 ± .0084.

Examination of the plotted catch curves immediately suggests that the animals in the 0+ age class are overrepresented. Testing for representativeness of the first age class, using the method described in Robson and Chapman (1961), indicates that in the 1967 Home Bay data the 0+ age class is overrepresented and that in the 1970 data the 0+ and 1+ age classes are overrepresented.

Best estimates of survival were computed for different segments,

Table 15. Comparison of survival estimates, for different segments of the catch curve, between the Home Bay 1967 and 1970 catch curves.

Comparison	1967 Survival	1970 Survival	t value	Probability of difference arising by chance
Ages (1+ to 6+)	.6514	.6985	0.4302, 510 df.	P > .5
Ages (7+ to 14+)	.8141	.8419	1.73, 429 df.	P > .05
Ages (15+ to 40+)	.6870	.7264	1.08, 101 df.	P > .2

along the catch curves assuming constant survival in these segments. Chapman and Robson (1960) describe a method which gives the best estimate of survivals, based on truncated samples when the assumption of constant survival rate is valid only for a limited number of age classes. Estimates calculated in this way are drastically lower than the previous best survivorship estimates calculated for the whole age distribution, indicating that although the mean survivorship values may be different along the different segments of the catch curve, they are either not of sufficiently great enough difference, or they decrease in such a uniform manner that the modified best survivorship estimates for truncated data, cannot be used on the present data. Because of this the ordinary formula for the best survivorship estimate was used to estimate the survivorship in the different segments, keeping in mind that the accuracy of the estimate would be only of a relative nature, but useful in comparing segments of different catch curves.

The survival estimates calculated for the age segments 1+ to 6+, 7+ to 14+ and 15+ to 40+ for the 1967 and 1970 data are shown in Table 15. The survival values from the different years were compared using a t-test (Table 15) and not found to be significantly different for any age segment. This reaffirms the previous view that the 1967 and 1970 data are from a stable population.

Survival rates were calculated in the same way for the 1970 Home Bay sex-specific data. Comparison of the male and female survivorship in the adolescent age groups (1+ to 6+) also shows no great difference, ($t = .33$, $P > .5$). The difference between survival

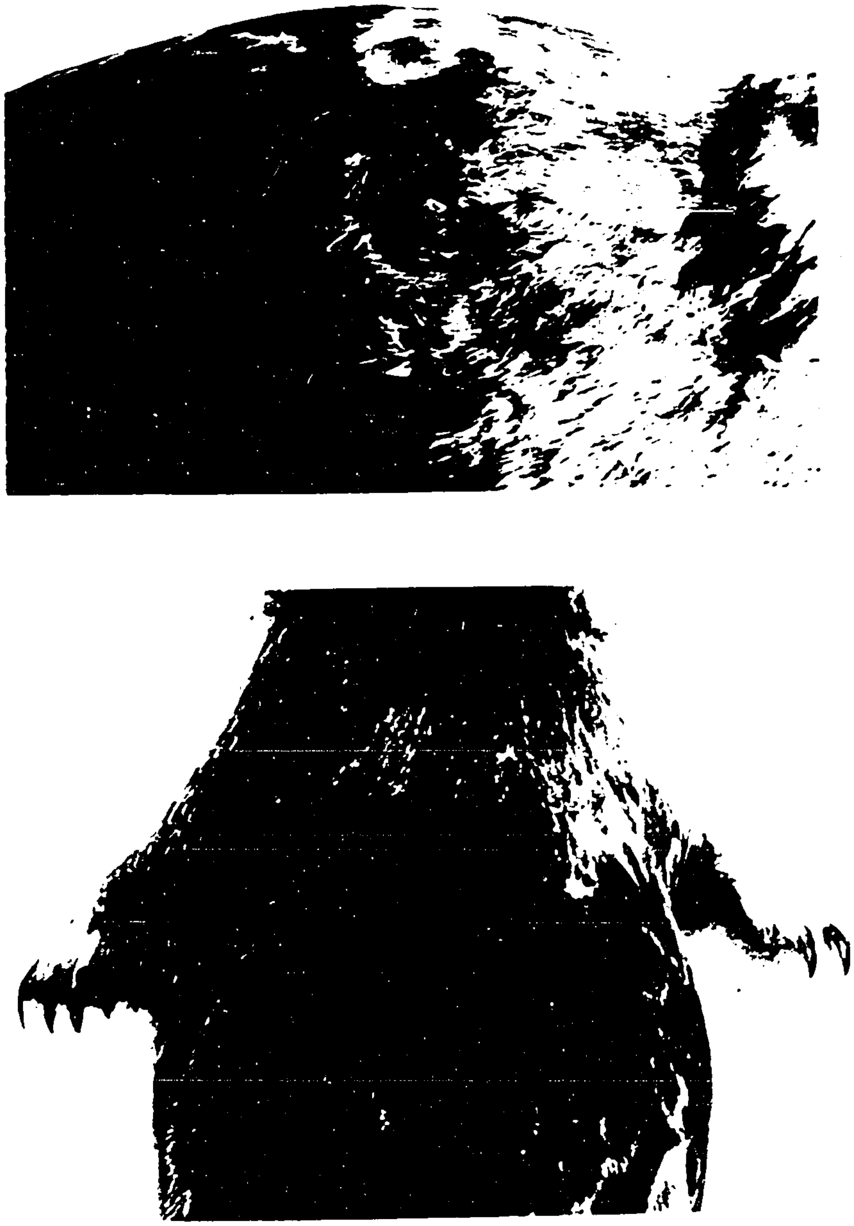


Fig. 30. A rutting male ringed seal, shot on the fast ice, during June 1969. The hole in the skin near the right flipper and missing claws were probably caused by fighting between males, during the breeding season.

[illegible] A [illegible] seal, [illegible] the [illegible],
[illegible] June [illegible]. The [illegible] the [illegible] the
[illegible] flippers and the [illegible] claws were [illegible]
[illegible] the [illegible].

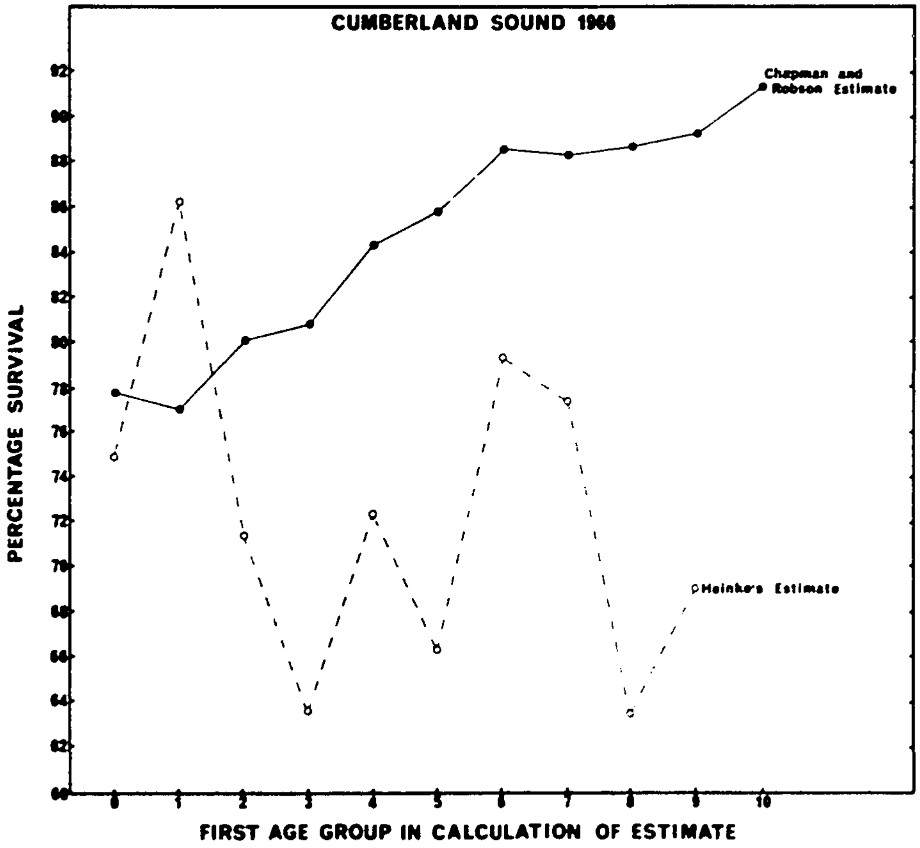


Fig. 31. Comparison of the Chapman and Robson (1960) best estimate of survival with Heinke's estimate, using age classes 0+ to 10+ as the first value in the catch curve, for the Cumberland Sound 1966 data.

Table 16. Analysis of the various catch curves in the study, showing the statistical comparison between the Chapman and Robson (1960) estimate of survival, and the Heinke (1913) estimate of survival.

Sample	Age classes considered	Survivor estimate (Chapman & Robson) with 95% confidence limits	Survivorship estimate (Heinke's)	Chi square value	Probability of difference arising by chance
Home Bay 1967	0 to 21 and over	.8262 ± .0100	.7325	52.59	P< .005 **
	1 to 21 and over	.8477 ± .0316	.8582	.0017	P >.9
	1 to 6	.6514 ± .0320	.7361		
	7 to 14	.8142 ± .0222	.8854		
	15 to 40	.6870 ± .0812	.6190		
Home Bay 1970	0 to 21 and over	.8206 ± .0120	.5766	339.00	P <.005 **
	1 to 21 and over	.8736 ± .0116	.9073	46.77	P <.005 **
	2 to 21 and over	.8792 ± .0122	.9058	0.04	P >.5
	1 to 6	.6985 ± .0354	.8121		
	7 to 14	.8419 ± .0204	.9059		
	15 to 40	.7264 ± .0612	.7457		
Home Bay 1967 & 1970	0 to 21 and over	.8229 ± .0084	.6543	337.00	P <.005 **
	1 to 21 and over	.8542 ± .0084	.8732	3.16	P >.05
Cumberland Sound 1966	0 to 21 and over	.7781 ± .0128	.7497	52.0	P< .005 **
	1 to 21 and over	.7700 ± .0152	.8636	39.0	P< .005 **
	2 to 21 and over	.8004 ± .0160	.7131	28.0	P< .005 **
Cumberland Sound 1967	0 to 21 and over	.6464 ± .0214	.5828	16.0	P < .005 **
	1 to 21 and over	.6308 ± .0252	.7060	20.0	P < .005 **
	2 to 21 and over	.6035 ± .0290	.7897	104.0	P < .005 **

rates in the adult females and males is .0351, but the difference is not quite significant ($t = 1.00$, $P > .2$). This lower survival of adult males has been shown in one other population study of seals (Bigg, 1969). He explains that this could be caused by fighting between the males during the breeding season. Evidence of injuries inflicted by other seals is often found on potent males in the fast ice areas during the period of the male rut (Fig. 30), but no direct evidence of mortality from this cause has been found.

The catch curves from the Cumberland Sound area for 1966 and 1967 were examined using the Chapman and Robson (1960) method. Fig. 31 shows the divergence of the Chapman and Robson survival estimate from Heinke's estimate for the 1966 catch curve using the age classes 0+ to 10+ as the first age class in the calculation. In all cases the chi square test indicated that the first age class in the calculation was overrepresented with respect to the rest of the data. The 1967 catch curve showed the same characteristics (Table 16) indicating that the Cumberland Sound animals do not belong to a stationary stable-age population. This result was not unexpected since evidence commented on previously suggests that Cumberland Sound is low in seal production and that catches are made up of young animals which have been born in adjacent areas.

Life Tables.

Age-frequency samples from the Home Bay area only were used to construct life tables since preliminary analysis of the Cumberland Sound data showed the age structure to be unrepresentative of a self-sustaining population. In order to smooth the original age-frequency distributions the age-specific frequencies were converted to common logarithms and a linear regression line was fitted to these values. In all cases the regressions were fitted to the frequencies of age class 1+ up to the last age class containing 5 or more individuals. This was done since age class 0+ has previously been shown to be overrepresented and because frequencies of less than 5 individuals, in an age class, are too low to give a realistic estimate of survival. Nevertheless, when a polynomial regression was fitted to the 1967 logarithms of the frequencies in all the age classes, including those with less than five individuals, the linear, quadratic and cubic terms all significantly reduced the variation around regression ($F = 55.4$, 48.2, 43.1 respectively; P in all cases is $< .05$). Caughley (1965) states that this indicates that the rate of mortality increases as the animals become older, but in the present case the small number of animals in the older age classes might bias the polynomial regression somewhat.

The assumption has been made that the population is stationary. Such a population forms a kl_x series only when all births for the year occur at an instant in time and the age-frequency sample is taken at that time. Since these conditions cannot be strictly met in practice, and it has been shown in any case that the 0+ age class is overrepresented, an estimated frequency for this age class has been used in the life table. This was calculated by using Sergeant's (1970, unpublished) age-specific-reproductive rates, along with the 1:1 sex ratio and the adjusted age-frequency distribution.

The various parameters in the life tables d_x, l_x, q_x, L_x, e_x,

Table 17. Life table for catch from Home Bay during the period July 1 to October 31, 1967.

Age in years	Age frequency	Adjusted age frequency	$1000d_x$	$1000l_x$	$1000q_x$	$1000L_x$	$1000e_x$	$1000m_x$
0	195	129[a]	189	1000	189	905.5	5.37	
1	81	79	116	811	143	753.3	5.50	
2	50	68	100	695	144	645.0	5.34	
3	63	60	88	595	148	551.0	5.15	
4	43	52	76	507	150	469.0	4.96	27.2
5	40	45	66	431	153	398.0	4.75	67.3
6	30	39	57	365	156	336.5	4.52	77.0
7	26	34	50	308	162	283.0	4.26	65.1
8	22	29	43	258	167	236.5	3.99	58.7
9	33	26	38	215	177	196.0	3.69	49.7
10	27	23	34	177	192	160.0	3.37	39.6
11	23	20	29	143	203	128.5	3.05	31.4
12	26	18	26	114	228	101.0	2.70	25.1
13	19	15	22	88	250	77.0	2.35	19.3
14	9	13	19	66	288	56.5	1.97	14.5
15	16	12	18	47	383	38.0	1.56	10.3
16	6	10	15	29	517	21.5	1.22	6.3
17	6	10	14	14	1000	7.0	1.00	3.0
18	2							
19	0							
20	2							
21	7							
26	1							
31	1							
36	0							

a= estimated see text (P. 112)

Table 18. Life table for catch from Home Bay during the period July 1 to October 31, 1970.

Age in years	Age frequency	Adjusted age frequency	$1000d_x$	$1000l_x$	$1000q_x$	$1000L_x$	$1000e_x$	$1000m_x$
0	301	94[a]	204	1000	204	898.0	6.02	
1	38	42	91	796	114	750.5	6.44	
2	32	38	83	705	118	663.5	6.21	
3	44	34	74	622	119	585.0	5.97	
4	31	31	67	548	122	514.5	5.71	30.0
5	35	28	61	481	127	450.5	5.43	75.1
6	23	25	54	420	129	393.0	5.15	88.6
7	19	23	50	366	137	341.0	4.84	77.4
8	20	21	46	316	146	293.0	4.52	71.9
9	19	19	41	270	152	249.5	4.21	62.5
10	17	17	37	229	162	210.5	3.87	51.2
11	23	15	33	192	172	175.5	3.52	42.2
12	15	14	30	159	189	144.0	3.15	35.0
13	21	13	28	129	217	115.0	2.76	28.4
14	14	11	24	101	238	89.0	2.39	22.2
15	15	10	22	77	286	66.0	1.98	16.9
16	9	9	20	55	364	45.0	1.57	12.1
17	5	8	17	35	486	26.5	1.19	7.7
18	6	8	17	18	1000	9.0	0.83	3.9
19	3							
20	6							
21	10							
26	1							
31	3							
36	1							

a = estimated see text (P. 112)

Table 19. Life table for catch of male seals from Home Bay during the period July 1 to October 31, 1970.

Age in years	Age frequency	Adjusted age frequency	$1000d_x$	$1000l_x$	$1000q_x$	$1000L_x$	$1000e_x$
0	149	30[a]	150	1000	150	925.0	6.26
1	19	17	85	850	100	807.5	6.28
2	11	17	85	765	111	722.5	5.92
3	20	15	75	680	110	642.5	5.60
4	14	14	70	605	116	570.0	5.24
5	13	13	65	535	121	502.5	4.86
6	15	12	60	470	128	440.0	4.46
7	6	12	60	410	146	380.0	4.04
8	14	11	55	350	157	322.5	3.64
9	13	10	50	295	169	270.0	3.23
10	11	10	50	245	204	220.0	2.79
11	9	9	45	195	231	172.5	2.37
12	9	8	40	150	267	130.0	1.93
13	11	8	40	110	364	90.0	1.45
14	5	7	35	70	500	52.5	1.00
15	6	7	35	35	1000	17.5	0.50
16	1						
17	3						
18	2						
19	0						
20	3						
21	3						
26	0						
31	2						
36	1						

a = estimated see text (P. 112)

Table 20. Life table for catch of female seals from Home Bay during the period July 1 to October 31, 1970.

Age in years	Age frequency	Adjusted age frequency	$1000d_x$	$1000l_x$	$1000q_x$	$1000L_x$	$1000e_x$
0	152	31[a]	144	1000	144	928.0	6.51
1	19	19	88	856	103	812.0	6.53
2	21	17	79	768	103	728.5	6.22
3	24	16	74	689	107	652.0	5.87
4	17	15	70	615	114	580.0	5.52
5	22	14	65	545	119	512.5	5.16
6	8	13	60	480	125	450.0	4.79
7	13	12	56	420	133	392.0	4.41
8	6	11	51	364	140	338.5	4.01
9	6	11	51	313	163	287.5	3.58
10	6	10	47	262	179	238.5	3.18
11	14	9	42	215	195	194.0	2.77
12	6	9	42	173	243	152.0	2.32
13	10	8	37	131	282	112.5	1.90
14	9	7	33	94	351	77.5	1.45
15	9	7	33	61	541	44.5	0.96
16	8	6	28	28	1000	14.0	0.50
17	2						
18	4						
19	3						
20	3						
21	7						
26	1						
31	1						
36	0						

a = estimated see text (P. 112)

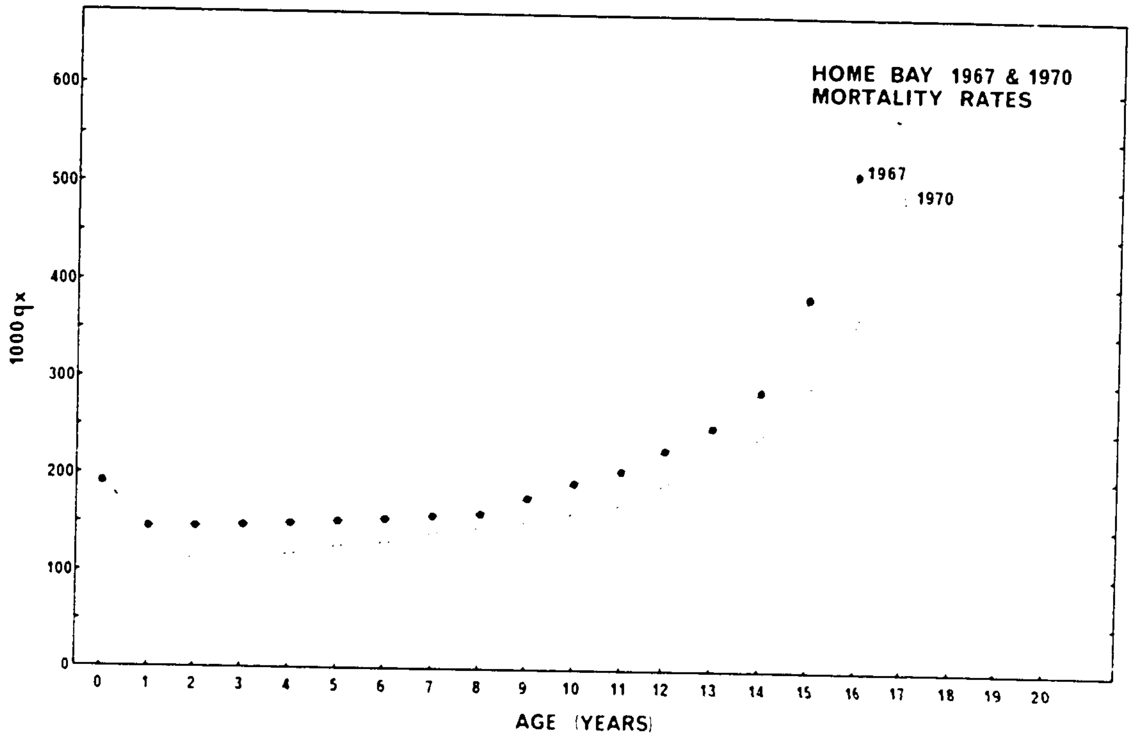


Fig. 32. Comparison of the 1967 and 1970 Home Bay mortality rates (q_x).

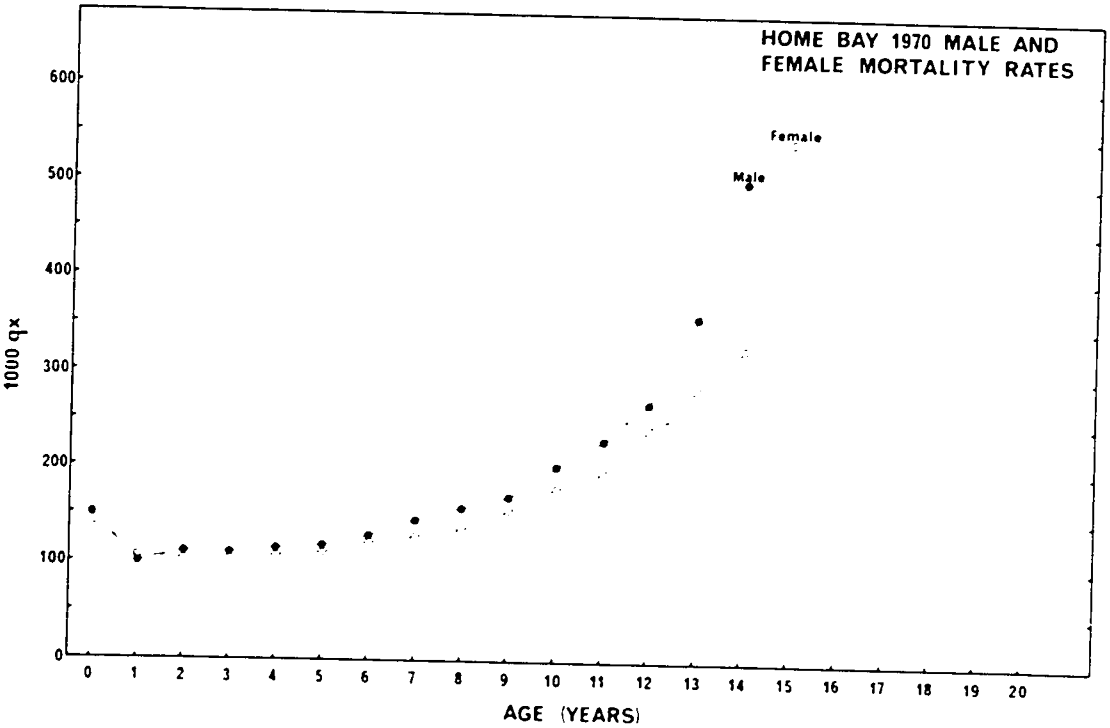


Fig. 33. Comparison of the 1970 Home Bay male and female mortality rates (q_x).

and m_x, have been calculated according to the formulas outlined in Deevey (1947) and summarized in Quick (1963). Tables 17, 18, 19, 20 show the complete time-specific life tables of the overall 1967 and 1970 Home Bay catches and the 1970 sex-specific tables. Caughley (1965) points out that the mortality rates are the least biased of the derived statistics in a kl_x series. This is explained by the fact that $q_x = d_x/l_x$ and is therefore independent of all but two age frequencies, whereas l_x and d_x values are dependent on all values preceeding them. Comparison of the mortality rates were made between the 1967 and 1970 Home Bay catches and between the 1970 male and female catches. Fig. 32 shows the 1970 to be very similar to the 1967 rates but slightly lower. The 1970 sex-specific data shows the female and male adolescent mortality rates to be almost identical, with a slight rise of the adult male mortality rates over the female (Fig. 33). This agrees with the difference in male and female survivorship values obtained for the adult segment of the curve using the method of Chapman and Robson (1960).

A number of statistics can be derived from the l_x and m_x series of a life table. Mean mortality rates calculated from the formula $\bar{q}_x = 1/\sum l_x$ are 17.05 for the 1967 Home Bay data and 15.33 for 1970. This compares well with the figures for 1966 and 1967 of 15.33 and 12.92 respectively obtained by the Chapman and Robson (1960) method. One other statistic, the mean length of a generation (the lapse of time between a female's birth and the birth of her offspring), which is defined as

$$T = \sum x l_x m_x / \sum l_x m_x$$

has been derived and was found to be 6.91 and 7.24 for the 1966 and 1967 data. Other statistics which are dependent on whether the life table is in fact representative of a stable-age distribution will be presented later when this question has been investigated.

Discussion.

The overall shape of the mortality rate curves (Fig. 32) obtained from the Home Bay 1967 and 1970 data are very similar to curves obtained in other life table studies of mammals, such as that of the Dall sheep *Ovis dalli* (Deevey, 1947; Taber and Dasman, 1957) the Orkney vole *Microtus orcadensis* (Leslie et al., 1955) and in human demographic studies (Dublin, Lotka and Spiegelman, 1949). This agrees well with Caughley's (1965) statement that mammals in general show a U-shaped q_x curve and fits Pearl's (1940) high-low-high mortality rate classification.

Although the survival estimates obtained by considering all the age classes and using the Chapman and Robson analysis, can be accepted as quite reliable from the Home Bay samples, the breaking down of the catch curve, into an adolescent and two adult age groups, greatly reduces the accuracy of the absolute values of these estimates because of the great reduction in sample size and change in the shape of the geometrical probability distribution, on which the Chapman and Robson (1960) best estimate is based. A certain amount of interpretation of the catch curve is required using what is known about the quality of the data when an attempt is made to assess survival rates through the different age classes in the population.

McLaren (1958b) presented a model life table showing the total mortalities for ringed seals of ages 0+ to 40+. His mortality figures for the very young and old age classes were obtained by making assumptions about the natural mortality and hunting mortality affecting these groups. The present study, by looking at the vital statistics obtained from the catch curve, also makes an attempt to construct a realistic life table. Under column s in Table 21 is listed the survivorship value for each age class. These values are defined as $N_1/N_0 = s = (1 - a)$, when $a = N + M - NM$, where N = natural mortality and M = hunting mortality. The survivorship for the 0+ age class of .61 is obtained in a way previously described from the adjusted life table for 1967 and using the m_x values from Sergeant (1970, unpublished data). The 0+ survivorship value from the 1970 life table was not used since the age class 1+ was shown to be biased by the Chapman and Robson analysis. McLaren (1958b) assumed a greater survivorship of .69 for the 0+ age class and since this survivorship value has a relatively large influence on the dynamics of the population, in the model used, the consequences of varying the magnitude of this value will be discussed in a later section. The survival values in the adolescent year classes 1+ to 6+, are shown to be lower than in the adult 7+ to 14+ ages by the Chapman and Robson survival estimates (Table 16). Because of the small number of age classes considered however, the value of these estimates are greatly biased in this type of analysis and cannot be taken as correct. The smoothed life tables indicate that there is very little difference between the survivorship of adolescents and adults, with a gradually increasing mortality as the

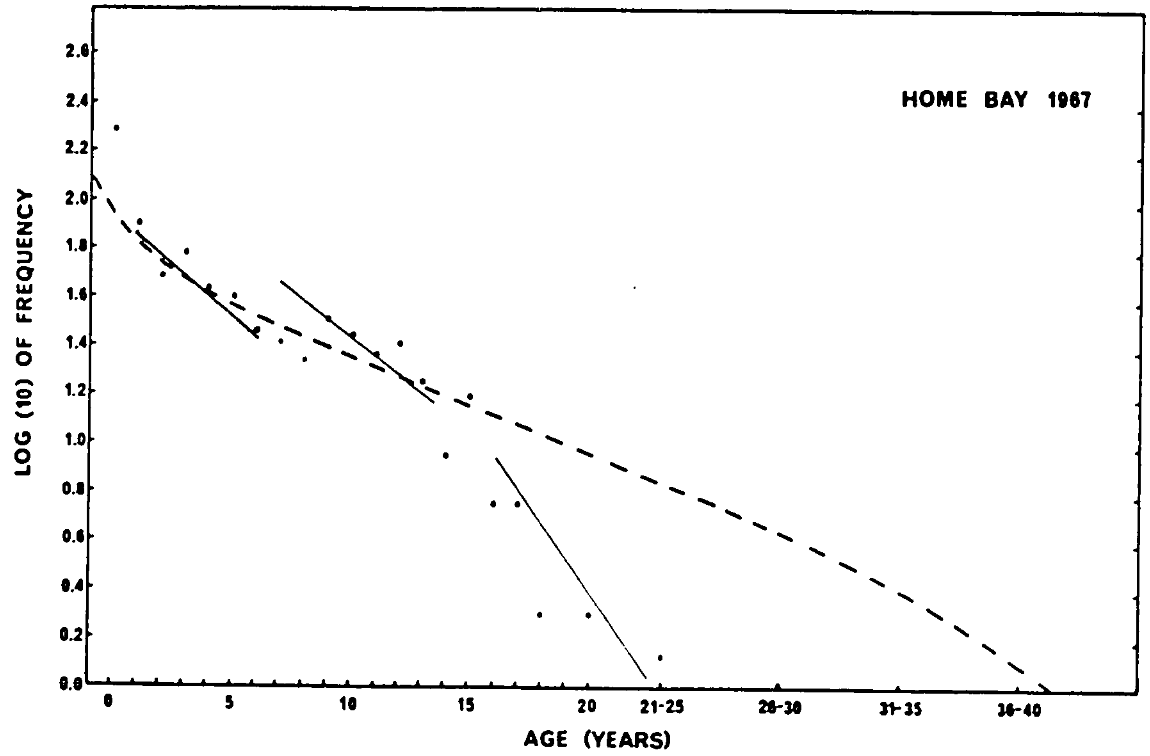


Fig. 34. Semilogarithmic plot, of age frequencies, from the 1967 Home Bay open water catch, with linear regression lines through age classes 1 to 6, 7 to 14, and 15 to 40.

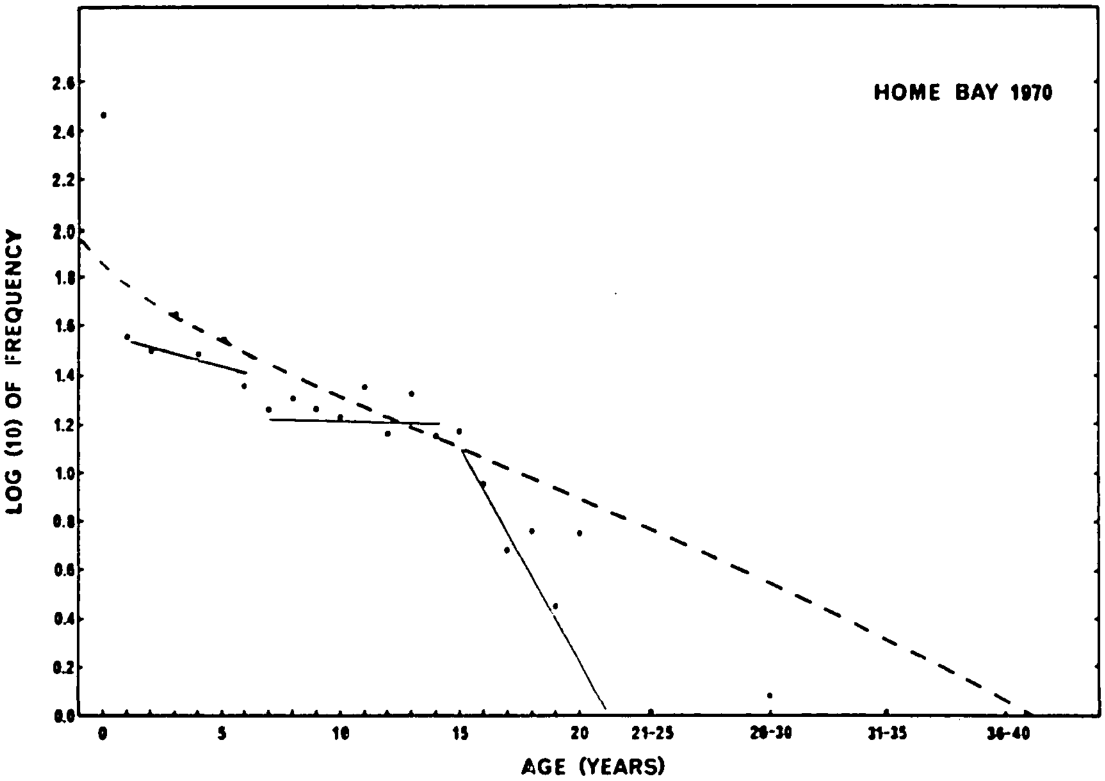


Fig. 35. Semilogarithmic plot, of age frequencies, from the 1970 Home Bay open water catch, with linear regression lines through age classes 1 to 6, 7 to 14 and 15 to 40.

animals age. This again is partially a function of the smoothing of the age frequencies. It was felt that it would be reasonable to assume that adolescent survivorship was somewhat below that of the adults though not by much and rising quickly to the same level, therefore values of .86 in age 1+ were increased to .89 in year class 6+. Adult survivorship was held constant as .90 to age class 14+. It was felt that a survivorship value as high as .90 for the age classes with the highest survival values was not unreasonable, in view of the fact that an overall survival of .85 was obtained for the total population. The mortality rate curves (Figs. 32, 33) show a steep rise in the age classes past 15 years. It is felt that the increase is somewhat too steep as shown by these curves and this is obviously caused by the fact that the oldest age classes considered in the life tables, because of the low frequencies in the older age classes, was 18+ years. Since no reliable data were available to show the shape of the survival curve past approximately the 20+ year class,an eye fitted curve was plotted to the survival estimates with the aid of a series of regression lines (Figs. 34, 35). In the composite life table survival values were decreased in a linear manner to a value of .70 at age 30+. The values were decreased more radically, again linearly, from age 31+ to 40. It will be shown later in a discussion of the theoretical aspects of the influence of the survivorship values on the final outcome of the stable-age distribution that the relative importance of the survivorship values of animals past a certain age class has a minimal effect on the characteristics of the final stable population. The arbitrariness of the assigned decreasing older survivorship values is therefore not considered a grave source of error.

DYNAMICS OF THE POPULATION

Population models are either deterministic or stochastic. Deterministic models are of two main types: those with a continuous age and time scale, and those having discrete age classes and time intervals. The continuous deterministic models are based on the theory of Verhulst (1838), and Pearl and Reed (1920), which described the exponential growth of a single species population, along with the logistic form of the growth curve. Lotka (1925), and Volterra (1937), among others, extended this model to describe the interactions of more than one species, using a system of differential equations.

The discrete deterministic model is based on analysis by the use of matrix algebra. Bernadelli (1941) and Lewis (1942) introduced this form of population analysis, which was thoroughly investigated and described by Leslie (1945, 1948). Various demographers, (e.g. Lopez, 1961; Pollard, 1966; Keyfitz, 1965, 1968), have used this approach to describe and project human populations. Relatively few biologists have used this type of analysis, mainly because of the difficulty in obtaining accurate ages on the individuals in the populations that they are dealing with. More recently this approach has been modified in order to make it applicable to populations that can only be divided into adult and juvenile age classes (Williamson, 1959) and for populations which are divided into unequal age groups (Lefkovitch, 1965). Certain theoretical aspects of populations have been described by looking at the mathematical characteristics of the matrices (Demetrius, 1969) and various attempts have been made to build density dependent population models using the matrix framework (Leslie, 1958; Pennicuick, Compton and Beckingham, 1968).

A Brief Description of the Leslie Matrix.

Leslie (1945, 1948), for the sake of simplicity, considered the female portion of the population only. The elements of the matrix are P_x and F_x, where P_x is the probability of a female aged x to x + 1 at time t, surviving to the age class x + 1 to x + 2 at time t + 1, and F_x is the number of daughters born in the interval t to t + 1 per female alive aged x to x + 1 at time t, who will be alive in the age group 0 to 1 at time t + 1. For a life table distribution defined by

$$L_x = \int_x^{x+1} l_x dx,$$

$$P_x = L_{x+1}/L_x.$$

The definition of F_x is more complicated. The number of daughters being born and surviving into the next age class is dependent on the value m_x, and on both the survivorship of the mothers, and the survivorship of the offspring once they are born. Leslie (1945), through a fairly complex argument defines this as

$$F_x = 2.\int_{\frac{1}{2}}^{1} l_x dx \; m_{x+\frac{1}{2} \to x+1} + 2.\int_{0}^{\frac{1}{2}} P_x \; m_{x+1 \to x+1\frac{1}{2}}.$$

In a population consisting of n age classes let $x_a(t)$ denote the number of individuals in age class a at time t. The age distribution at time t + 1 is given by

$$\begin{aligned} x_1(t+1) &= F_1x_1(t) + F_2x_2(t) + \ldots\ldots + F_nx_n(t) \\ x_2(t+1) &= P_1x_1(t) \\ x_3(t+1) &= P_2x_2(t) \\ x_n(t+1) &= P_{n-1}x_{n-1}(t). \end{aligned}$$

In matrix notation these equations are written

$$x(t + 1) = Mx(t)$$

where M is the Leslie matrix and x(t) is the age frequency vector. The matrices are thus

$$M = \begin{Bmatrix} F_1 & F_2 & \ldots\ldots\ldots F_{n-1} & F_n \\ P_1 & 0 & \ldots\ldots\ldots 0 & 0 \\ 0 & P_2 & \ldots\ldots\ldots 0 & 0 \\ \ldots & \ldots & \ldots\ldots\ldots\ldots & \ldots \\ & & P_{n-1} & 0 \end{Bmatrix} \qquad x(t) = \begin{Bmatrix} x_1(t) \\ x_2(t) \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ x_n(t) \end{Bmatrix}.$$

If in the matrix M, $x = n$ is the last age group in which reproduction occurs, all F_x figures for x n will be 0 and partitioning the matrix symetrically at this point will produce two new matrices, A which is now the projection matrix containing all the reproductive stages, and B whose F_x values = 0 having a determinent /B/ = 0. This latter matrix in no way affects the projection matrix A since it contains no reproducing adults. The projection matrix contains positive values in the first row and the principal subdiagonal and is therefore non-singular. The properties of such a matrix are described by the Perron - Forbenius theorem and are discussed in Gantmacher (1959).

Continued multiplication of the age-frequency vector by the

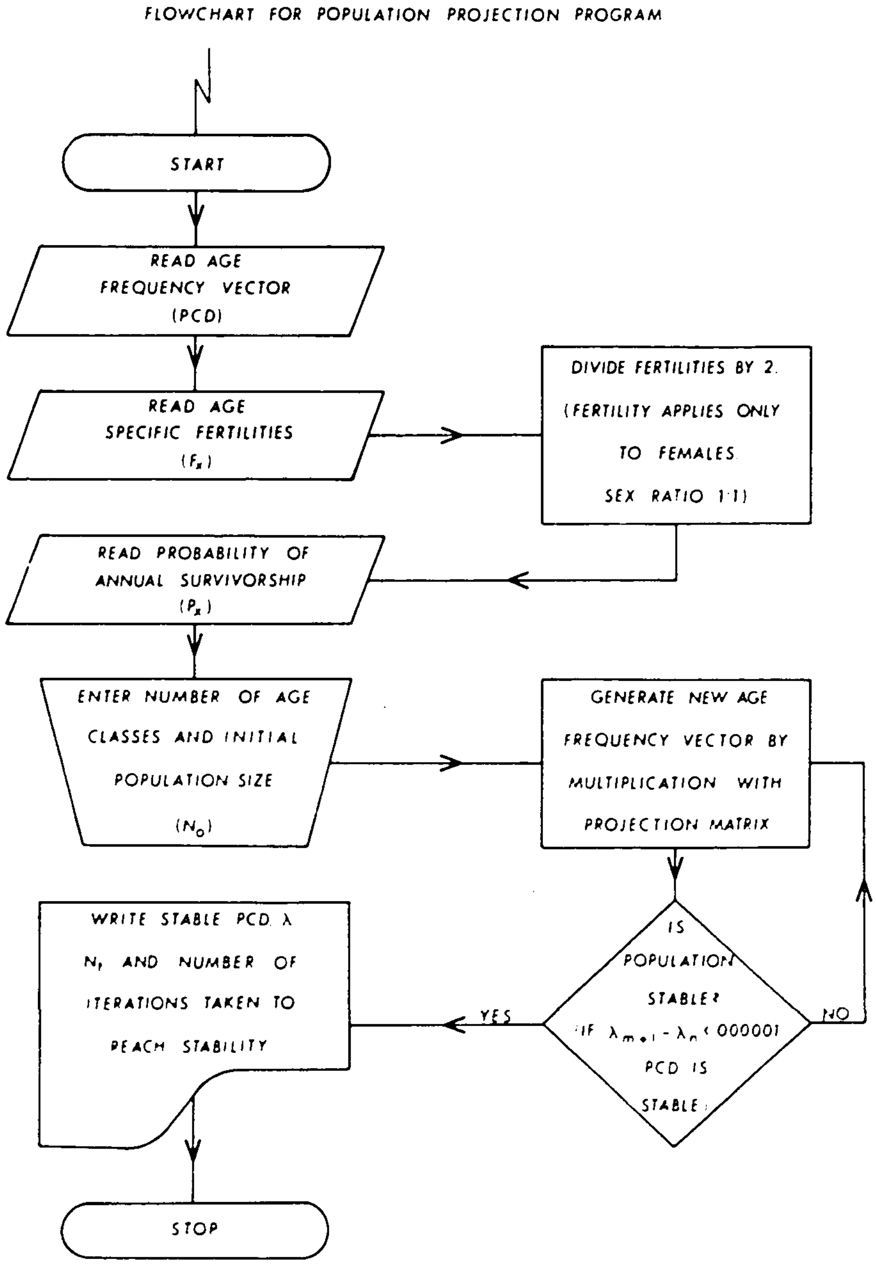


Fig. 36. Flow chart of the population projection program, SIMI3.

projection matrix results in a stable-age distribution where

$$x(t+1) = \lambda x(t) \text{ for } \lambda > 0 \text{ for all } t > t_x$$

when is the dominant latent root or eigenvalue, which is the proportion of individuals in one age class to those in the same age class during the preceeding generation, when this proportion has become constant after some time t_x, i.e.

$$\lambda = x_a(t_{x+n}) : x(t_{x+n-1}).$$

The eigenvalue thus represents the finite growth rate of the stable-age population and

$\lambda > 1$ for a growing population
$\lambda = 1$ for a stationary population
$\lambda < 1$ for a declining population.

The Projection Model.

Description. A computer program SIMI3 was developed which projects a population of a given initial size and given F_x and P_x values through to the point at which a stable-age vector is attained. At this point it prints out the stable-percentage-age distribution, the size of the stable-age population, the eigenvalue and the number of iterations taken to reach stability.

The actual program and some sample output have previously been described in Smith (1970). In order to relate this population model to that of Leslie's projection model some further explanation is appropriate. Fig. 36 is a flow chart of the actual program. The matrix multiplication performed by the computer on the age vector by the F_x and P_x values is identical to the multiplication by the Leslie projection matrix. It should be pointed out that for the ringed seal population, which contains no post-reproductive age classes, there is no need of partioning the Leslie matrix to obtain the projection matrix. The main difference between the projection model and the basic Leslie approach is that the model deals with the whole population, i.e. males as well as females. This presents no great difficulty since in the ringed seal there is apparently no significant difference in the survival of different sexes. In this model m_x is defined as the age-specific number of offspring per female (male as well as female offspring) and the F_x values are divided by 2 (Fig. 36) to make fertilities apply to half of the original population (females only) since the sex ratio is known to be unity.

The accurate calculation of the P_x and F_x values is very important since the model is dependent on these parameters to produce a realistic stable-age population and growth rate. The Leslie (1945) definition of F_x shows that this value is very dependent on the first integral L_x in the life table. It will also be shown later that the first part of the l_x curve has the greatest influence on the age structure and growth rate generated by the model. Because of this it was necessary to develop a program which would give the most accurate and representative calculations of the integrals at the beginning of the l_x curve.

An expanded version of SIMI3, SIMI4 was developed which allowed direct use of age-specific survivorship values (s) and age-specific fertilities (m_x) and calculates P_x and F_x according to Leslie's (1945) definition of these parameters. Since the model is dependent on the accurate calculation of the first integral L_o the program calls a subroutine CURVFT which fits a polynomial curve, up to degree

Table 21. Statistics derived from the best estimates of age - specific survival and fertility values for the Home Bay area.

Age	Survival (s)	Fertility (m_x)	l_x	L_x	P_x	F_x	Percentage age structure (from model)	Percentage age structure (Home Bay 1967)
0	.61		1.000	.759	.73	.00	15.57	18.91
1	.86		.610	.557	.88	.00	11.24	11.58
2	.87		.525	.491	.87	.00	9.73	9.97
3	.88		.456	.429	.88	.04	8.37	8.79
4	.88	.22	.402	.378	.88	.23	7.24	7.62
5	.88	.63	.353	.332	.88	.49	6.26	6.59
6	.89	.84	.311	.294	.89	.60	5.45	5.71
7	.89	.85	.277	.262	.89	.62	4.77	4.98
8	.90	.91	.246	.234	.90	.66	4.20	4.25
9	.90	.93	.222	.211	.90	.66	3.71	3.81
10	.90	.90	.200	.190	.90	.64	3.29	3.37
11	.90	.88	.180	.171	.90	.63	2.91	2.93
12	.90	.88	.162	.154	.90	.63	2.57	2.63
13	.90	.88	.145	.138	.90	.63	2.28	2.19
14	.90	.88	.131	.124	.90	.63	2.02	1.90
15	.89	.88	.118	.111	.89	.63	1.77	1.75
16	.88	.88	.105	.099	.88	.62	1.54	1.46
17	.87	.88	.092	.086	.87	.62	1.33	1.46
18	.86	.88	.080	.075	.86	.61	1.13	
19	.85	.88	.069	.064	.85	.61	.95	
20	.84	.88	.059	.054	.84	.61	.79	

Table 21 (continued).

Age	Survival (s)	Fertility (m_x)	l_x	L_x	P_x	F_x	Percentage age structure (from model)	Percentage age structure (Home Bay 1967)
21	.83	.88	.049	.045	.83	.60	.65	
22	.82	.88	.041	.037	.82	.60	.53	
23	.81	.88	.034	.030	.81	.60	.42	
24	.80	.88	.027	.024	.80	.59	.34	
25	.79	.88	.022	.019	.79	.59	.26	
26	.78	.88	.017	.015	.77	.58	.20	
27	.76	.88	.013	.012	.76	.58	.15	
28	.75	.88	.010	.009	.75	.57	.11	
29	.74	.88	.008	.007	.72	.56	.08	
30	.70	.88	.006	.005	.66	.54	.06	
31	.60	.88	.004	.002	.58	.51	.04	
32	.55	.88	.002	.001	.53	.49	.02	
33	.50	.88	.001	.000	.47	.47	.01	
34	.40	.88	.001	.000	.37	.43	.01	
35	.30	.88	.000	.000	.29	.40	.00	
36	.25	.88	.000	.000	.24	.38	.00	
37	.20	.88	.000	.000	.19	.37	.00	
38	.15	.88	.000	.000	.14	.35	.00	
39	.10	.88	.000	.000	.18	.36	.00	
40	.05	.88	.000	.000	0	.29	.00	

25, to the l_x data, while specifying that $l_o = 1$. Another subroutine called INT then calculates the values of the first two integrals L_o and L_1 from the polynomial equation. Only the first two integrals are calculated in this way, because it was found that after this point in the data, the fitted polynomial curve could sometimes depart radically from the shape of the l_x curve, depending on the regularity of the declining l_x values. The approximation $L_x = l_x + l_{x+1}/2$ was used to calculate all other integrals in the life table.

Intrinsic Rates of the Population.

The stable-age population. Lotka (1922, 1925, 1931, 1939) developed a system of mathematical analysis of population growth and structure, for populations that had a stable-age distribution. He showed that a stable-age structure and rate of increase would be attained if a constant mortality and fertility schedule was maintained over a period of time (Sharpe and Lotka, 1911; Lotka, 1922). The birth and death rates obtained from a stable population have been termed intrinsic rates and are very useful in describing the characteristics of a population and making comparisons between different populations since they are free from the influence of the current age distribution. It is evident that comparisons between reproductive rates of different populations will be misleading unless the mean lengths of generation are the same. Intrinsic reproductive rates include the generation length in their calculation making comparisons between them meaningful.

Intrinsic rates for the Home Bay population. Table 21 shows what are considered to be the most representative age-specific survivorship (s) values and the age-specific fertilities (m_x) used in the population projection. Column 8 of Table 21 shows the stable-percentage-age distribution obtained by using these values. Since the population age structure is stable the two equations describing the population,

$$N_t = N_o e^{rt} \text{ and } N_t = \lambda N_o,$$

are equivalent and consequently

$$e^r = \lambda \text{ or } \log_e \lambda = r.$$

The value for r obtained from the model is 0.016798. Calculation of the intrinsic birth and death rates were made according to the method described by Leslie (1948) and outlined in Birch (1948). The birth rate (total number of births in the time interval t to t + 1 expressed per head of the population at time t) is defined as

$$\beta = B_t/N_t,$$

where B_t is the number of offspring born alive in the interval t to t + 1 and N_t is the total number of individuals alive in the stable population at time t. In a stable life table defined by

$$L_x = \int_x^{x+1} l_x dx,$$

$$B_{t-x} = \beta N_{t-x} = \beta N_t \lambda^{-x} = \beta N_t e^{r-x}$$

so that, $\pi = \beta L_x \lambda^{-(x+1)}$ or $\pi = \beta L_x e^{-r(x+1)}$,

which defines the stable age distribution. From this, since

$$\sum_o^m \pi = 1$$

it follows that

Table 22. Assumed survivorship values for an unexploited population (natural mortality only); the computed life table, and the stable percentage - age distribution.

Age	Survivorship	l_o	L_x	P_x	F_x	Stable percentage age distribution (from model)
0	.80	1.000	.874	.87	0	16.32
1	.90	.800	.759	.91	0	12.72
2	.91	.720	.688	.91	0	10.33
3	.92	.655	.629	.94	.05	8.48
4	.96	.603	.591	.96	.28	7.14
5	.96	.579	.567	.96	.59	6.14
6	.97	.556	.547	.97	.72	5.32
7	.97	.539	.531	.97	.74	4.62
8	.97	.523	.515	.97	.79	4.02
9	.97	.507	.499	.97	.79	3.50
10	.97	.492	.484	.97	.77	3.04
11	.97	.477	.470	.97	.76	2.65
12	.97	.463	.456	.97	.76	2.30
13	.97	.449	.442	.97	.76	2.00
14	.94	.435	.429	.97	.75	1.74
15	.96	.422	.414	.96	.75	1.51
16	.96	.405	.397	.96	.75	1.30
17	.95	.389	.379	.95	.75	1.11
18	.95	.370	.361	.95	.75	0.95
19	.95	.351	.342	.95	.75	0.81
20	.95	.334	.325	.95	.75	0.69

Table 22 (continued).

Age	Survivorship	l_o	L_x	P_x	F_x	Stable percentage age distribution (from model)
21	.95	.317	.309	.95	.75	0.59
22	.94	.301	.292	.94	.74	0.50
23	.94	.283	.275	.94	.74	0.42
24	.94	.266	.258	.94	.74	0.35
25	.94	.250	.243	.94	.74	0.30
26	.94	.235	.228	.94	.74	0.25
27	.93	.221	.213	.93	.74	0.21
28	.92	.206	.197	.92	.73	0.17
29	.91	.189	.181	.90	.73	0.14
30	.88	.172	.162	.86	.71	0.12
31	.84	.151	.139	.82	.70	0.09
32	.80	.127	.114	.78	.68	0.07
33	.76	.102	.090	.74	.66	0.05
34	.72	.077	.067	.70	.65	0.03
35	.68	.056	.047	.66	.63	0.02
36	.64	.038	.031	.62	.62	0.01
37	.60	.024	.019	.56	.59	0.01
38	.50	.015	.011	.47	.55	0.00
39	.40	.007	.005	.57	.60	0.00
40	.30	.003	.003	0	.36	0.00

$$1/\beta = \sum_{x=0}^{m} L_x e^{-r(x+1)},$$

where x = m to m + 1 is the last age group of the complete life table. The birth rate calculated from the life table of Table 21, using the value of r = 0.016798, is = 0.20752. Leslie (1948) gives the relation between B and b, the instantaneous birth rate as

$$b = \beta \log_e \lambda / \lambda - 1 \text{ or } \beta r/e^r - 1.$$

The value for b was determined as 0.205726 and the instantaneous death rate d = r - b = 0.188928.

<u>Intrinsic rates for an unexploited population</u>. A life table was constructed using survivorships assumed to be representative of an unexploited population subject only to natural mortality (Table 22). No actual measurements of natural mortality are available and the assumed values of the age-specific natural mortalities have followed those of McLaren (1958b) to a large extent. The survivorships of the first two age classes differ from his assumed values in that they are slightly larger.

The intrinsic rate of increase r = 0.109007 for the unexploited population is, as expected, considerably higher than the intrinsic rate of increase for the exploited Home Bay population. The instantaneous birth rate b = 0.197074 is slightly lower than in the exploited population because the lower mortality schedule has made the overall percentage-age distribution (Column 7, Table 22) somewhat younger. This effect will be discussed more fully in the next section. The instantaneous death rate d = 0.088067 is much lower than for the Home Bay population.

Properties of the Model.

Effect of the original age-frequency distribution. An abundance of literature deals with the question of what would happen if a population projection would continue indefinitely with the age-specific rates observed at a particular point in time (Sharpe and Lotka, 1911; Haldane, 1927; Leslie, 1945). Lotka (1925) showed that a population subject to constant age-specific mortality and fertility rates would tend eventually toward a stable-age distribution whose structure and vital rates are completely independent of the original age distribution. This property of independence from the past age distribution has been termed strong ergodicity by Hajnal (1958) and has been investigated by a number of human demographers (Lorimer, 1951; Coale, 1956, 1957; Pollard, 1966; Keyfitz, Nagnur and Sharma, 1967; Keyfitz, 1965, 1968).

A comparison between the percentage-age distribution from the 1967 Home Bay log-adjusted life table and the stable percentage-age distribution computed from the best age-specific survival estimates for that population is shown in Table 21. A 18 X 2 contigency test showed that there was no significant difference between these percentage-age distributions (chi square = 0.2796, P >.995). The largest difference between the two distributions is seen in the lower value (3.31%) of the first age class in the computed stable-age distribution. This can be explained by two factors. First, the method used in calculating the number of 0 - 1 aged animals in the life table does not take into account prenatal mortality and therefore leads to a slight overestimation of this age frequency. Secondly, and more important, the population projection model, in computing the stable-age frequency, incorporates into the calculation of L_O the factor F_x, which has built into it the probability of the animals surviving through the first age class. The rest of the age-frequencies in the two distributions are remarkably alike indicating that the Home Bay 1967 sample is from a population with a stable-age distribution and that the population projection model is giving a fairly close estimate of the actual population using the survivorships shown in Table 21.

Effect of different survivorship and fertility schedules. It has been pointed out that in a stable-age distribution the age structure is wholly determined by the prevailing age-specific mortalities and fertilities. Various demographers dealing with the continuous mathematical analysis of population dynamics have examined the influence of survivorship and fertility on the age structure and growth rates of stable populations (Lorimer, 1951; Coale, 1956, 1957).

In the present study a brief look was taken at the influence of births and deaths on the growth rate and age structure of the population, by substituting different values in the population model SIMI4. To do this the survivorship and fertility values shown in Table 21, for the Home Bay population, were used as a point of departure. All changes to the stable-age structure and the growth rate are therefore compared to the stable-age structure and growth rate of this population.

The first point that was investigated was the effect of changing the survivorship or fertility factors at various points in the life

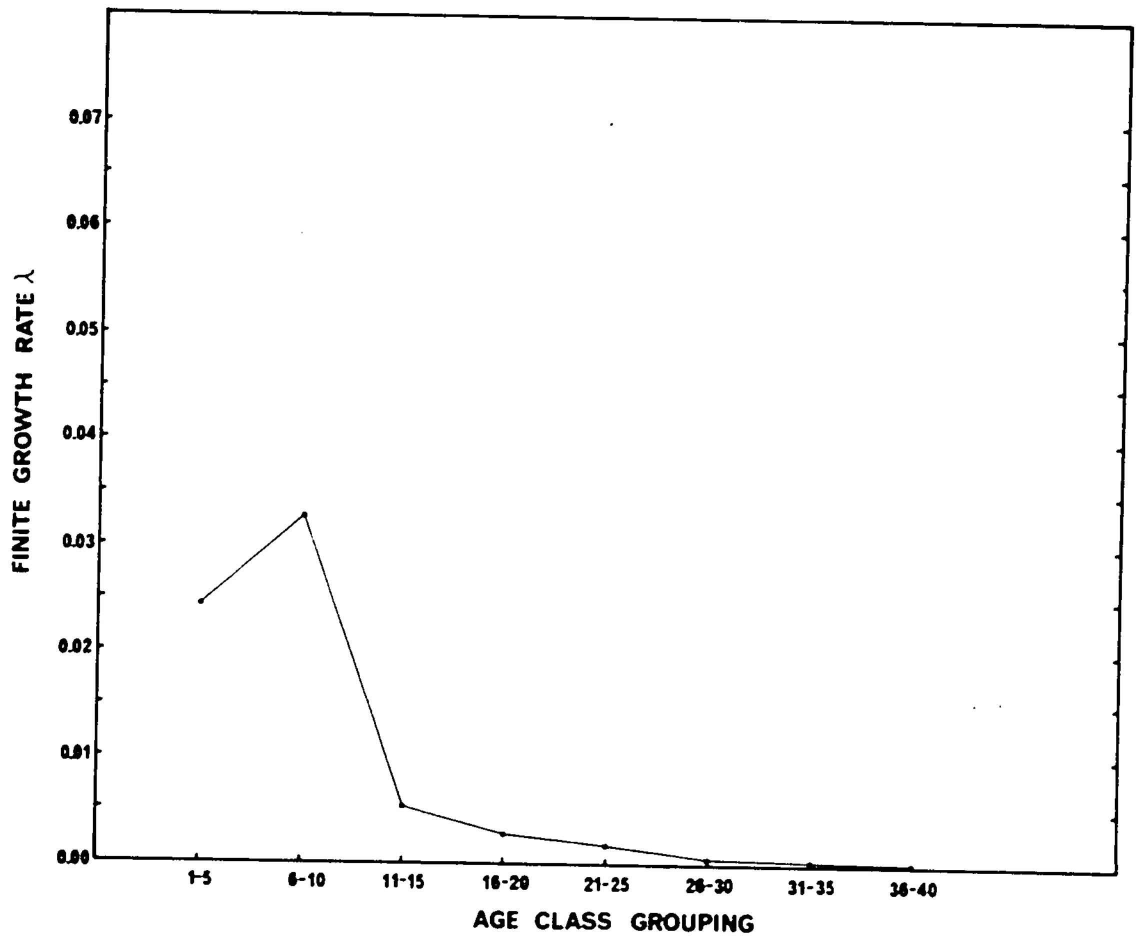


Fig. 37. Effect, on the population growth rate, of increasing survivorship values, at different places in the life table.

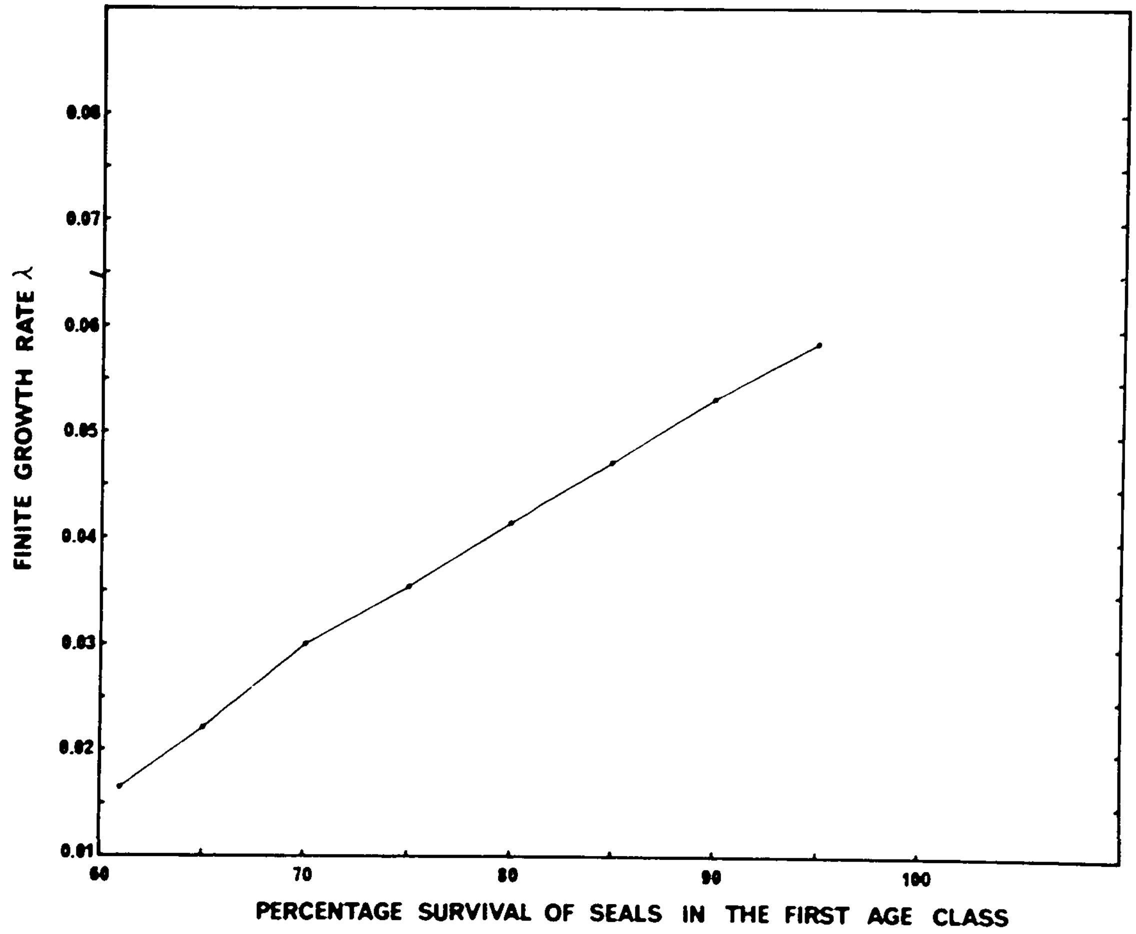


Fig. 38. Effect of increase in the survivorship value of the 0+ age class, on the growth rate of the population.

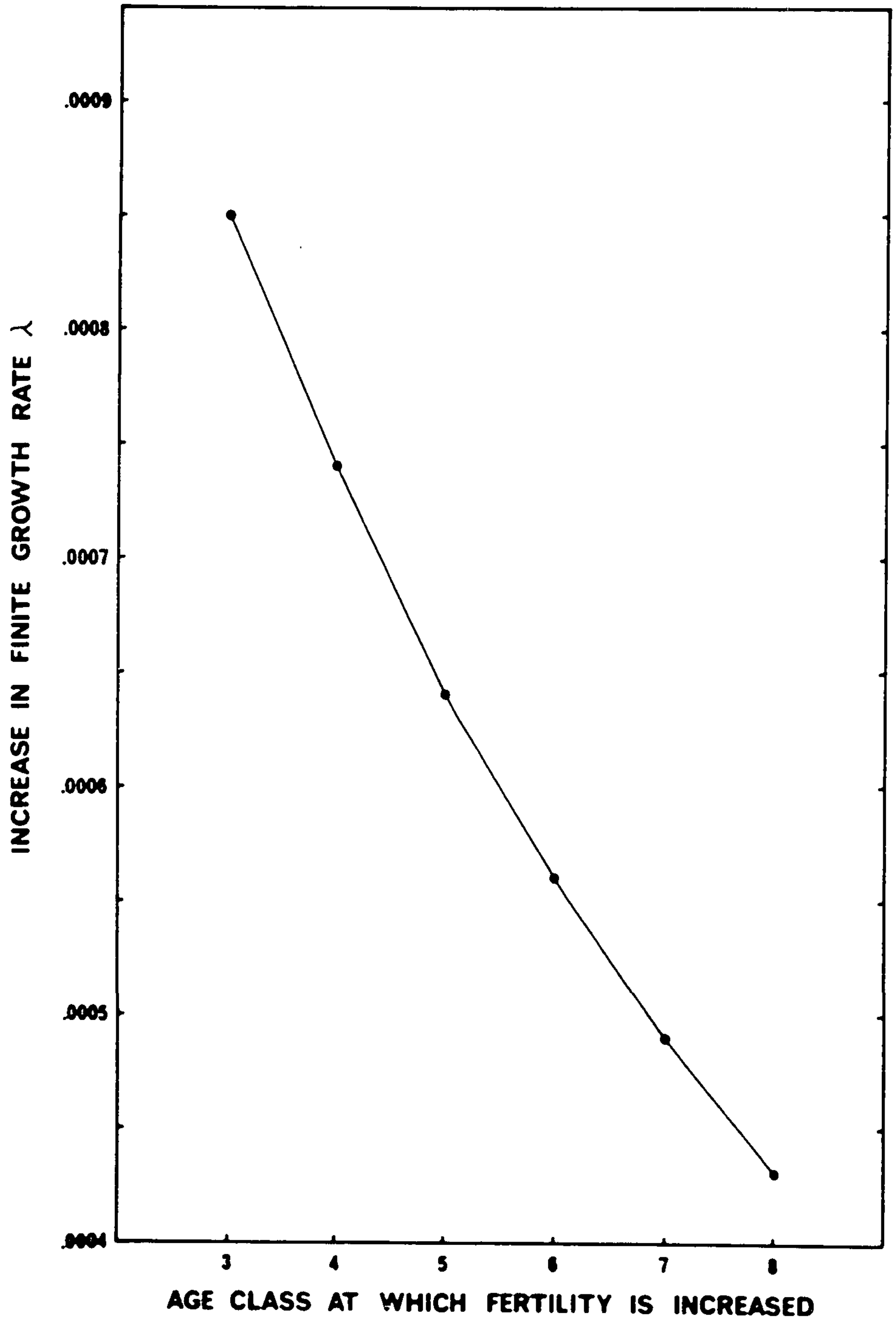


Fig. 39. Effect, on the population growth rate, of increasing the fertility values (m_x), in different age classes of the life table.

table. Fig. 37 shows the effect of increasing the survivorship by .05, in age groups of five year classes, at different points in the life table. The increase in the survivorship of the 0 age class alone by .05 to .30 is shown in Fig. 38. It is apparent from these figures that improvements in survivorship at the beginning of the life curve have a much greater effect on the growth rate of the population than improvements in survivorship in the later age classes.

The effect of increasing the m_x values by .05 at different ages along the l_x curve is shown in Fig. 39. Again, it is seen that increases of fertility at the beginning of the life table have the greater effect on the growth rate of the population. The effect of adding an age class to the reproducing animals (age class 3, in Fig. 39, was given the m_x value of .05) is shown to be greater than the equivalent increase in fertility in the age classes above it.

In order to understand the reason for the greater effect, on the population growth rate, of increases in mortality and fertility at the beginning of the life table, the age-specific reproductive values, which are the present values of the future offspring, were calculated. Fisher (1930) defines the reproductive value of an individual of age x as

$$v_x = e^{rx}/l_x \int_x^{\infty} e^{-rt} l_t m_t \, dt.$$

Leslie (1948) showed that the row vector η^* is equivalent to the total reproduction value v_x of Fisher (1930) and defines the age-specific reproductive values as the elements $y_x (x=0, 1, 2, \ldots\ldots, k)$ of the row vector η^* where

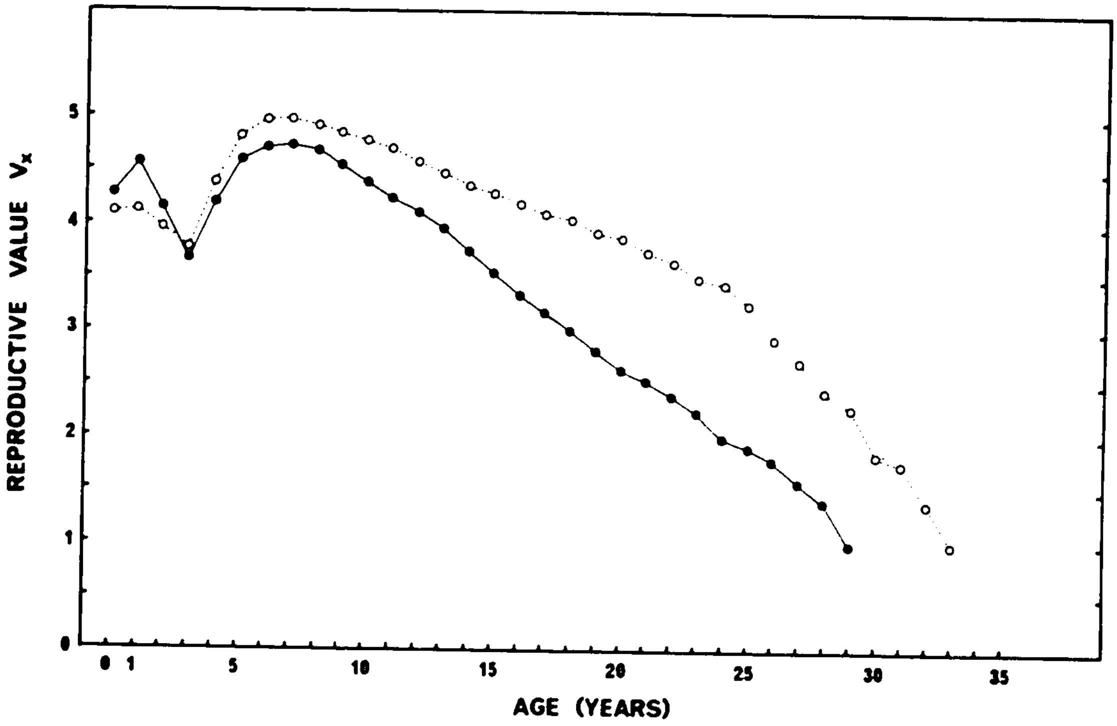


Fig. 40. Age-specific reproductive values (elements y_x of the row vector η^*) of the Home Bay population (solid line, solid dots) and the hypothetical unexploited population (broken line, open dot).

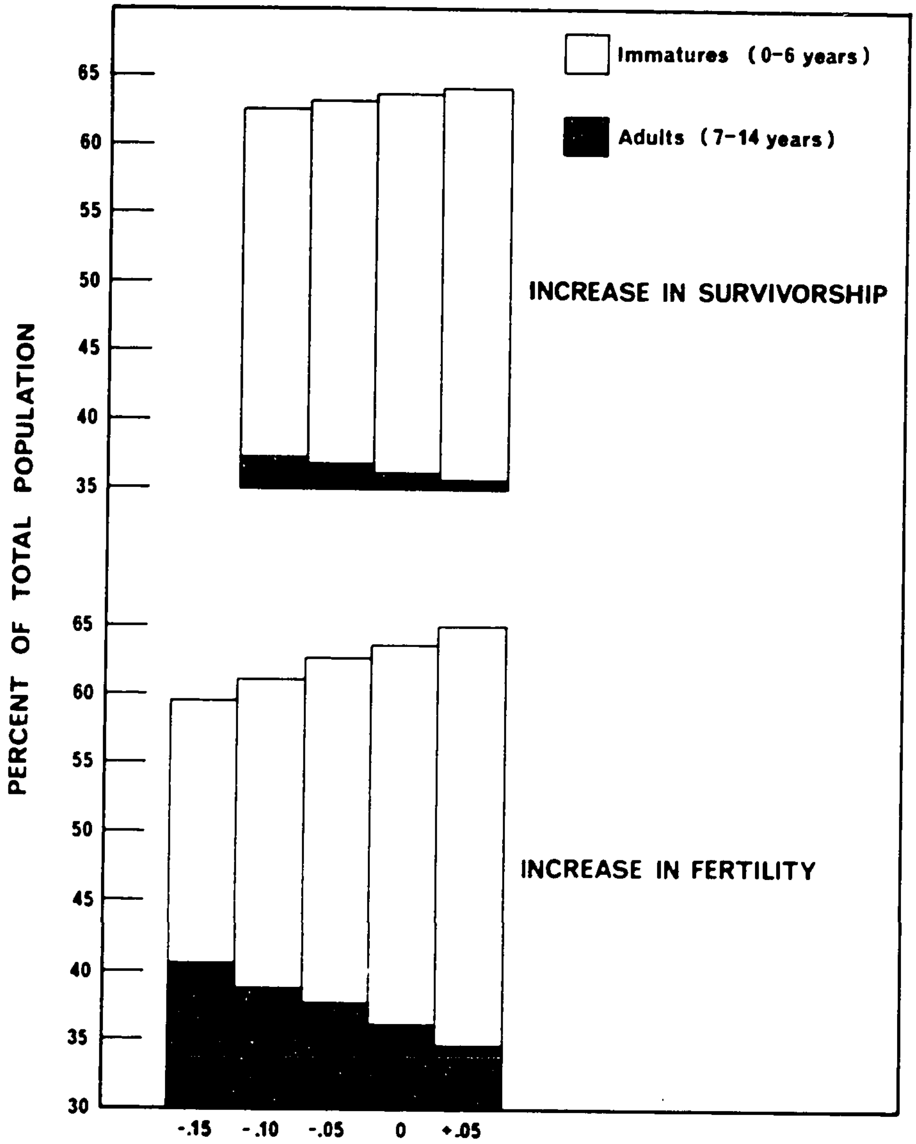


Fig. 41. Effect of increase in fertility and survivorship on the age structure of the population.

$$y_x = \sum_{x}^{k} \lambda^{-(x+1)} L_x F_x / L_x \;\; \lambda^{-(x)} .$$

Fig. 40 shows the age-specific reproductive values for the Home Bay 1967 population (Table 21) and the hypothetical unexploited population (Table 22). In both cases the reproductive values increase from age 0 to a maximum of 4.729 at age 6 for the Home Bay population and 4.961 at age 7 for the unexploited population. The reproductive values of the unexploited population are higher than those of the Home Bay sample which follows from the higher value of r. Since the reproductive value of an individual in a given age class can be defined as the dimunition of future population increase produced by removing a single animal from that age class (Slobodkin, p. 50, 1963), the shape of the reproductive value curve makes it obvious that changes in survivorship or fertility values in the early age classes have the greatest effect on the population growth rate.

The effect of increases in survivorship and fertility on the population age structure was examined by increasing and decreasing the original s and m_x values by the same proportion in all age classes of the population. Fig. 41 shows that both improvements in survivorship and fertility have the effect of making the population age structure younger.

MANAGEMENT CONSIDERATIONS

Sustainable Yields.

Home Bay. The sustainable annual yield of ringed seals for the Home Bay area was calculated from estimates of the total population size and annual catch, along with the estimate of the intrinsic rate of natural increase obtained from the population projection model.

The total annual catch in Home Bay was calculated using the mean number of furs traded (4,624) and the figure of 21.6 percent for sinking loss during the open water season (Haller et al., 1966). Table 23 shows the age frequencies of the catch during four different time periods of the year. The open water season, the period from 1 July to 31 October 1967, is equivalent to 22.62 percent of the catch. The total catch corrected for sinking loss is therefore 4,850 seals. It was further estimated that an additional 5.00 percent could be added to this figure to account for losses during hunting on the ice and at the floe edge, and to correct the estimate for skins not traded. The final total annual take for Home Bay was thus estimated as 5,093 ringed seals, 34.66 percent of which were pups, 34.51 percent adolescents and 30.88 percent adults.

The estimated total take is equivalent to 7.20 percent of the total estimated population size of 70,684 (Table 11). Since the intrinsic rate of increase of the Home Bay population was calculated to be 0.016798 this means that with a population of 70,684 and the present hunting and natural mortality, a surplus of 1,187 seals would be produced annually. This implies that the annual take could be increased from 5,093 to 6,280 seals,which means that the annual

Table 23. Seasonal distribution of the age sample from Home Bay 1967 - 1968.

Age	May 1-31, 1967.	June 1-30, 1967.	July 1-Oct. 31, 1967.	Nov. 1, 1967- April 30, 1968.
0	159	737	195	27
1	20	150	81	37
2	18	119	50	35
3	13	79	63	29
4	9	70	43	25
5	10	81	40	26
6	9	61	30	7
7	20	57	26	8
8	23	59	22	3
9	15	61	33	3
10	21	69	27	1
11	14	51	23	2
12	21	52	26	2
13	22	45	19	5
14	15	47	9	1
15	19	42	16	1
16	6	21	6	0
17	5	11	6	0
18	3	6	2	0
19	2	6	0	0
20	6	17	9	0
21-	2	6	1	1
26-	1	2	1	1
31-	0	0	1	0
36-	0	0	0	0
Total:	433	1849	729	214
Percent of annual catch:	13.42	57.33	22.62	6.63

sustainable yield for this population is 8.84 percent. This figure for the sustainable yield probably errs on the low side since the assumptions used to estimate the total size of the population have probably resulted in a slight overestimate.

Cumberland Sound. Table 24 shows the seasonal breakdown of the age sample from Cumberland Sound. The total annual catch was estimated in the same manner as described for the Home Bay area and determined to be 9,262 ringed seals. Since the total population size for Cumberland Sound was estimated to be 58,782 (Table 11), this results in an annual catch equivalent to 15.75 percent of the population, which is considerably higher than the estimated maximum sustainable yield of 8.84 percent.

It has been previously stated that there is strong evidence indicating that much of the Cumberland Sound catch is coming from adjacent areas of high seal productivity. The age composition of the Cumberland Sound catch confirms this in that there is a preponderance of yearling (29.23 percent) and adolescent seals (57.16 percent) in the annual catch. Since the Hoare Bay area lies immediately adjacent to Cumberland Sound, and the population there is largely made up of mature seals and is not exploited, it is very likely that the surplus production of seals from this area moves into Cumberland Sound. The population estimate of 36,376 for Hoare Bay, along with the intrinsic growth rate of 0.109007, from the model for an unexploited population, shows that the Hoare Bay population could contribute 3,965 seals annually to the Cumberland Sound catch. If the estimated annual surplus of 1,187 seals produced in the

Table 24. Seasonal distribution of the age sample from Cumberland Sound 1966 - 1967.

Age	May 1-31, 1966.	June 1-30, 1966.	July 1-Sept. 30, 1966.	Nov. 15, 1966- April 1, 1967.
0	114	425	228	37
1	71	216	132	26
2	93	159	140	32
3	85	109	126	25
4	35	51	62	13
5	23	35	54	9
6	13	22	22	3
7	7	20	19	4
8	10	15	23	2
9	8	19	13	3
10	5	18	18	4
11	4	6	14	3
12	3	7	8	2
13	4	9	8	2
14	6	7	6	0
15	5	6	7	0
16	4	4	6	1
17	3	2	2	0
18	0	1	4	0
19	2	2	5	0
20	0	2	1	0
21-	4	6	7	2
26-	0	2	5	1
31-	0	0	1	0
36-	0		0	0
Total:	499	1143	911	169
Percent of annual catch:	18.33	41.99	33.46	6.20

Home Bay area is added to this figure, the total number of seals contributed to the Cumberland Sound catch from adjacent areas is 4,142. This would mean that the resident population of Cumberland Sound is being harvested at the level of 6.91 percent, which is somewhat below sustainable yield. There is also a strong possibility that the coastline to the south of Cumberland Sound is contributing to the annual catch. It is therefore likely that a slight increase in the annual catch is possible in Cumberland Sound but no definite estimates of the extent of this increase can be given at present, without further quantitative data on the number of seals moving in from the adjacent unexploited areas.

Research Implications and Management Recommendations.

Two different situations exist in the two hunting areas studied in this investigation. Home Bay, a large area which is ideal for ringed seal production in terms of coastal complexity and ice stability, and whose ringed seal population is harvested by one Eskimo community, Broughton Island, is somewhat underexploited, but could not sustain a great increase in hunting pressure. The Cumberland Sound area, unlike Home Bay, is not suited for high ringed seal production because of the high tidal amplitude and strong currents, which make the ice very unstable. Because it is bounded by adjacent areas of productive coastline, it receives a large part of the surplus production from their unexploited populations, and is able to sustain an annual yield far above what could be supported by its resident population. McLaren (1958a) suggested that a similar situation existed, in Cape Dorset on southwestern Baffin Island, an area of simple coastline, which has a complex coastline adjacent to it. It is probable that this kind of situation exists in many ringed seal hunting areas throughout the arctic.

Recent development of the market for hair-seal pelts, especially in Europe, has made the hunting of ringed seal highly profitable for the Eskimo hunter (Foote, 1967). Advances in hunting technology, notably the introduction of the snowmobile, have greatly added to the cost of hunting. This, combined with the demand for pelts, has turned what was formerly a subsistance activity, where seals were used for food, clothing and to a lesser extent trade, to what is now an almost exclusively seal-skin trading economy. The rapidly changing way of life in the Eskimo communities, with its increased cost of living, makes it necessary for the present day hunters to look towards increasing their catch, while improving the efficiency of their hunting efforts. This, of necessity, is resulting in the extension of the boundaries of the hunting territories. The snowmobile makes it possible for hunters to hunt far away from their village, during the periods of fast ice, and to cover much more ground than was formerly hunted by dogsled. There are indications that groups of hunters will soon be joining together to buy large boats which will enable them to hunt and net seals in areas that were previously unexploited. These developments might have serious consequences in depleting the stocks of seals in areas, where a situation such as is seen in Cumberland Sound, exists.

The added investment in hunting equipment might well be wasted, if the currently exploited stock of an area is dependent on the surrounding unexploited populations, to sustain the present annual yield.

The above considerations make it evident that an integrated management program should soon be implemented if the growing Eskimo population is to continue to harvest the ringed seal on a sustained basis. More reliable estimates are needed on local population sizes, the extent of movement of seals, estimates of natural mortality and rates of increase in exploited and unexploited stocks, and figures on total catches for all Eskimo communities. Such information could be gathered at the local level by establishing some standard form of hunt-return questionnaire, which would provide catch-effort data and which could be used in conjunction with studies of local areas, resembling the present investigation.

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TECHNICAL REPORT NO. 224

COMPUTER PROGRAMS FOR ANALYSIS OF RINGED SEAL POPULATION DATA

by

T. G. Smith

FISHERIES RESEARCH BOARD OF CANADA
Arctic Biological Station
Ste. Anne de Bellevue, P.Q.

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APPENDICES

INTRODUCTION

This report describes six computer programs developed during a study of ringed seal populations on the east coast of Baffin Island. The investigation began in Cumberland Sound in 1966 and was extended to the Home Bay area in 1967. Collections of specimens were obtained by the staff of the Arctic Biological Station, Fisheries Research Board of Canada and from the Eskimo hunters. The local hunters were provided with 1:200,000 maps of their hunting area on which was printed a grid, each square approximately 25 square miles in area. Data on over 10,000 ringed seals were gathered, most of which came from the Eskimo hunters and consist of age, locality and date on which the animal was killed. Approximately 1200 specimens also include information on the reproductive organs and body measurements.

Programs were written in FORTRAN IV language, compiled by a FORTRAN IV G Level 1 Compiler, and run on the McGill University IBM 360 computers, Models 65 and 75. The Model 65 computer provided a time-sharing facility operating on the RAX (remote access) system. Programs and data were typed into this computer using a Datacom 35 teletype terminal. This feature was used extensively at the program development stage, particularly for the population projection program. The Model 75 computer O/S (operating system) was used in most cases when the programs were completely developed. For this system data were punched on cards by an IBM 029 Keypunch and then read into the computer using an IBM 2540 Card Read Punch. Large data decks were transferred to magnetic tapes for storage. Output was obtained on an IBM 1403 High Speed Printer.

I would like to thank Mr. David Burrage who acted as Programming Consultant during this study.

PROGRAM DESCRIPTION, INPUT AND OUTPUT

A. Program for sex- and age-specific density and frequency distributions for different time periods.

1. Description

This program prints age- and sex-specific frequency and density distributions for each grid square in the hunting areas, as well as the totals from the grid squares for as many different date periods as specified. Other variants of this program included: non sex-specific; frequency only; density only; totals only (individual grid locations ignored). The program consists of a main section plus two subroutines OUTPUT and FUNCTION N DATE. The OUTPUT subroutine contains the print-out format while the FUNCTION N DATE subroutine converts the date obtained from the main part of the program to an ordered number and returns it to the main section for testing and sorting.

2. Input

The card order in the deck is as follows: (1) program deck; (2) one card specifying the number of grid locations, number of data cards and number of date periods; (3) the "Minimum Biological Data" deck (one card per seal); (4) the deck of cards specifying the location of the grid squares and their ice areas (one card per grid square); (5) the card or cards specifying the day, month, and year at the beginning and end of each date period (one card per date period).

The individual layout of the different types of cards in this deck is given in Appendix C, Program A.

3. Output

In the sex-specific runs the male data is printed first followed by the female data printed in exactly the same manner. The print sequence is as follows: one page of age frequencies per grid square; two pages of age densities per grid square. This continues until all the grid locations have been considered. The last page of the output contains the totals from all the grid locations for the age frequencies and densities.

A sample of the male output for a run in which individual grid locations are considered is shown in Appendix B, Program A.

B. Program for computing life tables from age-frequency distributions.

1. Description

This program computes the standard statistics of a current life table from an age-frequency distribution. All figures are expressed on the basis of an initial cohort of 1000 seals.

2. Input

The card order in the deck is as follows: (1) program cards; (2) one card specifying the number of age-frequency distributions to be considered; (3) card or cards specifying the age-frequency distribution.

The individual layout of the different types of cards in this deck is given in Appendix C, Program B.

3. Output

The print-out consists of seven labelled columns. The age frequency is changed to represent a cohort of 1000 animals. Statistics on age-specific survivorship, mortality, mean survivors between age classes and mean life expectancies are calculated. Life tables are printed for age frequencies in the order they are put into the deck and there are no labels identifying the specific life table in the print-out.

A sample of the output from this program is given in Appendix B, Program B.

C. Age-specific computation of standard biological measurements for different time periods.

1. Description

This program is composed of the main section dealing with the standard biological measurements plus two subroutines, MSD and FUNCTION N DATE. The subroutine MSD calculates the sample size, mean, standard deviation and range for each age-specific measurement. The FUNCTION N DATE subroutine has been described previously.

2. Input

The card order in the deck is as follows: (1) program deck;

(2) one card specifying the number of data cards and the number of date periods; (3) the deck of cards containing the standard biological measurements; (4) the card or cards specifying the day, month and year at the beginning and end of each date period (one card per date period).

The individual layout for the different types of cards in this deck is given in Appendix C, Program C.

3. Output

The print-out consists of 13 numbered columns. A key to the column content is given at the end of the program print-out (Appendix A, Program C). Five of the columns give a measurement calculated from several data. Column 4 gives the estimated weight using the age-specific mean values for nose-tail length and maximum girth in the estimating formula of Usher and Church (1969a, b). Columns 6 and 7 give measures of testis and mammary size using the formula $\frac{\text{length + width}}{2}$. Columns 12 and 13 give the percentage of animals with a foetus and the percentage of animals lactating.

D. Analysis of age-specific male reproductive data for different time periods.

1. Description

This program consists of the main section dealing with the various measurements on the male reproductive material plus two subroutines MSD and FUNCTION N DATE which have already been described.

2. Input

The card order in the deck is as follows: (1) program deck;

(2) one card specifying the number of date cards and numbers of date periods; (3) the deck of cards containing the reproductive data; (4) the card or cards specifying the day, month and year at the beginning and end of the date period (one card per date period).

The individual layout of the different types of cards in this deck is given in Appendix C, Program D.

3. Output

The output consists of five numbered columns. A key listing the content of the different columns is given at the end of the program print-out (Appendix A, Program D). Column 5 gives the percentage of sexually mature animals in the age class, based on the number of animals containing spermatozoa in the testis or epididymis tubules.

A sample of the output from this program is given in Appendix B, Program D.

E. Analysis of age-specific female reproductive data for different time periods.

1. Description

The program consists of the main section dealing with the female reproductive material plus the two subroutines MSD and FUNCTION N DATE described previously.

2. Input

The card order in the deck is as follows: (1) program deck; (2) one card specifying the number of data cards and number of the date periods; (3) the deck of cards containing the reproductive data; (4) the card or cards specifying the day, month, and year at the beginning and end of each date period (one card per date period).

The individual layout of the different types of cards in this deck is given in Appendix C, Program E.

3. Output

The print-out consists of 18 numbered columns. A key to the content of the columns is given at the end of the program print-out (Appendix A, Program E). Column N7 on page 2 of the output is the number of animals in each age class on which reproductive data were obtained. This was calculated by summing the number of animals in each age class that had measurements in columns 45-48 of the reproductive data card. The number of animals sexually mature (Columns SP on page 2 of the output) was calculated using the formula $\frac{CL(n) + CA(n+1)}{n + (n+1)}$ where CL(n)= the number of seals in age class (n) containing a corpus luteum, and CA(n+1) the number of seals in age class (n+1) containing a recent corpus albicans.

A sample of the output from this program is given in Appendix B, Program E.

F. Population projection program to generate a stable age distribution, given age-specific survivorship and fecundity values.

1. Description

This program multiplies an age-frequency vector by the matrices of age-specific survivorship and fecundity values, until a stable age distribution is attained.

2. Input

This program is run on the RAX (remote access) system using a Datacom 35 teletype to type in the data. The program (SIM 13) is in the SAVE library of the system. The data, consisting of an initial age-frequency distribution (PCD), an age-specific fecundity matrix (FX) and an age-specific survivorship matrix (PX) are typed in and also saved under their respective codes. The format of the data, PCD, FX and PX is shown in Appendix C, Program F.

Once the program begins to run, more data must be typed in after the statement "Enter Data" is printed on the output sheet. The data required here are the number of age classes and the initial population size. These are entered using the format I2, I6.

3. Output

The population projection is run by calling the program and data from the save library into the input stream using the appropriate job control statements (Appendix B, Program F). The output consists of the eigenvalue of the stable age matrix, the number of iterations taken to reach a stable age distribution, the total number of seals in the population at this time and a print-out of the percentage distribution for all age classes (Appendix B, Program F).

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APPENDIX A

Program Print-out

PROGRAM A

```
C PROGRAM FOR SEX AND AGE SPECIFIC DENSITY AND FREQUENCY DISTRIBUTIONS
C FOR DIFFERENT TIME PERIODS
C
      INTEGER*2 D(4310,6),GL(425),COUNT(425,25),COUNT2(425,25)
      REAL TDENS(25),DENS(425,25),AREA(425),TDENS2(25),DENS2(425,25)
      INTEGER*2 TOTAL(25),NUM(24),TOTAL2(25)
      INTEGER*2 DB,MB,YB,DE,ME,YE,KSW
      INTEGER X
      COMMON NGL,NUM,GL,DB,ME,YE,DE,MB,YB,KSW
C READ NO. OF GRID LOCATIONS ,NO. OF SEALS, NO. OF TIME PERIODS
      READ 150,NGL,NDC,NPER
150   FORMAT(3I4)
C READ DATA FOR EACH SEAL
      READ (5,38)((D(I,J),J=1,6),I=1,NDC)
38    FORMAT (5X,3I2,T18,I4,T29,I1,I2)
C CALCULATION OF TOTAL ICE AREAS
      TAREA=0.
      DO 52 K=1,NGL
C READ GRID LOCATIONS AND ICE AREAS
      READ (5,39) GL(K),AREA(K)
39    FORMAT (3X,I4,F4.2)
52    TAREA=TAREA+AREA(K)
C
C ASSIGNMENT OF SEALS TO APPROPRIATE DATE PERIOD, GRID LOCATION,
C SEX AND AGE
C
      DO 981 JJJ=1,NPER
      DO 51 K=1,NGL
      DO 51 L=1,25
      COUNT2(K,L)=0
51    COUNT(K,L)=0
C READ FIRST AND LAST DAYS OF TIME PERIOD
      READ (5,37) DB,MB,YB,DE,ME,YE
37    FORMAT (6I3)
      NBEG=NDATE(DB,MB,YB)
      NEND=NDATE(DE,ME,YE)
      DO 10 K=1,NGL
      DO 9 I=1,NDC
      IF(GL(K).NE.D(I,4)) GO TO 9
C TEST TO SEE IF DATE LIES WITHIN APPROPRIATE TIME PERIOD
      X=NDATE(D(I,1),D(I,2),D(I,3))
      IF (X.LT.NBEG.OR.X.GT.NEND) GO TO 9
      IF(D(I,6).LT.21) GO TO 12
      DO 13 LL=21,36,5
      IF (D(I,6).LT.LL.OR.D(I,6).GT.LL+4) GO TO 13
      MM=(LL-1)/5+18
CC
C CALCULATION OF AGE FREQUENCY PER GRID LOCATION
      IF(D(I,5).EQ.1) COUNT(K,MM)=COUNT(K,MM)+1
      IF(D(I,5).EQ.2) COUNT2(K,MM)=COUNT2(K,MM)+1
      GO TO 9
13    CONTINUE
12    DO 8 L=1,21
      IF(D(I,6).EQ.L-1 .AND.D(I,5).EQ.2) COUNT2(K,L)=COUNT2(K,L)+1
```

```
          IF (D(I,6).EQ.L-1 .AND.D(I,5).EQ.1) COUNT(K,L)=COUNT(K,L)+1
    8     CONTINUE
    9     CONTINUE
    10    CONTINUE
    C
    C CALCULATION OF DENSITY PER GRID LOCATION
          DO 41 K=1,NGL
          DO 42 L=1,25
          DENS(K,L)=COUNT(K,L)/AREA(K)
          DENS2(K,L)=COUNT2(K,L)/AREA(K)
    42    CONTINUE
    41    CONTINUE
          DO 62 I=1,21
    62    NUM(I)=I-1
    C CALCULATION OF TOTAL FREQUENCY
          DO 101 K=1,25
          TOTAL(K)=0
          TOTAL2(K)=0
          DO 100 I=1,NGL
          TOTAL2(K)=TOTAL2(K)+COUNT2(I,K)
    100   TOTAL(K)=TOTAL(K)+COUNT(I,K)
     101  CONTINUE
    C CALCULATION OF TOTAL DENSITY
          DO 111 K=1,25
          TDENS2(K)=TOTAL2(K)/TAREA
    111   TDENS(K)=TOTAL(K)/TAREA
          KSW=1
    C
    C CALLS OF OUTPUT SUBROUTINE
          CALL OUTPUT (COUNT,DENS,TDENS,TOTAL)
          KSW=2
          CALL OUTPUT(COUNT2,DENS2,TDENS2,TOTAL2)
    C
    981   CONTINUE
          STOP
          END

        SUBROUTINE OUTPUT(COUNT,DENS,TDENS,TOTAL)
  C
  C SUBROUTINE FOR PRINTING ALL RESULTS
  C
        REAL TDENS(25),DENS(425,25)
        INTEGER*2 GL(425),COUNT(425,25)
        INTEGER*2 TOTAL(25),NUM(24)
        INTEGER*2 DB,MB,YB,DE,ME,YE,KSW
        COMMON NGL,NUM,GL,DB,ME,YE,DE,MB,YB,KSW
        K1=1
        K2=50
        IF (NGL.LT.50) K2=NGL
  301   IF (KSW.EQ.1) WRITE (6,66) DB,MB,YB,DE,ME,YE
  66    FORMAT('1',40X,'  MALE AGE FREQUENCIES FROM',3I3,' TO',3I3//)
        IF (KSW.EQ.2) WRITE (6,67) DB,MB,YB,DE,ME,YE
  67    FORMAT('1',40X,'FEMALE AGE FREQUENCIES FROM',3I3,' TO',3I3//)
        WRITE (6,63) (NUM(I),I=1,21)
  63    FORMAT (' ',7X,21I5,'  21-  26-  31-  36-'//' GRID'/)
```

```
      DO 200 K=K1,K2
200   PRINT 29,GL(K),(COUNT(K,L),L=1,25)
29    FORMAT (' ',I4,3X,25I5)
      WRITE (6,61)
61    FORMAT (1H1,40X,'NUMBER IN THE AGE CLASSES/SQUARE NAUTICAL MILES'//)
     2/)
      WRITE (6,73) (NUM(I),I=1,13)
73    FORMAT (' ',5X,13I7//' GRID'/)
      DO 600 K=K1,K2
600   WRITE (6,64) GL(K),(DENS(K,L),L=1,13)
64    FORMAT (' ',I4,3X,13F7.3)
      WRITE (6,61)
      WRITE (6,71) (NUM(I),I=14,21)
71    FORMAT (' ',5X,8I7,'    21-     26-     31-     36-'//' GRID'/)
      DO 300 K=K1,K2
300   WRITE (6,74) GL(K),(DENS(K,L),L=14,25)
74    FORMAT (' ',I4,3X,12F7.3)
      IF (K2.EQ.NGL) GO TO 302
      K1=K1+50
      K2=K2+50
      IF (K2.LT.NGL) GO TO 301
      K2=NGL
      GO TO 301
302   CONTINUE
      PRINT 500,DB,MB,YB,DE,ME,YE
500   FORMAT(1H1,20X,'TOTAL NUMBER/AGE CLASS FROM',3I3,' TO',3I3//)
      PRINT 502,(NUM(I),I=1,21)
502   FORMAT (' ',7X,21I5,'  21-  26-  31-  36-'//)
      PRINT 802,TOTAL
802   FORMAT (' ',7X,25I5////////////)
      PRINT 503,DB,MB,YB,DE,ME,YE
503   FORMAT(' ',20X,'DENSITY/AGE CLASS FROM',3I3,' TO',3I3//)
      WRITE (6,800) (NUM(I),I=1,13)
800   FORMAT (' ',5X,13I7//)
      PRINT 803,(TDENS(  L),L=1,13)
803   FORMAT (' ',7X,13F7.3///////)

      WRITE (6,801) (NUM(I),I=14,21)
801   FORMAT (' ',5X,8I7,'    21-     26-     31-     36-'//)
      PRINT 804,(TDENS(L  ),L=14,25)
804   FORMAT (' ',7X,12F7.3//////)
      RETURN
      END

      FUNCTION NDATE(D,M,Y)
C
C SUBROUTINE USED TO ACCEPT THE NUMBERS FOR DAY, MONTH AND YEAR AND
C TO RETURN AN ORDERED NUMBER TO THE MAIN PROGRAM FOR DATE TESTING
C THIS IS ONLY APPLICABLE TO DATES AFTER 31 DECEMBER 1965
C
      INTEGER*2 D,M,Y
      INTEGER NYR(12)/31,29,31,30,31,30,31,31,30,31,30,31/
      IF (D.EQ.0.OR.M.EQ.0) GO TO 10
      NDATE=D+366*(Y-66)
```

```
                     MM=M-1
                     IF (MM.EQ.0) GO TO 7
                     DO 6 I=1,MM
          6          NDATE=NDATE+NYR(I)
                     GO TO 7
          10         NDATE=0
          7          RETURN
                     END
```

PROGRAM B

```
C PROGRAM FOR COMPUTING LIFE TABLES FROM AGE FREQUENCY DISTRIBUTIONS
      INTEGER TOTAL(25)
      INTEGER NUM(25)
      INTEGER LT(26,3)
      REAL XMEAN(25),EX(25)
C READ NUMBER OF AGE FREQUENCY DISTRIBUTIONS
      DATA NUM(22),NUM(23),NUM(24),NUM(25)/' 22-',' 26-',' 31-',' 36-'/
      READ (5,127) NDIST
127   FORMAT (I2)
C READ AGE FREQUENCY DISTRIBUTION
      DO 487 IJ=1,NDIST
      READ (5,300) TOTAL
300   FORMAT (25I3)
      DO 255 I=1,21
255   NUM(I)=I-1
C TOTALLING OF NUMBER PER AGE FREQUENCY DISTRIBUTION
      TTOTAL=0
      DO 253 K=1,25
253   TTOTAL=TTOTAL+TOTAL(K)
      LT(26,2)=0
      LT(1,2)=1000
C
C CALCULATION OF DIFFERENT ELEMENTS OF THE LIFE TABLE
      DO 250 K=1,25
      LT(K,1)=IFIX(1000.*TOTAL(K)/TTOTAL+0.5)
      IF (K.LE.24) LT(K+1,2)=LT(K,2)-LT(K,1)
      IF (LT(K,2).EQ.0) LT(K,3)=0
      IF (LT(K,2).NE.0) LT(K,3)=1000.*LT(K,1)/LT(K,2)+0.5
      XMEAN(K)=(LT(K,2)+LT(K+1,2))/2.
250   CONTINUE
      S=0.
      DO 251 L=1,25
      K=26-L
      S=S+XMEAN(K)
      IF(LT(K,2).EQ.0)EX(K)=0
      IF(LT(K,2).NE.0)EX(K)=S/LT(K,2)
C
C OUTPUT STATEMENTS
251   CONTINUE
      WRITE (6,256)
256   FORMAT('1','  AGE CLASS NUMBER PER NUMBER PER 1000  SURVIVORS PER
     2   AGE SPECIFIC  MEAN SURVIVORS         MEAN LIFE')
      WRITE (6,257)
257   FORMAT(' ',13X,'AGE CLASS   PER AGE CLASS       1000          MORTALI
     2TY RATE BETWEEN CLASSES       EXPECTANCY')
      WRITE (6,258) (NUM(K),TOTAL(K),(LT(K,J),J=1,3),XMEAN(K),EX(K),K=1,2
     221)
258   FORMAT('0',I7,I11,I14,2I16,F17.1,F16.2)
      WRITE (6,259) (NUM(K),TOTAL(K),(LT(K,J),J=1,3),XMEAN(K),EX(K),K=2
     22,25)
259   FORMAT('0',A7,I11,I14,2I16,F17.1,F16.2)
487   CONTINUE
      STOP
      END
```

PROGRAM C

```
C AGE SPECIFIC COMPUTATION OF STANDARD BIOLOGICAL MEASUREMENTS FOR
C DIFFERENT TIME PERIODS
C
       INTEGER DB,YB,DE,YE
       INTEGER AGE(638),S(638),XL(638),U1(638),U2(638)
       REAL M(11),SD(11)
       REAL B(638,11),A(638),C(638) ,D(2000)
       INTEGER ND(11),DY(638),MN(638),YR(638) ,NUM(13)
       DO 170 I=1,13
170    NUM(I)=I
C READ NUMBER OF DATA CARDS AND DATE PERIODS
       READ (5,12) NDC,NPER
12     FORMAT (2I3)
C READ DATA MATRIX
       READ (5,1) (S(I),AGE(I),(B(I,J),J=1,3),A(I),C(I),B(I,8),B(I,9)
      2,U1(I),U2(I),B(I,10),B(I,11),XL(I),B(I,5),DY(I),MN(I),YR(I),I=1,N
      2C)
1      FORMAT(28X,I1,I2,2X,2F3.0,F2.0,2F3.0,7X,F3.0,1X,F5.2,
      22I1,2F3.0,3X,I1,F4.1,T6,3I2)
       DO 999 IJ=1,NPER
C READ FIRST AND LAST DATES OF TIME PERIOD
       READ (5,37) DB,MB,YB,DE,ME,YE
37     FORMAT (6I3)
       NBEG=NDATE(DB,MB,YB)
       NEND=NDATE(DE,ME,YE)
       WRITE (6,127) DB,MB,YB,DE,ME,YE
127    FORMAT ('1PERIOD FROM',3I3,' TO',3I3)
       WRITE (6,169) NUM
169    FORMAT ('0','COL. NO.',3X,I1,12I10/'0','AGE')
C CONSTRUCTION OF MATRIX FROM WHICH THE SOBROUTINE MSD CALCULATES
C THE ELEMENTARY STATISTICS
       DO 22 I=1,NDC
       B(I,6)=0.
       B(I,7)=0.
       IF (S(I).EQ.1) B(I,6)=(A(I)+C(I))/2.
       IF (S(I).EQ.2) B(I,7)=(A(I)+C(I))/2.
       IF (B(I,1).EQ.0.OR.B(I,2).EQ.0.) GO TO 32
       B(I,4)=0.015*B(I,1)*B(I,2)*B(I,2)/(2.2045*2.54**3)
       GO TO 22
32     B(I,4)=0.
22     CONTINUE
       L=0
10     K=0
       N1=0
       N2=0
       N3=0
       N4=0
C SEARCH FOR SEALS BELONGING TO THE SAME AGE CLASS
       DO 7 I=1,NDC
       IF (AGE(I).GT.20.AND.AGE(I).NE.99) AGE(I)=(AGE(I)-1)/5+17
       IF (AGE(I).NE.L) GO TO 7
       X=NDATE(DY(I),MN(I),YR(I))
       IF (X.LT.NBEG.OR.X.GT.NEND) GO TO 7
       DO 6 J=1,11
```

```
      K=K+1
      D(K)=B(I,J)
 6    CONTINUE
C CALCULATION OF PERCENTAGES
      IF (U1(I).EQ.4.OR.U2(I).EQ.4) N1=N1+1
      IF (S(I).EQ.2) N2=N2+1
      IF (XL(I).GE.2) N3=N3+1
      IF (XL(I).GE.1) N4=N4+1
7     CONTINUE
      IF (N2.EQ.0) PC1=0.
      IF (N2.NE.0) PC1=100.*N1/N2
      IF (N4.EQ.0) PC3=0.
      IF (N4.NE.0) PC3=100.*N3/N4
C OUTPUT STATEMENTS
      CALL MSD(D,K,11,M,SD,ND,NCT)
      LL=K/11
      WRITE (6,3) L,ND,N2,N4,L,M,PC1,PC3,L,SD ,LL
3     FORMAT('0',I2,13I10/' ',I2,13F10.1/' ',I2,11F10.1,'  CLASS TOTAL I
     2S ',I3)
      L=L+1
      IF (L.LT.25) GO TO 10
999   CONTINUE
      STOP
      END

C
C SUBROUTINE MSD TO CALCULATE AGE SPECIFIC ELEMENTARY STATISTICS
C FOR DIFFERENT MEASUREMENTS
      SUBROUTINE MSD(D,N,NC,M,SD,ND,NCT)
      INTEGER NCT(NC),ND(NC)
      REAL B(638,11),SD(NC),M(NC)
      REAL D(N)
      L=N/NC
      K=0
 2    K=K+1
      DO 20 J=1,11
 20   B(K,J)=D(11*(K-1)+J)
      IF (K.LT.L) GO TO 2
      DO 1 J=1,NC
      SUM=0.
      SUMSQ=0.
      NCT(J)=0
      IF (L.NE.0) GO TO 4
      M(J)=0
      ND(J)=0
      SD(J)=0
      GO TO 1
 4    DO 22 I=1,L
      IF (B(I,J).EQ.0.) NCT(J)=NCT(J)+1
      SUM=SUM+B(I,J)
      SUMSQ=SUMSQ+B(I,J)**2
 22   CONTINUE
```

```
      ND(J)=L-NCT(J)
      IF (ND(J).NE.1.AND.ND(J).NE.0) GO TO 3
      M(J)=0.
      SD(J)=0.
      GO TO 1
3     M(J)=SUM/ND(J)
      SD(J)=SQRT(SUMSQ/(ND(J)-1)-M(J)**2*ND(J)/(ND(J)-1))
1     CONTINUE
      RETURN
      END

C
C SUBROUTINE USED TO ACCEPT THE NUMBERS FOR DAY, MONTH AND YEAR AND
C TO RETURN AN ORDERED NUMBER TO THE MAIN PROGRAM FOR DATE TESTING
C THIS IS ONLY APPLICABLE TO DATES AFTER 31 DECEMBER 1965
      FUNCTION NDATE(D,M,Y)
      INTEGER D,Y
      INTEGER NYR(12)/31,29,31,30,31,30,31,31,30,31,30,31/
      IF (D.EQ.0.OR.M.EQ.0) GO TO 10
      NDATE=D+366*(Y-66)
      MM=M-1
      IF (MM.EQ.0) GO TO 7
      DO 6 I=1,MM
6     NDATE=NDATE+NYR(I)
      GO TO 7
10    NDATE=0
7     RETURN
C
C KEY TO COLUMN CONTENT OF STANDARD BIOLOGICAL MEASURMENTS
C
C COL. 1= NOSE TAIL LENGHT (CM.)
C COL. 2= MAXIMUM GIRTH (CM.)
C COL.3= BLUBBER THICKNESS (CM.)
C COL. 4= ESTIMATED WEIGHT (FORMULA OF USHER AND CHURCH 1969)
C COL. 5= MEASURED WEIGHT
C COL. 6= TESTIS SIZE (LENGTH + WIDTH/2)
C COL. 7= MAMMARY SIZE (LENGTH + WIDTH/2)
C COL. 8= FOETUS LENGTH (CROWN RUMP)
C COL. 9= FOETUS WEIGHT
C COL. 12= NUMBEROF SPECIMENS CONSIDERED, PERCENT WITH A FOETUS
C COL. 13= NUMBER OF SPECIMENS CONSIDERED, PERCENT LACTATING,
C TOTAL IN THE AGE CLASS
C
C ELEMENTS IN COLS. 1 TO 11 ARE: NUMBER OF SPECIMENS, MEAN AND
C STANDARD DEVIATION
      END
```

PROGRAM D

```
C
C PROGRAM FOR COMPILATION OF MALE REPRODUCTIVE DATA
C
      REAL M(2),SD(2),XMAX(2),XMIN(2),B(80,2),C1(80),E1(80),DD(200)
      INTEGER ND(2),DY(80),YR(80),MN(80),AGE(80)
      INTEGER DB,YB,DE,YE
C READ NUMBER OF DATA CARDS AND DATE PERIODS
      READ (5,12) NDC,NPER
12    FORMAT (2I3)
      DO 999 I=1,NDC
C READ DATA MATRIX
      READ (5,29) DY(I),MN(I),YR(I),AGE(I),B(I,1),C1(I),B(I,2),E1(I)
29    FORMAT (5X,3I2,T30,I2,2(F4.1,F2.0))
999   CONTINUE
      DO 997 IJ=1,NPER
C READ FIRST AND LAST DATES OF TIME PERIOD
      READ (5,37) DB,MB,YB,DE,ME,YE
37    FORMAT (6I3)
      NBEG=NDATE(DB,MB,YB)
      NEND=NDATE(DE,ME,YE)
      WRITE (6,127) DB,MB,YB,DE,ME,YE
127   FORMAT ('1PERIOD FROM',3I3,' TO',3I3)
      WRITE (6,128)
128   FORMAT('0COL     1      2      3      4       5'/'0AGE')
      L=0
10    K=0
      N=0
      N1=0
      PCSP=0.
      PCSPE=0.
C
C SEARCH FOR SEALS BELONGING TO THE SAME AGE CLASS
      DO 7 I=1,NDC
      IF (AGE(I).GT.20.AND.AGE(I).NE.99) AGE(I)=(AGE(I)-1)/5+17
      IF (AGE(I).NE.L) GO TO 7
      X=NDATE(DY(I),MN(I),YR(I))
      IF (X.LT.NBEG.OR.X.GT.NEND) GO TO 7
      DO  6 J=1,2
      K=K+1
      DD(K)=B(I,J)
 6    CONTINUE
      IF (C1(I).NE.0.)  N=N+1
      PCSP=PCSP+C1(I)
      IF (E1(I).NE.0.)  N1=N1+1
      PCSPE=PCSPE+E1(I)
7     CONTINUE
      IF (K.EQ.0) GO TO 21
      CALL MSD(DD,K, 2,M,SD,ND,NCT,XMAX,XMIN)
C
C CALCULATION OF MEAN PERCENTAGES
      LL=K/2
      IF (N.EQ.0)  XMNSP=0.
      IF (N.NE.0)  XMNSP=PCSP/N
      IF (N1.EQ.0)  XMNSPE=0.
```

```
      IF (N1.NE.0)  XMNSPE=PCSPE/N1
      SM=100.*N1/LL
C
C OUTPUT STATEMENTS
      WRITE (6,57) L,ND,N,N1,L,M,XMNSP,XMNSPE,L,SD,LL,SM,L,XMAX,L,
57    FORMAT ('0',I2,4I6/' ',I2,4F6.1/' ',I2,2F6.1,' TOTAL',I6,F6.
     2I2,2F6.1/' ',I2,2F6.1)
      GO TO 54
21    WRITE (6,53) L
53    FORMAT(' ','NONE IN AGE CLASS',I4)
54    L=L+1
      IF (L.LT.25) GO TO 10
997   CONTINUE
      STOP
      END

C SUBROUTINE MSD TO CALCULATE AGE SPECIFIC ELEMENTARY STATISTICS
C FOR DIFFERENT MEASUREMENTS
      SUBROUTINE MSD(D,N,NC,M,SD,ND,NCT,XMAX,XMIN)
      REAL XMAX(NC),XMIN(NC)
      REAL B( 80,2 ),SD(NC),M(NC)
      INTEGER NCT(NC),ND(NC)
      REAL D(N)
      L=N/NC
      K=0
2     K=K+1
      DO 20 J=1,NC
20    B(K,J)=D( 2*(K-1)+J)
      IF (K.LT.L) GO TO 2
      DO 1 J=1,NC
      SUM=0.
      SUMSQ=0.
      NCT(J)=0
      XMAX(J)=0.
      XMIN(J)=999.9
      IF (L.NE.0) GO TO 4
      M(J)=0
      ND(J)=0
      SD(J)=0
      GO TO 1
4     DO 22 I=1,L
      IF (B(I,J).EQ.0.) NCT(J)=NCT(J)+1
      XMAX(J)=AMAX1(B(I,J),XMAX(J))
      IF (B(I,J).NE.0) XMIN(J)=AMIN1(B(I,J),XMIN(J))
      SUM=SUM+B(I,J)
      SUMSQ=SUMSQ+B(I,J)**2
22    CONTINUE
      ND(J)=L-NCT(J)
      IF (ND(J).NE.1.AND.ND(J).NE.0) GO TO 3
      M(J)=0.
      SD(J)=0.
      GO TO 1
3     M(J)=SUM/ND(J)
      SD(J)=SQRT(SUMSQ/(ND(J)-1)-M(J)**2*ND(J)/(ND(J)-1))
1     CONTINUE
      RETURN
      END
```

```
C
C SUBROUTINE USED TO ACCEPT THE NUMBERS FOR DAY, MONTH AND YEAR AND
C TO RETURN AN ORDERED NUMBER TO THE MAIN PROGRAM FOR DATE TESTING
C THIS IS ONLY APPLICABLE TO DATES AFTER 31 DECEMBER 1965
      FUNCTION NDATE(D,M,Y)
      INTEGER D,Y
      INTEGER NYR(12)/31,29,31,30,31,30,31,31,30,31,30,31/
      IF (D.EQ.0.OR.M.EQ.0) GO TO 10
      NDATE=D+366*(Y-66)
      MM=M-1
      IF (MM.EQ.0) GO TO 7
      DO 6 I=1,MM
6     NDATE=NDATE+NYR(I)
      GO TO 7
10    NDATE=0
7     RETURN
C
C KEY TO COLUMN CONTENT MALE REPRODUCTIVE DATA
C COL. 1= TESTIS TUBULE DIAMETER
C COL. 2= EPIDIDYMIS TUBULE DIAMETER
C COL. 3= NUMBER OF SPECIMENS, MEAN PERCENT SPERM IN TESTIS TUBULE
C COL. 4= NUMBER OF SPECIMENS, MEAN PERCENT SPERM IN EPIDIDYMIS TUBULE
C COL. 5= PERCENT SEXUALLY MATURE IN AGE CLASS
C
C ELEMENTS OF COL. 1 AND 2 ARE: NUMBER OF SPECIMENS, MEAN DIAMETER,
C STANDARD DEVIATION, RANGE (MAX. AND MIN. VALUES)
      END
```

PROGRAM E

```
C AGE SPECIFIC ANALYSIS OF FEMALE REPRODUCTIVE DATA FOR
C DIFFERENT DATE PERIODS
      INTEGER ND(16),NUM(18)
      REAL M(16),SD(16),XMAX(16),XMIN(16)
      INTEGER NN(25),NP(25),NO(25),NS(25),NT(25)
      INTEGER DY(600),YR(600) ,MN(600)
      INTEGER SEX(600),AGE(600),G(600),O(600),T(600),U(600)
      REAL  A(600),BB(600),C(600),D(600),E(600),F(600),H(600),P(600),R(60
     200),S(600)
      REAL B(600,16),DD(3000)
      INTEGER DB,YB,DE,YE
C READ NUMBER OF DATA CARDS AND DATE PERIODS
       READ (5,12) NDC,NPER
12    FORMAT (2I3)
      DO 999 I=1,NDC
C READ DATA MATRIX
      READ (5,29)  SEX(I),AGE(I),A(I),BB(I),C(I),D(I),E(I),F(I),G(I),H(I
     2),P(I),O(I),R(I),S(I),T(I),U(I),DY(I),MN(I),YR(I)
29    FORMAT (T29,I1,I2,12X,2(F1.0,2F2.0),2(I1,2F2.0),2I1,T6,3I2)
999   CONTINUE
      DO 732 I=1,18
732   NUM(I)=I
       DO 981 JJJ=1,NPER
      READ (5,37) DB,MB,YB,DE,ME,YE
37    FORMAT (6I3)
      NBEG=NDATE(DB,MB,YB)
      NEND=NDATE(DE,ME,YE)
      WRITE (6,127) DB,MB,YB,DE,ME,YE
127   FORMAT ('1PERIOD FROM',3I3,' TO',3I3)
      WRITE (6,735) NUM
735   FORMAT ('0COL', 4X,I1,17I6/'0','AGE')
C
C CONSTRUCTION OF MATRIX FROM WHICH THE SOBROUTINE MSD CALCULATES
C THE ELEMENTARY STATISTICS
      DO 1 I=1,NDC
      IF (G(I).EQ.0) GO TO 8
      B(I,3)=0.
      B(I,4)=0.
      DO 52 J=9,12
52    B(I,J)=0.
      IF (G(I).NE.1) GO TO 66
      B(I,1)=A(I)
      B(I,2)=D(I)
      B(I,5)=BB(I)
      B(I,6)=C(I)
      B(I,7)=E(I)
      B(I,8)=F(I)
66    IF (G(I).NE.2) GO TO 77
      B(I,1)=D(I)
      B(I,2)=A(I)
      B(I,7)=BB(I)
      B(I,8)=C(I)
      B(I,5)=E(I)
      B(I,6)=F(I)
      GO TO 77
8     B(I,3)=A(I)
      B(I,4)=D(I)
      B(I,1)=0.
      B(I,2)=0.
      DO 51 J=5,8
```

```
51      B(I,J)=0.
        B(I,9)=BB(I)
        B(I,10)=C(I)
        B(I,11)=E(I)
        B(I,12)=F(I)
77      CONTINUE
        B(I,13)=H(I)
        B(I,14)=P(I)
        B(I,15)=D(I)
        B(I,16)=S(I)
1       CONTINUE
C
        L=0
10      K=0
        N=0
        N1=0
        N2=0
        N5=0
        N6=0
        N7=0
        N8=0
C
C  SEARCH FOR SEALS BELONGING TO THE SAME AGE CLASS
        DO 7 I=1,NDC
        IF (AGE(I).GT.20.AND.AGE(I).NE.99) AGE(I)=(AGE(I)-1)/5+17
        IF (AGE(I).NE.L) GO TO 7
        X=NDATE(DY(I),MN(I),YR(I))
        IF (X.LT.NBEG.OR.X.GT.NEND) GO TO 7
C
        DO 6 J=1,16
        K=K+1
        DD(K)=B(I,J)
 6      CONTINUE
C
C  CALCULATION OF PERCENTAGES FOR COLS. 17 AND 18 ON
C  THE FIRST PAGE OF THE OUTPUT
        IF (U(I).EQ.1.OR.U(I).EQ.2)  N5=N5+1
        IF (G(I).EQ.1.AND.D(I).EQ.2 .OR.G(I).EQ.2.AND.D(I).EQ.1)     N=N+1
        IF (G(I).NE.0.AND.D(I).NE.0) N6=N6+1
        IF (OB(I).NE.0) N7=N7+1
        IF (S(I).NE.0) N8=N8+1
        IF (T(I).NE.0)  N2=N2+1
        N1=N1+T(I)
 7      CONTINUE
        IF (K.EQ.0) GO TO 21
        CALL MSD(DD,K,16,M,SD,ND,NCT,XMAX,XMIN)
        LL=K/16
        IF (N2.EQ.0) XMEAN=0.
        IF (N2.NE.0) XMEAN=FLOAT(N1)/N2
        IF (N6.EQ.0) PCCA=0.
        IF (N6.NE.0) PCCA=100.*N/N6
        NM(L+1)=ND(13)
        NP(L+1)=ND(15)
        NO(L+1)=N7
        NS(L+1)=N8
        NT(L+1)=N5
C
C  OUTPUT STATEMENTS FOR PAGE 1 OF THE RESULTS
        WRITE (6,31) L,ND,N6,N2,L,M,PCCA,XMEAN,L,SD,LL,L,XMAX,L,XMIN
31      FORMAT ('0',I2,18I6         /' ',I2,18F6.1/' ',I2,16F6.1,' TOTAL',
```

```
      IF (B(I,J).NE.0) XMIN(J)=AMIN1(B(I,J),XMIN(J))
      SUM=SUM+B(I,J)
      SUMSQ=SUMSQ+B(I,J)**2
22    CONTINUE
      ND(J)=L-NCT(J)
      IF (ND(J).NE.1.AND.ND(J).NE.0) GO TO 3
      M(J)=0.
      SD(J)=0.
      GO TO 1
3     M(J)=SUM/ND(J)
      SD(J)=SQRT(SUMSQ/(ND(J)-1)-M(J)**2*ND(J)/(ND(J)-1))
1     CONTINUE
      RETURN
      END
C SUBROUTINE USED TO ACCEPT THE NUMBERS FOR DAY, MONTH AND YEAR A
C TO RETURN AN ORDERED NUMBER TO THE MAIN PROGRAM FOR DATE TESTIN
C THIS IS ONLY APPLICABLE TO DATES AFTER 31 DECEMBER 1965
      FUNCTION NDATE(D,M,Y)
      INTEGER D,Y
      INTEGER NYR(12)/31,29,31,30,31,30,31,31,30,31,30,31/
      IF (D.EQ.0.OR.M.EQ.0) GO TO 10
      NDATE=D+365*(Y-66)
      MM=M-1
      IF (MM.EQ.0) GO TO 7
      DO 6 I=1,MM
6     NDATE=NDATE+NYR(I)
      GO TO 7
10    NDATE=0
7     RETURN
C
C
C KEY TO COLUMN CONTENT FEMALE REPRODUCTIVE DATA
C
C PAGE 1 OF OUTPUT
C COL. 1= NUMBER OF FOLLICLES IN OVARY WITH CORPUS LUTEUM
C COL.2= NUMBER OF FOLLICLES IN OVARY WITHOUT CORPUS LUTEUM
C COL. 3= NUMBER OF FOLLICLES IN RIGHT OVARY. (NO CORPUS LUTEUM )
C COL. 4= NUMBER OF FOLLICLES IN LEFT OVARY. (NO CORPUS LUTEUM)
C COLS. 5 AND 6= DIAMETERS OF LARGEST FOLLICLE IN OVARY
C WITH CORPUS LUTEUM
C COLS. 7 AND 8= DIAMETERS OF LARGEST FOLLICLE IN OVARY
C WITHOUT CORPUS LUTEUM
C COLS. 9 AND 10= DIAMETER OF LARGEST FOLLICLE IN
C RIGHT OVARY. (NO CORPUS LUTEUM)
C COLS. 11 AND 12= DIAMETERS OF LARGEST FOLLICLE IN
C LEFT OVARY. (NO CORPUS LUTEUM)
C COLS 13 AND 14= DIAMETERS OF CORPUS LUTEUM
C COLS. 15 AND 16= DIAMETERS OF CORPUS ALBICANS
C COL. 17= NUMBER WITH CORPUS ALBICANS IN OPPOSITE OVARY TO
C CORPUS LUTEUM PERCENTAGE OF SEALS WITH CORPUS ALBICANS IN
C OPPOSITE OVARY TO THE CORPUS LUTEUM
C COL. 18= NUMBER OF SPECIMENS COUNTED FOR TOTAL NUMBER OF CORPORA
C ALBICANTIA  MEAN NUMBER OF CORPORA ALBICANTIA PER OVARY PAIR
C TOTAL NUMBER OF ANIMALS IN AGE CLASS
```

```
     26/' ',I2,16F6.1/' ',I2,16F6.1)
      GO TO 54
21    WRITE (6,53) L
53    FORMAT(' ','NONE IN AGE CLASS',I4)
C
      NN(L+1)=0
      NP(L+1)=0
      NO(L+1)=0
      NS(L+1)=0
      NT(L+1)=0
54    L=L+1
      IF (L.LT.25) GO TO 10
      PRINT 834
834   FORMAT ('1CLASS',8X,'N7    SP',8X,'N8  PCRB',15X,'PCREP')
C
C CALCULATION OF PERCENTAGES FOR PAGE 2 OF THE RESULTS
      DO 833 L=1,24
      IF (NO(L).EQ.0.AND.NO(L+1).EQ.0)  SP=0.
      IF (NO(L).NE.0.OR.NO(L+1).NE.0)  SP=(NN(L)+NP(L+1))*100./(NO(L)+NO
     2(L+1))
      IF(NS(L).EQ.0) PCRB=0.
      IF (NS(L).NE.0) PCRB=NT(L)*100./NS(L)
      PCREP=PCRB*SP/100.
      LL=L-1
C
C OUTPUT FOR PAGE 2 OF THE RESULTS
      PRINT 832,LL,NO(L),SP,NS(L),PCRB,PCREP
832   FORMAT (' ',I5,2(I10,F6.1),F20.1)
833   CONTINUE
981   CONTINUE
      STOP
      END
C SUBROUTINE MSD TO CALCULATE AGE SPECIFIC ELEMENTARY STATISTICS
C FOR DIFFERENT MEASUREMENTS
      SUBROUTINE MSD(D,N,NC,M,SD,ND,NCT,XMAX,XMIN)
      REAL XMAX(NC),XMIN(NC)
      REAL B(550,16),SD(NC),M(NC)
      INTEGER NCT(NC),ND(NC)
      REAL D(N)
      L=N/NC
      K=0
2     K=K+1
      DO 20 J=1,NC
20    B(K,J)=D(16*(K-1)+J)
      IF (K.LT.L) GO TO 2
      DO 1 J=1,NC
      SUM=0.
      SUMSQ=0.
      NCT(J)=0
      XMAX(J)=0.
      XMIN(J)=10.0
      IF (L.NE.0) GO TO 4
      M(J)=0
      ND(J)=0
      SD(J)=0
      GO TO 1
4     DO 22 I=1,L
      IF (B(I,J).EQ.0.) NCT(J)=NCT(J)+1
      XMAX(J)=AMAX1(B(I,J),XMAX(J))
```

```
C
C ELEMENTS OF COLS. 1 TO 16 ARE  NUMBER OF SPECIMENS, STANDARD
C DEVIATION , RANGE (MAX. AND MIN. VALUES)
C
C PAGE 2 OF FEMALE REPRODUCTIVE OUTPUT
C COL. N7=NUMBER OF SEALS PER AGE CLASS WITH REPRODUCTIVE DATA
C COL. SP = PERCENTAGE ANIMALS SEXUALLY MATURE PER AGE CLASS
C COL. N8= NUMBER OF SEALS WITH A CORPUS LUTEUM PER AGE CLASS
C COL. PCRB= PERCENT OF SEALS WITH REPRODUCTIVE BODY PER AGE CLAS
C COL. PCREP= PERCENT SEXUALLY PRODUCTIVE PER AGE CLASS
C
C NOTE *** AGE CLASSES 21,22,23,24, CORRESPOND TO YEAR CLASSES
C 21 TO25, 26 TO 30, 31 TO 35, 36 TO 40.
      END
```

PROGRAM F

```
/LOAD FORTG
C POPULATION PROJECTION PROGRAM TO GENERATE A STABLE AGE
C DISTRIBUTION,GIVEN AGE SPECIFIC SURVIVORSHIP AND
C FECUNDITY VALUES.
      REAL PCD(41),F(41),P(40),AD(41),NEWAD(41)
      REAL NN(1000)
      INTEGER T
C READ PERCENTAGE AGE DISTRIBUTION.
      READ (5,1) PCD
1     FORMAT (10F4.2)
C READ AGE SPECIFIC FECUNDITIES.
      READ (5,11) F
C READ PROBABILITY OF ANNUAL SURVIVORSHIP.
      READ (5,11) P
11    FORMAT (10F4.4)
      DO 999I=1,25
999   F(I)=0.5*F(I)
      NIT=999
C READ THE NUMBER OF AGE CLASSES AND AN ARBITRARY INITIAL
C POPULATION SIZE.
      READ (9,9) M,N
9     FORMAT (I2,I6)
      NN(1)=N
      EV1=0.
      AD(1)=1.0
      DO 7 I=1,M
7     NEWAD(I)=N*PCD(I)/100.
      DO 21 T=1,NIT
      IT=T-1
      EV2=NEWAD(1)/AD(1)
C TEST FOR THE STABILITY OF THE AGE DISTRIBUTION.
      IF (ABS(EV2-EV1).LT.0.000001) GO TO 68
      EV1=EV2
C
C THE MATRIX MULTIPLICATION.
      DO 4 I=1,M
4     AD(I)=NEWAD(I)
      NEWAD(1)=0.
      DO 5 I=1,M
5     NEWAD(1)=NEWAD(1)+AD(I)*F(I)
      K=M-1
      NN(T+1)=NEWAD(1)
      DO 6 I=1,K
      NEWAD(I+1)=AD(I)*P(I)
6     NN(T+1)=NN(T+1)+NEWAD(I+1)
21    CONTINUE
68    DO 69 I=1,M
69    NEWAD(I)=NEWAD(I)*100./NN(T)
C
C OUTPUT STATEMENTS
      WRITE (6,70) EV2,T,NN(T),NEWAD
70    FORMAT ('0EIGENVALUE=',F10.5,'  ITERATIONS=',I2/
     2'0TOTAL STABLE POPULATION=',F8.0/'0PERCENTAGE AGE DISTRIBUTION'
     2/(' ',10F6.2))
      STOP
      END
```

APPENDIX B

Sample Output

```
                                      MALE AGE FREQUENCIES FROM  1  5 67 TO 30  9 67

        0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20 21- 26- 31- 36-

GRID

1823    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
1923    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2023    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2123    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2223    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2323    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2423    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2523    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
1522    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
1622    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
1822    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
1922    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2022    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2122    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2222    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2322    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2422    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2522    2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
1621    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
1721    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
1821    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2021    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2121    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2221    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2321    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2421    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2521    2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2621    1   0   0   1   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
2721    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2821    1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2921    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
3021    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
3121    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
3221    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
3321    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2020    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2120    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2220    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2320    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2420    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2520    1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2620    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2720    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2820    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
2920    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
3020    0   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
3120    1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
3220    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
3320    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
3420    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

NUMBER IN THE AGE CLASSES/SQUARE NAUTICAL MILES

GRID	0	1	2	3	4	5	6	7	8	9	10	11	12
1823	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1923	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2023	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2123	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2223	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2323	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2423	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2523	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1522	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1622	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1822	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1922	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2022	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2122	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2222	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2322	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2422	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2522	0.092	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1621	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1721	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1821	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2021	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2121	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2221	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2321	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2421	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2521	0.160	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2621	0.060	0.0	0.0	0.060	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.060	0.0
2721	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2821	0.108	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2921	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3021	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3121	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3221	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3321	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2020	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2220	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2320	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2420	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2520	0.074	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2620	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2720	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2820	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2920	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3020	0.0	0.071	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3120	0.134	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3220	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3320	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3420	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

NUMBER IN THE AGE CLASSES/SQUARE NAUTICAL MILES

GRID	13	14	15	16	17	18	19	20	21-	26-	31-	36-
1823	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1923	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2023	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2123	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2223	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2323	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2423	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2523	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1522	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1622	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1822	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1922	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2022	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2122	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2222	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2322	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2422	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2522	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1621	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1721	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1821	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2021	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2121	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2221	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2321	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2421	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2521	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2621	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2721	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2821	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2921	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3021	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3121	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3221	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3321	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2020	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2220	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2320	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2420	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2520	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2620	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2720	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2820	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2920	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3020	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3220	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3320	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3420	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

```
                    TOTAL NUMBER/AGE CLASS FROM  1  5 67 TO 30  9 67

      0    1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20  21-  26-  31-  36-

      8    1    0    1    0    0    0    0    0    0    0    1    0    0    0    0    0    0    0    0    0    0    0    0    0



                   DENSITY/AGE CLASS FROM  1  5 67 TO 30  9 67

      0        1        2        3        4        5        6        7        8        9       10       11       12

   0.014    0.002    0.0      0.002    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.002    0.0


     13       14       15       16       17       18       19       20      21-      26-      31-      36-

    0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
```

AGE CLASS	NUMBER PER AGE CLASS	NUMBER PER 1000 PER AGE CLASS	SURVIVORS PER 1000	AGE SPECIFIC MORTALITY RATE	MEAN SURVIVORS BETWEEN CLASSES	MEAN LIFE EXPECTANCY
0	17	195	1000	195	902.5	4.78
1	10	115	805	143	747.5	4.70
2	15	172	690	249	604.0	3.81
3	12	138	518	266	449.0	3.92
4	4	46	380	121	357.0	4.16
5	5	57	334	171	305.5	3.66
6	9	103	277	372	225.5	3.31
7	4	46	174	264	151.0	3.97
8	3	34	129	266	111.0	4.22
9	2	23	94	245	82.5	4.56
10	1	11	71	155	65.5	4.88
11	1	11	60	183	54.5	4.68
12	2	23	49	469	37.5	4.62
13	0	0	26	0	26.0	7.27
14	0	0	26	0	26.0	6.27
15	0	0	26	0	26.0	5.27
16	0	0	26	0	26.0	4.27
17	1	11	26	423	20.5	3.27
18	0	0	15	0	15.0	4.30
19	0	0	15	0	15.0	3.30
20	0	0	15	0	15.0	2.30
22-	1	11	15	733	9.5	1.30
26-	0	0	4	0	4.0	2.50
31-	0	0	4	0	4.0	1.50
36-	0	0	4	0	2.0	0.50

PROGRAM B

PROGRAM C

```
PERIOD FROM  1  5 67 TO 30  9 67

CCL. NO.  1        2        3        4        5        6        7        8        9       10       11       12       13

AGE

 0       68       61       64       61        1        1        0        0        0       20       20       56        0
 0     91.3     74.6     31.0    213.5      0.0      0.0      0.0      0.0      0.0     11.3     10.3      7.1      0.0
 0     24.9     10.7      7.9     74.5      0.0      0.0      0.0      0.0      0.0      5.5      4.8  CLASS TOTAL IS 87

 1        7        6        7        6        0        1        0        0        0       12       12       12        0
 1     96.0     74.0     27.6    228.4      0.0      0.0      0.0      0.0      0.0      8.0      7.9      0.0      0.0
 1     10.3      9.4      4.4     75.8      0.0      0.0      0.0      0.0      0.0      5.3      5.3  CLASS TOTAL IS 16

 2        5        5        5        5        0        0        0        0        0        9        9        9        1
 2     96.0     76.2     30.2    233.8      0.0      0.0      0.0      0.0      0.0      8.9      9.2      0.0      0.0
 2      9.7      4.6      4.3     45.8      0.0      0.0      0.0      0.0      0.0      4.6      4.9  CLASS TOTAL IS 13

 3        4        3        4        3        0        1        0        0        0        6        6        6        1
 3     99.5     79.0     30.3    253.5      0.0      0.0      0.0      0.0      0.0      9.2      9.2      0.0      0.0
 3      6.6      2.0      5.2      7.3      0.0      0.0      0.0      0.0      0.0      6.1      6.0  CLASS TOTAL IS  8

 4        9        4        5        4        0        0        0        0        0       19       19       19        0
 4    104.4     85.5     32.8    313.9      0.0      0.0      0.0      0.0      0.0      8.3      9.1     10.5      0.0
 4      2.8      3.9      7.3     28.8      0.0      0.0      0.0      0.0      0.0      4.7      5.6  CLASS TOTAL IS 22

 5        8        8        8        8        0        0        0        0        0       16       16       16        1
 5    106.9     85.1     31.9    329.3      0.0      0.0      0.0      0.0      0.0      9.4      8.8      0.0      0.0
 5     12.3      8.2      5.4     95.0      0.0      0.0      0.0      0.0      0.0      3.6      2.9  CLASS TOTAL IS 19

 6        5        4        5        4        0        0        0        0        0       33       33       33        1
 6    113.4     87.8     38.8    351.6      0.0      0.0      0.0      0.0      0.0     10.9     10.7      3.0      0.0
 6     13.7      9.0      7.9     95.2      0.0      0.0      0.0      0.0      0.0      3.7      3.6  CLASS TOTAL IS 33

 7        3        2        3        2        0        0        0        0        1       43       43       43        0
 7    121.7     88.5     30.7    385.1      0.0      0.0      0.0      0.0      0.0     16.3     16.5      2.3      0.0
 7     12.1     12.0      4.0    135.0      0.0      0.0      0.0      0.0      0.0     24.4     26.0  CLASS TOTAL IS 44

 8        6        6        6        6        0        0        1        0        0       68       66       68        2
 8    119.5     90.2     27.7    408.7      0.0      0.0      0.0      0.0      0.0     14.4     14.0      7.4     50.0
 8      8.8      6.7      6.0     87.8      0.0      0.0      0.0      0.0      0.0      4.2      4.0  CLASS TOTAL IS 68

 9        8        8        8        8        0        0        2        0        0       57       60       60        2
 9    124.8     98.0     32.3    505.1      0.0      0.0    238.8      0.0      0.0     15.4     15.8      8.3     50.0
 9      9.7      8.5      8.5    124.4      0.0      0.0     12.4      0.0      0.0      3.4      4.3  CLASS TOTAL IS 62

10        4        4        4        4        0        0        0        0        0       66       66       66        2
10    116.8     93.3     30.0    437.6      0.0      0.0      0.0      0.0      0.0     15.7     15.8      0.0      0.0
10     10.8     14.9      7.5    165.7      0.0      0.0      0.0      0.0      0.0      3.4      3.5  CLASS TOTAL IS 66

11        9        8        9        8        0        3        0        0        0       45       45       46        0
11    129.6     96.0     29.4    482.5      0.0     38.2      0.0      0.0      0.0     16.6     16.0      6.5      0.0
11      6.0      0.6      3.0     80.6      0.0      7.0      0.0      0.0      0.0      2.8      3.0  CLASS TOTAL IS 51

12        6        5        5        5        0        3        0        0        0       36       36       36        1
12    129.8     98.2     33.4    514.0      0.0     40.7      0.0      0.0      0.0     15.5     14.9      0.0    100.0
12      9.6      9.4      4.3    112.7      0.0      2.9      0.0      0.0      0.0      3.5      3.1  CLASS TOTAL IS 39

13        2        2        2        2        0        1        0        0        0       26       26       26        0
13    130.5    103.5     29.5    580.9      0.0      0.0      0.0      0.0      0.0     14.8     14.7      3.8      0.0
13     14.8      0.7      6.4     74.0      0.0      0.0      0.0      0.0      0.0      3.2      3.5  CLASS TOTAL IS 28
```

PROGRAM D

```
PERIOD FROM  1  5 67 TO 30  9 67

COL      1      2      3      4      5

AGE

 0      4      4      0      0
 0   53.1   68.0    0.0    0.0
 0    8.1    6.9 TOTAL      4    C.0
 0   59.5   76.5
 0   42.5   59.5

 1      5      5      0      0
 1   54.4   85.0    0.0    0.0
 1    7.6   24.8 TOTAL      5    0.0
 1   68.0  119.0
 1   51.0   59.5

 2      5      5      0      0
 2   52.7  100.3    0.0    0.0
 2    7.1   23.6 TOTAL      5    C.0
 2   59.5  127.5
 2   42.5   76.5

 3     11     11      0      0
 3   54.9   88.1    0.0    0.0
 3    4.4   21.9 TOTAL     11    0.0
 3   59.5  110.5
 3   51.0   34.0

 4     14     14      0      0
 4   52.8   77.1    0.0    0.0
 4    8.3   23.9 TOTAL     14    0.0
 4   68.0  144.5
 4   42.5   51.0

 5      8      8      0      0
 5   60.6   88.2    0.0    0.0
 5    7.1   20.8 TOTAL      8    0.0
 5   68.0  119.0
 5   51.0   59.5

 6     11     11      0      0
 6   58.0   86.5    0.0    0.0
 6    8.3   23.7 TOTAL     11    0.0
 6   76.5  136.0
 6   51.0   51.0

 7      4      4      0      0
 7   72.3  110.5    0.0    0.0
 7   17.7   34.7 TOTAL      4    0.0
 7   93.5  136.0
 7   51.0   59.5

 8      2      2      0      0
 8   80.8  136.0    0.0    0.0
 8   30.1   12.0 TOTAL      2    0.0
 8  102.0  144.5
 8   59.5  127.5
```

PROGRAM E

```
PERIOD FROM  1  5 67 TO 30  9 67

COL     1      2      3      4      5      6      7      8      9     10     11     12     13     14     15     16     17     18

AGE

 0      5      4      4      4      4      5      5      5      5      3      3      3      2      2      2      2      2      2
 0    1.5    1.5    0.0    1.0    7.0    5.5    6.0    6.0    3.7    3.7    5.0    4.0   12.0    9.5    6.0    6.0   50.0    1.0
 0    0.7    0.7    0.0    0.0    1.4    0.7    1.4    1.4    0.6    0.6    3.0    2.6    1.4    0.7    1.4    1.4 TOTAL      7
 0    2.0    2.0    0.0    1.0    8.0    6.C    7.0    7.0    4.0    4.0    8.0    7.0   13.0   10.0    7.0    7.0
 0    1.0    1.0   19.9    1.0    6.0    5.0    5.0    5.0    3.0    3.0    2.0    2.0   11.0    9.0    5.0    5.0

 1      8      8      8      8      8      8      8      8      8      1      1      1      1      1      1      1      1      1
 1    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0  100.0    1.0
 1    0.0    0.0    0.0    0.0    0.0    0.0    0.C    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0 TOTAL      9
 1    2.0    0.0    1.0    0.0    6.0    4.0    4.0    3.0    5.0    4.0    2.0    2.0   14.0   12.0    7.0    7.0
 1    2.0   19.9    1.0   19.9    6.0    4.0    4.0    3.0    5.0    4.0    2.0    2.0   14.0   12.0    7.0    7.0

 2      7      5      5      5      5      7      7      7      7      2      2      2      0      0      0      0      0      0
 2    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    3.0    3.0    2.0    2.0    0.0    0.0    0.0    0.0    0.0    0.0
 2    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    1.4    1.4    0.0    0.0    0.0    0.0    0.0    0.0 TOTAL      7
 2    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    4.0    4.0    2.0    2.0    0.0    0.0    0.0    0.0
 2   19.9   19.9   19.9   19.9   19.9   19.9   19.9   19.9    2.0    2.0    2.0    2.0   19.9   19.9   19.9   19.9

 3      4      2      2      2      2      4      4      4      4      2      2      2      0      0      0      0      0      0
 3    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    3.5    3.0    6.0    5.0    0.0    0.0    0.0    0.0    0.0    0.0
 3    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.7    1.4    5.7    4.2    0.0    0.0    0.0    0.0 TOTAL      4
 3    0.0    0.0    0.0    1.0    0.0    0.0    0.0    0.0    4.0    4.0   10.0    8.0    0.0    0.0    0.0    0.0
 3   19.9   19.9   19.9    1.0   19.9   19.9   19.9   19.9    3.0    2.0    2.0    2.0   19.9   19.9   19.9   19.9

 4     11     12     12     12     12     10     10     12     12      4      4      4      6      6      4      4      4      4
 4    1.8    2.8    1.0    0.0    6.5    4.8    5.0    5.0    4.5    4.5    3.0    2.8   10.8    9.8    6.8    6.3   75.0    1.0
 4    1.0    1.7    0.0    0.0    2.0    1.2    1.2    1.2    1.7    1.7    1.4    1.3    1.2    1.5    1.9    1.7 TOTAL     16
 4    3.0    5.0    1.0    0.0   10.0    6.0    6.0    6.0    6.0    7.0    4.0    4.0   13.0   11.0    8.0    8.0
 4    1.0    1.0    1.0   19.9    5.0    3.0    3.0    3.0    2.0    3.0    1.0    1.0   10.0    8.0    4.0    4.0

 5      5     15     15     14     14      5      5     11     11      1      2      2     11     11      5      5      5      5
 5    2.5    1.8    0.0    0.0    6.3    5.1    4.8    4.1    0.0    0.0    2.0    2.0   10.5    9.5    8.6    6.2   60.0    1.0
 5    1.6    1.6    0.0    0.0    2.1    1.9    1.7    1.4    0.0    0.0    1.4    1.4    2.2    2.4    2.1    1.3 TOTAL     16
 5    5.0    5.0    1.0    0.0   10.0    9.0    7.0    6.0    5.0    4.0    3.0    3.0   13.0   14.0   12.0    8.0
 5    1.0    1.0    1.0   19.9    3.0    3.0    3.0    2.0    5.0    4.0    1.0    1.0    6.0    5.0    7.0    5.0

 6      6     31     31     30     30      5      5     20     20      2      3      3     28     28     13     13     13     13
 6    1.7    1.8    0.0    1.5    5.3    4.5    4.6    3.8    3.0    3.0    4.7    3.3   11.3    9.4    7.2    6.4   84.6    1.0
 6    1.1    1.1    0.0    0.7    2.1    1.8    2.0    1.6    2.8    2.8    3.5    2.5    1.2    1.4    1.3    1.1 TOTAL     33
 6    5.0    5.0    1.0    2.0   10.0    9.0    9.0    8.0    5.0    5.0    8.0    6.0   14.0   13.0   10.0    9.0
 6    1.0    1.0    1.0    1.0    1.0    1.0    1.0    1.0    1.0    1.0    1.0    1.0    9.0    7.0    5.0    5.0

 7      8     39     39     39     39      6      6     14     14      3      3      3     36     36     28     28     28     28
 7    1.9    1.5    0.0    0.0    5.6    4.3    4.6    4.0    3.3    2.7    3.0    2.7   11.4    9.4    7.3    6.3   85.7    1.1
 7    1.0    0.8    0.0    0.0    2.2    1.7    1.8    1.8    1.5    0.6    2.0    1.5    1.4    1.5    1.8    1.2 TOTAL     42
 7    4.0    4.0    2.0    1.0   11.0    9.0   10.0   10.0    5.0    3.0    5.0    4.0   15.0   12.0   13.0    9.0
 7    1.0    1.0    2.0    1.0    2.0    2.0    2.0    2.0    2.0    2.0    1.0    1.0    9.0    5.0    4.0    4.0

 8      7     60     60     60     60      6      6     16     16      4      4      4     58     58     48     48     48     48
 8    2.2    1.7    0.0    1.0    5.5    4.3    4.8    4.1    3.5    3.3    5.5    4.8   11.8    9.8    7.1    6.0   77.1    1.1
 8    1.2    1.0    0.0    0.0    2.2    1.7    1.9    1.6    1.9    1.5    2.9    1.9    1.6    1.5    1.4    1.2 TOTAL     64
 8    6.0    4.0    1.0    1.0   11.0   10.0   11.0   10.0    6.0    5.0    9.0    6.0   15.0   14.0   11.0    9.0
 8    1.0    1.0    1.0    1.0    2.0    2.0    1.0    1.0    2.0    2.0    2.0    2.0    8.0    6.0    4.0    3.0
```

CLASS	NT	SP	NB	PCRB	PCREP
0	5	42.9	2	0.0	0.0
1	2	25.0	1	0.0	0.0
2	2	0.0	0	0.0	0.0
3	2	36.4	0	0.0	0.0
4	9	52.4	6	0.0	0.0
5	12	58.5	11	0.0	0.0
6	29	84.8	28	0.0	0.0
7	37	85.7	36	0.0	0.0
8	61	91.2	58	5.2	4.7
9	53	94.0	54	1.9	1.7
10	64	97.2	65	0.0	0.0
11	44	97.4	45	4.4	4.3
12	33	103.6	35	0.0	0.0
13	23	92.1	24	0.0	0.0
14	15	81.3	13	7.7	6.2
15	17	95.2	16	0.0	0.0
16	4	100.0	4	0.0	0.0
17	2	100.0	2	50.0	50.0
18	2	150.0	3	0.0	0.0
19	0	100.0	0	0.0	0.0
20	3	100.0	4	0.0	0.0
21	4	100.0	4	0.0	0.0
22	0	0.0	0	0.0	0.0
23	0	0.0	0	0.0	0.0

PROGRAM F

```
/input
/include sim13
/data
/include pcd
/include fx1
/include px1
/endrun
*IN PROGRESS
MAIN    = 0017CA BYTES
LAST LOC USED 004B17
EXECUTION BEGINS     2.3S
*ENTER DATA.
41 80000

EIGENVALUE=   1.00293  ITERATIONS=66

TOTAL STABLE POPULATION= 102353.

PERCENTAGE AGE DISTRIBUTION
 15.81 12.92 10.95  9.28  7.87  6.67  5.65  4.79  4.06  3.44
  2.92  2.47  2.09  1.77  1.50  1.27  1.08  0.92  0.78  0.66
  0.56  0.47  0.40  0.34  0.29  0.24  0.21  0.18  0.14  0.10
  0.07  0.05  0.03  0.02  0.01  0.00  0.00  0.00  0.00  0.00
  0.00
STOP         0
*END

*GO
/off
*GOOD-BYE
```

APPENDIX C

Card Layouts

PROGRAM A

Card Type Number in deck	Column Number	Format	Data
(1)		(See App. A, Prog. A)	Program Deck
(2)	1-4	I4	Number of grid locations
	5-8	I4	Number of data cards
	9-12	I4	Number of date periods
(3)	"MINIMUM BIOLOGICAL DATA" CARD		
	1-2	I2	Data type
	3-5	I3	General location
	6-11	I6	Day, Month, Year of collection
	12-13	I2	Species
	14-17	I4	Field specimen number
	18-21	I4	Grid location (easting-northing)
	22	I2	Hunt type
	23-28	I6	Hunter identification number
	29	I1	Sex
	30-31	I2	Age
	32	I1	Age particulars
	33	I1	Embryo or foetus present
(4)	1-3	I3	Card number (used for hand sorting)
	4-7	I4	Grid square (easting and northing)
	8-11	F4.2	Ice area (nautical square miles)
(5)	1-3	I3	Day at beginning of date period
	4-6	I3	Month at beginning of date period
	7-9	I3	Year at beginning of date period
	10-12	I3	Day at end of date period
	13-15	I3	Month at end of date period
	16-18	I3	Year at end of date period

PROGRAM B

Card Type Number in deck	Column Number	Format	Data
(1)		(See App. A, Prog. B)	Program Deck
(2)	1-2	I2	Number of age-frequency distributions
(3)	1-3) 4-6) etc.)	25I3	Number of seals in age class 0+ Number of seals in age class 1+ Etc.

PROGRAM C

Card Type Number in deck	Column Number	Format	Data
(1)		(See App. A, Prog. C)	Program Deck
(2)	1-3	I3	Number of data cards
	4-6	I3	Number of date periods
(3) "STANDARD BIOLOGICAL MEASUREMENTS" CARD			
	1-33		Same as on "Minimum Biological Data" Card
	34-36	I3	Nose-tail length cm
	37-39	I3	Maximum girth cm
	40-41	I2	Blubber thickness mm
	42-44	I3	Testis or mammary length cm
	45-47	I3	Testis or mammary width mm
	48-50	I3	Testis or mammary depth mm
	51-54	I4	Testis or mammary weight cm
	55-57	I3	Foetal length mm
	58	I1	Length particulars
	59-63	I5	Foetal weight g
	64-65	I2	Reproductive condition of uterus
	66-68	I3	Diameter of right uterine horn
	69-71	I3	Diameter of left uterine horn
	72-74	I3	Width of placental scar mm
	75	I1	Lactation (quantity)
	76-79	I4	Specimen body weight kg
	80	I1	Primary associated data forms
(4) (See card type (5) Program A)			

PROGRAM D

Card Type Number in deck	Column Number	Format	Data
(1)		(See App. A, Prog. D)	Program Deck
(2)	(See card type (2) Program C)		
(3)	"REPRODUCTIVE DATA" CARD		
	1-33		Same as on "Minimum Biological Data" Card
	32-35	F4.1	Testis tubule diameter (microns)
	36-37	I2	Percent sperm in testis tubules
	38-41	F4.1	Epididymis tubule diameter (microns)
	42-43	I2	Percent sperm in epididymis tubules
(4)	(See card type (5) Program A)		

PROGRAM D

Card Type Number in deck	Column Number	Format	Data
(1)		(See App. A, Prog. D)	Program Deck
(2)	(See card type (2) Program C)		
(3)	"REPRODUCTIVE DATA" CARD		
	1-33		Same as on "Minimum Biological Data" Card
	32-35	F4.1	Testis tubule diameter (microns)
	36-37	I2	Percent sperm in testis tubules
	38-41	F4.1	Epididymis tubule diameter (microns)
	42-43	I2	Percent sperm in epididymis tubules
(4)	(See card type (5) Program A)		

PROGRAM E

Card Type Number in deck	Column Number	Format	Data
(1)		(See App. A, Prog. E)	Program Deck
(2)	(See card type (2) Program C)		
(3)	"REPRODUCTIVE DATA" CARD		
	1-33		Same as on "Minimum Biological Data" Card
	44	I1	Number of follicles greater than 5 mm diameter in right ovary
	45-48	2I2	Two diameters (mm) of largest follicles
	49	I1	Numbers of follicles greater than 5 mm diameter in left ovary
	50-52	2I2	Two diameters (mm) of largest follicles
	54	I1	Corpus luteum (0 = none, 1 = right ovary, 2 = left ovary)
	55-58	2I2	Two diameters (mm) of corpus luteum
	59	I1	Recent corpus albicans (0 = none, 1 = right ovary, 2 = left ovary)
	60-63	2I2	Two diameters (mm) of corpus albicans
	64	I1	Number of corpora albicantia in the ovary pair
	65	I1	Embryo (0 = none, 1 = blastocyst, 2 = foetus)
	66-69	I4	Embryo size mm
	70	I1	Reproductive tract (0 = no information, 1 = nulli-, 2 = primi-, 3 = multiparous)
(4)	(See card type (5) Program A)		

PROGRAM F

```
/display pdd
*IN PROGRESS
0001  16911166 816 637 541 476 428 390 355 323
0002   294 267 245 225 209 196 182 169 156 143
0003   133 123 113 102  93  85  77  70  63  55
0004    47  37  28  19  13   7   4   2   1   1
0005     1
*END

*GO
/display fx1
*IN PROGRESS
0001                    26  36  46  56  66  77
0002  85  85  85  85  85  85  85  85  85  85
0003  85  85  85  85  85  85  85  85  85  85
0004  85  80  75  70  60  50  40  30  20  10
0005  0
*END

*GO
/display px1
*IN PROGRESS
0001  82  85  85  85  85  85  85  85  85  85
0002  85  85  85  85  85  85  85  85  85  85
0003  85  85  85  85  85  85  85  80  75  70
0004  65  60  55  50  45  40  35  30  20  10
*END

*GO
```