METHODS OF DETERMINING THE NUMBERS AND AVAILABILITY OF RINGED SEALS IN THE EASTERN CANADIAN ARCTIC

Ian A. McLaren*

Introduction

FOLLOWING upon studies of the life history of the ringed seal, *Phoca hispida* Schreber, its bionomics are being considered in order to develop a rational basis for exploitation. A preliminary report on the economics of seal hunting has been published previously (McLaren 1958), but was not written for wide distribution. A discussion of population ecology and sustainable hunting yield, which is central to the problem of exploitation, is given by McLaren (1961). The present paper is concerned with those methods that can be used in the field without collection of specimens. The work is by no means finished, and is presented here in the hope that readers whose activities take them to the north can make observations to help test and improve the accuracy of the estimates and methods. The pertinent observations are listed at the end of the paper, and it can be seen that most are neither difficult nor time consuming.

Census from shipboard

Most species of seals tend to congregate in geographically circumscribed areas, which facilitates direct assessment of numbers, either from the air (e.g., Surkov 1957) or from the ground (e.g., Bartholomew and Hubbs 1952). Unfortunately the ringed seal is not sociable and does not lie out on land, so that in summer population estimates must be made from counts of seals scattered in the open coastal waters. Sometimes it is possible to make complete counts of seals in some well-delimited body of water, but this is generally impractical. Large areas of water are best covered by some variant of the "strip-census" method.

Two published forms of strip census of marine mammals from ships under way have shortcomings. One method involves arbitrary estimate of the width of the census strip, within which all animals are presumed counted (Taylor *et al.* 1955), and the other attempts to include a correction for the decreasing probability that animals at greater distances will be

*Arctic Unit, Fisheries Research Board of Canada

seen (Mackintosh and Brown 1956). Neither accounts for the fact that sea mammals spend some of their time under water, where they may escape being seen from a moving ship. There is also, of course, a large literature on the strip census of terrestrial mammals and terrestrial and marine birds, but much of this is not pertinent for the same reason.

It is first necessary to determine the width of the strip, within which can be counted all or a calculable proportion of the animals actually present. The observer at sea is untroubled by many of the variables of terrain which plague the census-taker on land, but weather, sea conditions and eyesight all remain to influence the distance at which a seal can be seen. The present method is designed to standardize these influences. Firstly, since even slight ruffling of the sea surface makes visibility limited and variable, the census must be carried out in flat-calm weather, preferably when there is a bright, pearly overcast. On such days the heads of seals stand out against the uniformly light water, and visibility is almost wholly determined by the visual acuity of the observer. Secondly, the limit of visibility is determined by the observer himself at the time of the census by dropping floating objects the size of seals' heads over the stern and timing their disappearance in the ship's wake at known speeds. As a standard measure of visual acuity, black bars on a white background in bright light should be discriminated by normal eyes when the distance between the bars subtends an angle of about 30 seconds (Pirenne 1948). This suggests that a black disc, six inches in diameter, should not be visible against a white background in daylight much beyond a half mile. From determinations made under field conditions as described, it is believed that an object the size of a seal's head will only rarely be seen beyond a third of a mile.

The actual count of seals must be carried out from a ship or boat that is steadily under way; those that change speed or course frequently (as in seal hunting) are not suitable. The line of sight must be unobscured by ice or land to the limit of visibility. The observer must be diligent, but need not be experienced, as it takes no more skill to see a seal's head against a uniform background than to see a floating object used as a standard. Any aids (binoculars, assistants) can be used to help spot seals, as long as such seals can be seen by the observer himself with the naked eye. He should stand at the bow, or any place with unimpeded vision, and swing his line of sight steadily through 180° to cover all water ahead and abeam. Scanning should be sufficiently rapid so that no seals are missed when they surface briefly. The non-gregarious ringed seal is rarely common enough to cause confusion, but if the time, direction, and estimated distance are noted, an occasional "repeat" can be eliminated.

Having counted all the seals in a strip of water twice as wide as the limit of visibility, we can determine the theoretical number present as follows. (I am indebted to Dr. Joseph T. Armstrong for pointing out an error in an earlier discussion of the method and for formulating the proof given here.)

It can be seen from Fig. 1 that where r is the limit of visibility and v is the speed of the ship, then the length of time t that a point can be kept (continuously) under surveillance is:

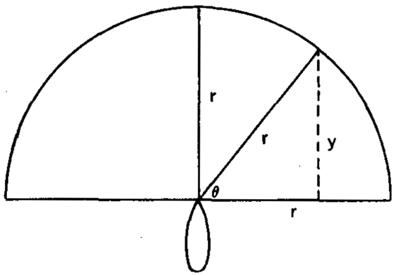

Fig. 1.

$$t = \frac{y}{v} = \frac{r \sin\theta}{v}$$

Now assume that the average seal is under water for u minutes and on the surface between dives for s minutes, and that no point can be kept under surveillance for as long as u minutes and that no seal is counted twice in any event (see above). Then the probability (p) of seeing a seal located at a given point under surveillance may be expressed as:

$$p = \frac{t}{s+u} + \frac{s}{s+u}$$

And, where t is the length of time a point can be kept under surveillance (above):

$$p = \frac{r \sin\theta}{v(s+u)} + \frac{s}{s+u}$$

Therefore the average probability ($\bar{p}$) is expressed as:

$$\bar{p} = \frac{1}{\frac{\pi}{2}-0} \int_0^{\frac{\pi}{2}} \left(\frac{r \sin\theta}{v(s+u)} + \frac{s}{s+u} \right) d\theta$$

$$= \frac{1}{\frac{\pi}{2}-0} \int_0^{\frac{\pi}{2}} \frac{r \sin\theta}{v(s+u)} d\theta + \frac{1}{\frac{\pi}{2}-0} \int_0^{\frac{\pi}{2}} \frac{s}{s+u} d\theta$$

$$\bar{p} = \frac{2r}{v(s+u)\pi} + \frac{s}{s+u} \qquad (1)$$

Now, where N_o is the number of seals counted in the census strip and N_t the theoretical number present, then:

$$N_t = \frac{N_o}{\bar{p}} \tag{2}$$

Numerical example: Along the south coast of Frobisher Bay, 43 ringed seals were counted in a known area (distance travelled times twice the limit of visibility). When the ship's speed was 0.12 nautical miles per minute, the limit of visibility for the observer was determined at 0.32 miles, and the average seal was estimated to be on the surface for 1 minute and below for 3, then the theoretical number would be:

$$\bar{p} = \frac{2 \cdot 0.32}{0.12(3+1)3.14} + \frac{1}{3+1}$$

$$= 0.68$$

$$N_t = \frac{43}{0.68}$$

$$= 63 \text{ seals.}$$

There are certain assumptions underlying this method which may influence the accuracy of the estimates, and which therefore deserve brief consideration here.

First of all it may be seen that the limit of visibility, and the times spent by seals below and on the surface are all applied in the formula as averages, but these must be rather variable. Large seals will be visible farther than average seals and small ones not as far, and it can be shown that the result of this will be a slight overestimate (by a few per cent) when the approximate range of size of the ringed seal is taken into account. A variable time spent on the surface introduces a slight underestimate, which is to some extent cancelled by the effect of a variable time spent under water, when average figures are used for these times. All in all, it is believed that the bias introduced by these assumptions is not serious, and could not be eliminated without a very cumbersome formulation.

Secondly, no attempt is made to attach a variance to the estimate of seal numbers, although this will be affected by the distribution patterns of the seals. The probability that a census will be unrepresentative is smallest when the seals are *evenly* distributed, larger when they are *randomly* distributed, and largest when they are *clustered*. The ringed seal is not sociable, although individuals may group in particularly favourable areas — to feed where there is upwelling, for instance. Of course censuses may be used to detect just such concentrations, but as with any method that can be devised, the more numerous the local areas are that can be covered, the more accurate are the population estimates over wider areas.

Thirdly, we have not considered the possible effect of the presence of the ship on the behaviour of the seals. It is well known that seals, especially young ones, may be attracted by a boat. Eskimos will often stop the boat to entice the seals closer for a rifle shot. Whether a ship steadily under way will be as attractive is questionable. It is very unlikely that seals will be able to converge into the path of a ship travelling at more than a few knots, but it might be argued that seals that are already sufficiently close to the course will be encouraged to surface prematurely when the ship passes. The problem is somewhat like the "flushing-distance" effect in censusing birds (Hayne 1949), although its formulation will have to be accommodated to the fact that seals will come to the surface ultimately whether "flushed" or not. Some insight may be gained into the possible significance of this effect from hypothetical examples. It can be shown that since seals closest to the ship are most likely to be influenced, the correction, if any, will be smallest when the distance travelled by the ship during an average seal's dive is about equal to the limit of visibility. Let us assume that all seals within 100 yards of the ship are caused to surface, that 50 per cent of those between 100 and 200 yards surface prematurely, and that no seal beyond 200 yards pays any attention. In the numerical example of the census method given earlier, this marked effect on seal behaviour would result in an overestimate of the population of only about 4 per cent. However, if the ship in that example had been travelling twice as fast (almost 15 knots), the estimate would have been about 20 per cent too high. It seems unlikely that corrections as high as these hypothetical ones would apply. A fast-moving ship is unlikely to give much time for seals to react, even if they are disturbed by its presence. The author has noted in carrying out censuses that seals that appear well ahead on the ship's track rarely reappear to be counted close at hand, and that seals are often spotted first when they are well astern, even in the ship's wake, where they would not be counted by the present census method.

The census method outlined here should give figures in absolute densities, but results to date appear to be underestimates in the light of other information. None of the assumptions analysed above would seem to be a source of important error, and most of them would result in slight overestimates at any rate. The method would probably profit most from further data on two important variables in equation (1) — the average times spent by seals under water and on the surface in different depths and conditions of water.

Numbers of seals based on fast-ice areas

There is ample evidence (see McLaren 1961) that ringed seal populations in regions where they are not being overexploited are not limited by food or density-dependent mortality, but by conditions of the land-fast ice. The amount and quality of fast ice determine the number of suitable "sites" for the construction of birth lairs in the ice and snow. The successful rearing of pups and even pregnancy rates are conditioned by population density. Therefore a given coastline, with an annually constant formation of fast ice, will impose an upper size limit and a stable age-distribution on the resident seal population.

Although local weather, river outflow, tides, and other factors may be effective, the most important determinant of the amount and quality of fast ice and its snow cover is the degree of coastal complexity. The most stable fast ice with the greatest snow cover is found in bays, fiords, and in island-filled regions. We might expect the number of sites suitable for birth lairs on the ice to be a function (not necessarily linear) of distance from shore. A large series of complete counts of such lairs on ice of different conditions might be the best basis for estimating the total population represented by a coastline. This is probably not possible, since the lairs are hidden and difficult to find.

In the meanwhile, another partly deductive method has been developed. The ringed seal does not as a rule lie out on pack ice. There is reason to believe that almost the entire population can be counted on the fast ice which remains at the peak of the basking season in the late spring; both the resident adults, which lie out increasingly in the waxing sun, and the immatures, which have come in from a winter spent in the open water, are present at this time. The seasonal and geographic variations in the numbers of seals basking on the ice must be considered. Counts made in Frobisher Bay best illustrate the seasonal progression, and information from other localities suggests that the time of the peak varies almost directly with latitude (see Fig. 2).

The few suitable observations available at present (from southwest Baffin Island, Frobisher Bay, Ellesmere Island) suggest that the best ice for breeding purposes will have at least 35 seals per square mile basking on it in spring. This would be equivalent to about 7 suitable sites for birth lairs, as deduced from life tables (McLaren 1961). But, as Ellis (1957) has pointed out, seal breathing holes and birth lairs are generally scattered throughout smaller and narrower bays, whereas they occur within a mile or so of shore on more open coastlines. This pattern is of course related to the suitability of fast ice for the construction of birth lairs. Also, by the time peak counts are made much of the unstable, offshore fast ice has been converted to pack ice, giving up its basking seals to the ice remaining attached to shore. For these reasons the figure of 35 seals per square mile is presumed to apply only to ice within 1 mile of shore and greater than 1 mile from the open water. Unfortunately, there are only pre-peak counts of seals from less suitable ice, but for the present two other classes of ice have been defined. Ice close to shore on open coasts or around the peripheral islands of more complex coasts — precisely, ice within 1 mile of shore *and* within 1 mile of open water — is believed to represent about 10 seals per square mile. For ice greater than 1 mile offshore, we suggest a figure of 5 per square mile. Fast ice does not generally form much beyond the outermost capes and skerries of a coast, and where it does it is probably too unstable and poorly covered with snow to be used by reproducing seals, and is usually broken off by the time peak counts are made. For these reasons, areas outside the straight lines joining the outermost points of a coast are treated as open water. The principles of this method are illustrated in Fig. 3.

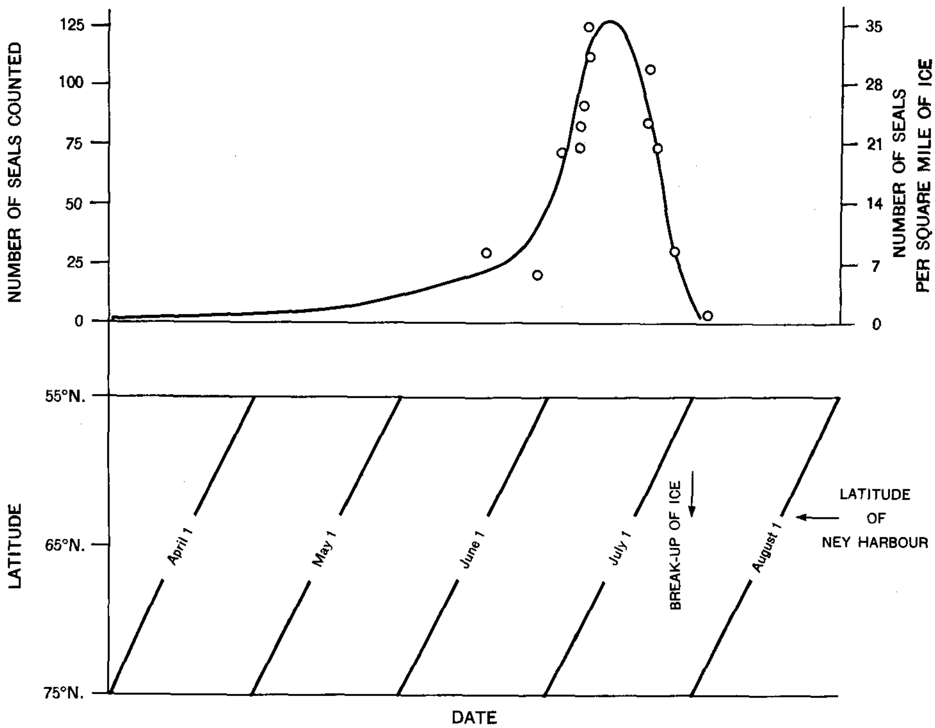

Fig. 2. The progression and peak of numbers of seals basking on the fast ice of Ney Harbour, Frobisher Bay, in 1957. The same form of curve is presumed to apply throughout the range of the ringed seal, and the best estimate of the effect of latitude is shown in the lower part of the graph, implying that, for example, the season is roughly a month earlier in southern Hudson Bay than in northern Baffin Island.

Using these criteria, fast-ice areas have been measured planimetrically and population estimates derived for the eastern Canadian Arctic south of Lancaster Sound. There are complications in other areas (including the totally ice-locked central Arctic), which have not yet been resolved.

It can be seen that the results are at present based on few observations. Nevertheless, the deductive element — that ice closer to shore is overwhelmingly important — probably gives the figures relative if not absolute validity. There is no doubt that the method itself will have to be made more exact and probably more complex, and this can best be done if more counts of seals on the fast ice are available from as many areas as possible.

Availability of seals

Except very locally, the ringed seal stocks of the eastern Arctic do not appear to be over-utilized at present, and the economic problem appears to be availability of seals in most regions. The number of seals inhabiting a coast determines the sustainable yield (not dealt with in this paper), but does not necessarily reflect their availability to the hunter. Availability, for any given set of conditions and method of hunting, is directly related to seal density, which is in turn a function of both population size and the area in which the population is dispersed.

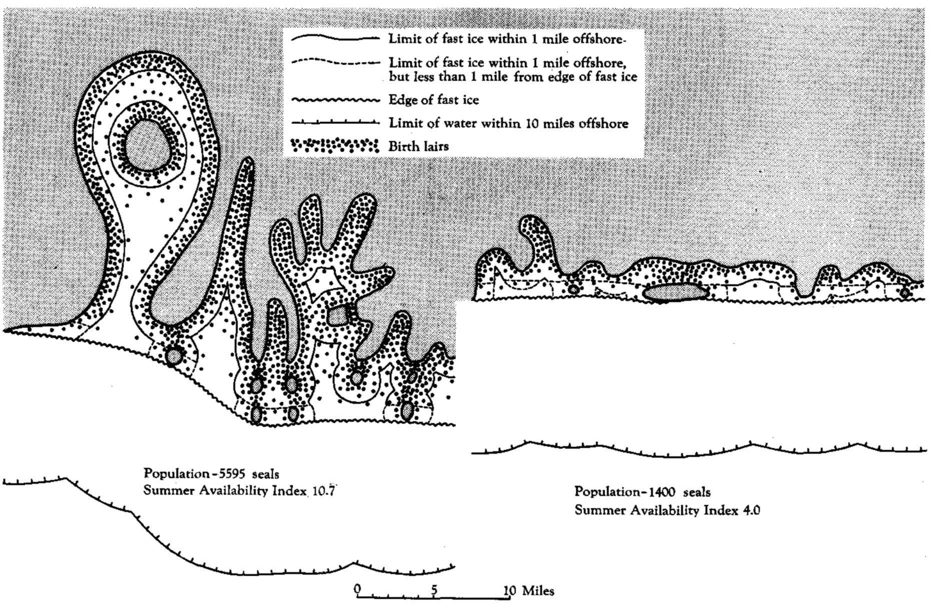

Fig. 3. The theoretical population of ringed seals based on the amount and quality of fast ice assumed to form on two hypothetical coastlines. The density of birth lairs on a given area of fast ice is shown in direct proportion to the number of seals presumed to be represented by that ice (about 1 birth lair per 5 seals). See text for further details.

The Eskimos do some of their hunting from boats in the open-water season. The ringed seal is essentially a coastal species, dispersing along shores but not very far offshore. If we can presume that its tendency to move offshore is the same on all coasts, then a very simple index of availability can be derived by dividing the theoretical, ice-based population size of a region by the area of water within a suitable distance of shore. This does not deny the possibility of local concentrations, as long as these bear no regular relationship to distance from shore, but is meant to apply to large sections of coast. We may examine the results of such a method by reference to Fig. 3. If we divide the populations of these imaginary coasts by the area of water within 15 miles of shore, then the availability of seals on the complex coast relative to the simple coast is 3.0 to 1; divided by water within 10 miles of shore, it is 2.7 to 1; using the area within 5 miles of shore, it is 2.0 to 1. More information is needed on the patterns of distribution of seals in summer, but it is at present believed that a limit of offshore dispersal of about 10 miles is reasonable. The indexes of availability thus derived agree quite well with the results of shipboard censuses and information on hunting conditions.

Other seasons and circumstances may be similarly treated. The availability of immature seals hunted in the open water off the ice edge in winter should follow the summer availability quite well. There are complications in that more immature seals, which would normally move to areas of open water, tend to be trapped and forced to winter under the extensive and rapidly forming ice of complex coasts; although this effect can be formulated, it may be too cumbersome for the minor correction it introduces. From the discussion of numbers of seals it will be clear that equivalent fast ice in different regions is expected to support equivalent seal populations, so that the Eskimo who hunts at the breathing holes of seals should have comparable success throughout the ringed seal's range. Likewise the hunter who stalks seals during their short season on the spring ice should experience everywhere the same progression and peak of seal numbers, although the timing of the season will vary (see Fig. 2). Again, indexes of availability can be derived by dividing the populations of seals by the areas of ice or water in which they are dispersed. The densities of seals are sure to vary locally, but the indexes should be applicable over wide areas, and besides we can expect that the Eskimos of different regions will take similar advantage of local concentrations wherever they occur.

Although with refinement these indexes should give average densities of seals in actual numbers per square mile, they are still abstractions of availability and must be converted to catches per unit of effort. This has been done empirically using the results of day-long hunting trips carried out seriously in ideal weather in several regions of the eastern Arctic. The results indicate, for example, that a powered craft of whaleboat size hunting on the simulated complex coast of Fig. 3 might expect killing on an average 3.6 ringed seals per day, while a boat similarly engaged on the less hospitable open coast would produce only 1.4 seals. In the spring, this difference between the coasts would not be apparent to the hunter on the ice. Two weeks before the peak of the basking season, the hunter on either coast might expect to kill an average of about 2.8 seals per day, but he might expect 6.8 seals for his day's effort at the height of the basking season. At present we rely on data from 16 hunts at the ice edge in winter, 22 hunts on the spring ice, and about 75 trips in all types of boats in summer.

Though there are many other factors (including local depletion, hunting initiative) that will affect the expectations of hunters, only two modifications seem quantitatively definable at present. The estimates of catch per unit of effort are in fact based on kill, but there is an important loss by sinking when seals are shot in the water, most serious just after the ice breaks up. Fig. 4 outlines our best present estimate of this loss in terms of the three dimensions of date (since sinking is due mainly to seasonal blubber variation), latitude (since blubber loss is related to the basking and fasting season, as outlined on Fig. 2), and seawater density (since the buoyancy of seals is directly related). Unfortunately, there are few empirical data relating sinking loss to seawater density, and this part of the graph is based on seasonal variations in amount of blubber and on considerations of specific gravities.

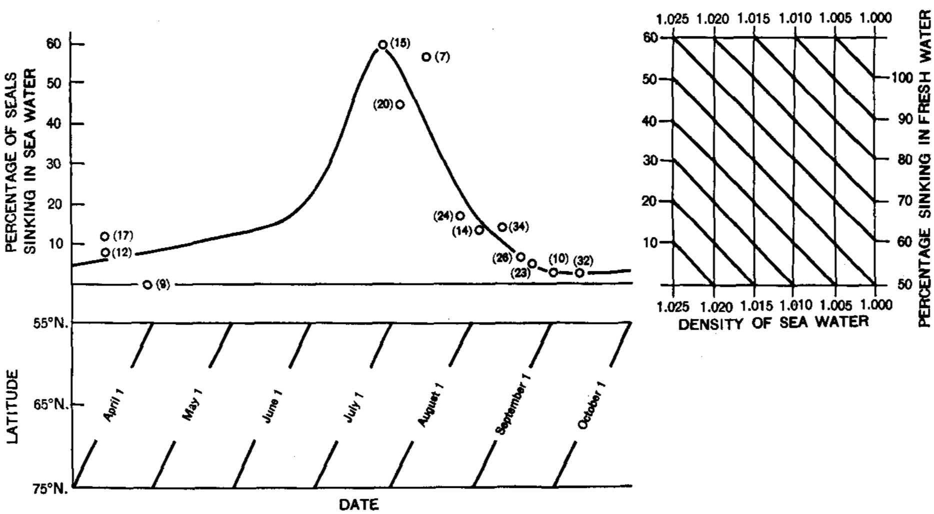

Fig. 4. The best present estimate of the loss of seals by sinking, in terms of date, latitude, and seawater density. Each point on the graph is the mean of dates and percentages lost of a bi-weekly sample in one of several localities of the Eastern Arctic. The shape of the curve prior to the peak was determined by consideration of the basking and fasting season, which underlies the loss of blubber and the tendency to sink.

The second major calculable modification is the weather. All our figures on catches per unit effort are based on hunting in ideal, or nearly ideal, weather. Hunting seals at their breathing holes is restricted for technical reasons to days of complete calm or very little wind, and onshore winds will generally choke the open water at the fast-ice edge with pack ice, making hunting there impossible. In spring, the numbers of seals on the ice may be affected by temperature, wind, and sunshine, although the seals tend to ignore the weather more as the season progresses towards break-up. In summer the wind is all important and makes hunting from boats unprofitable in all but the most sheltered waters. It should be possible to determine the probability of occurrence of suitable weather for a given type of hunting for any time of year and locality. Weather records are being examined and it is hoped, for example, that isopleths of the expectations of calm and near-calm days in various seasons can be plotted for the regions concerned.

In closing, we may summarize the features of availability that have been discussed with a didactic equation, which will also pose further questions. In this equation W_d is the day-by-day probability of suitable weather for a given type of hunting, S_d is the proportion of seals expected to sink if killed in the water on that date, I_d is the theoretical ice-based availability index for the coast, and K_d is a constant, specific for each form of hunting, that will convert the availability index to kill per hunter per day. Where, as seems generally to be true, the Eskimos are not over-utilizing the stock, and when we presume that the most productive form of hunting will be pursued on a given date, then C is the potential number of seals that may be taken annually by a hunter of that region.

$$C = \sum_{d=1}^{365} W_d(1+S_d)K_dI_d \qquad (3)$$

When his annual catch is less than C, this gives a measure of unexploited economic potential, or perhaps of his initiative. This equation can also give some insight into possible means of improving such a hunting economy. Nothing, of course, can be done about W_d, the weather. The ringed seal, unlike some other sea mammals, can rarely be pursued into sufficiently shallow water where, if it sinks, it can be hooked from the bottom. Also, although harpoon guns have often been suggested as a means of reducing sinking loss, anyone who has hunted ringed seals knows that such weapons would be almost wholly impractical for this small species. For these reasons it appears that S_d cannot be directly reduced. The availability index, I_d, is geographically determined, and again not subject to modification. There is only one variable in equation (3) through which C can be increased by human agency, that is K_d, which might be considered as a measure of the technological advantages enjoyed by the hunter.

It should also be pointed out that not all the variables apply to some forms of hunting. The best example of this is the use of seal nets. Nets, if well placed, should be unaffected by weather (W_d) and there should be no sinking loss (S_d). Although the K_d of nets is very low, they should be of great value in regions where the weather is bad in summer, or where the surface salinities are low and result in excessive sinking. This was shown quite well by netting experiments in the Belcher Islands, southern Hudson Bay, in the summer of 1960 (McLaren and Mansfield 1960).

This equation can be manipulated in several other ways. For example, if utilization of the region's seal population can be extended to the level of maximum sustainable yield (which is a usual aim of subsistence economies), then improvement will lie partly in harvesting this yield with minimum waste and maximum efficiency. The time of year when C is highest, the smallest values of S_d, and the least expensive means of raising K_d all certainly enter into such improvement. However, much of the problem at this point is non-biological and becomes the concern of the technologist, economist, and sociologist.

Summary of desirable field observations

Observations and ways of making them are listed here in the hope that travellers and residents in the Canadian Arctic will contribute to our understanding of the ringed seal as an important resource. Information should be sent to:

Fisheries Research Board of Canada
Arctic Unit
505 Pine Ave. West
Montreal 18, P.Q.

Readers wishing to know more about seals can obtain a guide (Mansfield 1961) as an aid to identification from this office.

1) Summer census of seals in the water. Only observations from ships or boats steadily under way at known speed on flat-calm days are suitable. The limit of visibility is determined by the census-taker by dropping floating objects the size of seals' heads over the stern and timing their disappearance in the ship's wake. The observer diligently counts all seals seen within 180° ahead and abeam. As long as he can see the seals with the naked eye, the observer may use any aids actually to spot them (assistants, binoculars). The times, positions, and estimated distances of the observed seal heads should be noted if there is danger of counting the same seal twice. (See also discussion of method in the text).

2) Times spent by seals under water and on the surface. If undisturbed seals can be observed from land or boats (preferably with power off), the times of successive dives and surfacings can be noted. The most useful information would include depth of water, even crudely as "deep fiord", "shallow bay", "well offshore", etc.

3) Counts of seals on the fast ice. Seals can readily be seen from high vantage points over wide areas of ice, especially with binoculars. Only areas which are not obscured by glare, haze, and distance should be censused. The date, place, temperature, wind, and cloudiness (the last three need be only approximate) should be noted. Since the number of seals will vary with the class of ice, the ice on which the seals are counted should be outlined on a large-scale map, or a sketch-map made. It would be helpful if at least an impression of the distribution of seals on different parts of the mapped ice could be given. Of most value would be a series of counts carried out on the same area of fast ice through the entire basking season to break-up (as in Fig. 2 of this paper). The results would be doubly valuable where the seals are undisturbed by hunting.

4) Break-up of ice. Observations on the time of break-up (departure of fast ice from the heads of bays) would complement observations of seal numbers on the ice.

5) Catches per unit of effort. Many reports on hunting conditions in the Arctic fail to distinguish between actual seal abundance and problems of weather, sociology, etc. Information is needed on the number of seals which can be killed (including those that sink) per unit time by serious hunters using various methods, during different seasons, in as many regions of the Arctic as possible. The requirements of these records are as follows: A. The hunts must be carried out in ideal weather for the form of hunting (calm or near calm for boats, in summer, sunny and not too windy or unseasonably cold for hunting on the spring ice, etc.). B. The hunters must be serious and unhampered (not hunting incidentally when travelling or when short of ammunition, for example). C. The technical nature of the hunting must be noted in the following categories (the observer may think of others or qualify these): hunting at the ice edge in winter or spring (with date); hunting on the fast ice in spring (with date, and whether on foot or with dogs); hunting at breathing holes in winter (with date); hunting from boats in the open-water season (date, type of boat, numbers of hunters per boat). D. The amount of actual hunting effort in hours or at least rough fractions of a day must be given.

6) Sinking losses. This information must be included in reports of catch per unit of effort (above). The requirements are date, region of hunting, numbers killed, and numbers lost. If at all possible some impression of the salinity of the sea water should be gained. Sometimes local geography (well offshore, at mouth of river, etc.) will give an indication of salinity, but tightly sealed surface samples are best of all and will be analysed by this office.

7) Weather records. All available records from arctic and subarctic weather stations are being examined, but pertinent observations from other coastal regions would be welcome. Formal synoptic data will be analysed, but the easiest and most valuable observations would be on the occurrence of periods of calm or light variable winds (Beaufort Scale 0-1) for durations of at least half a day. Such days can be noted at sea when the surface is oily-smooth or only ruffled in patches.

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