COMMUNITY RELATIONSHIPS AND POPULATION DYNAMICS OF TERRESTRIAL MAMMALS OF ISLE ROYALE, LAKE SUPERIOR*

Second Annual Report

(Covering the tenth year in the Isle Royale studies)

1967-68

by

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MAMMAL POPULATIONS OF ISLE ROYALE

At the inception of these studies in 1858, it was postulated that work featuring such long-lived animals as the moose and wolf would need to be of a long-term nature. An initial 10-year period seemed minimal for gathering the records necessary to demonstrate conclusively the dynamics of predator-prey relationships under these conditions. It was evident also that time would be needed for studies of the populations of smaller mammals. Following is a summary of the four phases of the program and personnel (aside from the director) who carried the burden of the field research.

Phase 1.	Ecology of the timber wolf. June 1958 to June 1962	L. David Mech (Grad. Stud.)
Phase 2.	Beaver-moose-wolf relationships June 1960 to June 1963	Philip C. Shelton (Grad. Stud.)
Phase 3.	Ecology and coactions of the moose August 1963 to August 1966	Peter A. Jordan (post-doctoral)
Phase 4.	Community relationships of mammals September 1965 to present February 1967 to present	Wendel J. Johnson (Grad. Stud.) Michael L. Wolfe, Jr., (post-doctoral)

The segment of the program now in progress will continue, at least, through June 1969, at which time an extension of certain more specialized aspects will be considered if funding is available.

According to the present division of labor, Wolfe is concentrating on the wolf-moose studies as a post-doctoral project, and Johnson is studying the fox and its food linkage (primarily the snowshoe hare, red squirrel, and woodmouse) as the subject of his doctoral thesis. This report is organized accordingly.

Periods of field activity followed closely the pattern of former years. Wolfe and Johnson were on the island from the second week in May to the end of October. From early June until the end of August they were assisted by undergraduates John A. Coble and John C. Keeler. The winter camp was opened on 30 January and closed 17 March. Wolfe was in the field for the entire seven weeks, and Allen and Johnson left on 2 March.

Our winter pilot, Donald E. Murray, served the project with his usual efficiency for the tenth consecutive year. William J. Martila again piloted the field plane for the fall moose survey and made the connecting flights (Cessna 180) from Eveleth, Minnesota to the island during the winter period. Staff members of Isle Royale National Park who participated in the winter study were,

successively, Alvin E. Olson, Zeb V. McKinney, Bruce J. Miller (Superintendent), Warner M. Forsell, and Richard W. Igo. C. Newton Sikes, of Grand Portage National Monument, followed Olson for a period on the island.

Winter Conditions, 1968

Weather during February and March was sufficiently exceptional and unfavorable as to require particular comment. It impeded work with the aircraft and had a profound influence on the distribution and habits of moose and wolves and probably foxes. Such a combination of conditions has not been seen in any previous winter period of this study.

Winds upwards of 25 mph were not uncommon, precluding low-level flying on otherwise ideal days. This is reflected in the total hours flown (140), which is well below the average for other winters. The snow accumulation on the ground also was subnormal. Depth at the time of the arrival of the field party on 30 January was 9.3 inches-- about 2 feet is usual for this date. Only two significant snowfalls occurred during February and the first two weeks of March, producing a maximum average measurement of 14.3 inches. By the second week in March warm weather had melted much of the residual snow cover exposing large areas of ridgetops and south-facing slopes. These conditions prompted termination of the winter study four days earlier than anticipated. Snow depth in the woods at Windigo on 17 March averaged 8.8 inches.

Mean daily minimum and maximum temperatures recorded at Windigo for the 6 weeks and 5 days of the winter period were $+4.9^{\circ}$ F and $+26^{\circ}$ F, respectively. These figures are 7-10 degrees higher than those from the previous winter and confirm subjective impressions of a winter generally milder than the last.

At the time of our arrival, Lake Superior and the larger bays and harbors were largely ice-free. Shelf ice, particularly along the south shore, was poorly developed. By mid-February, ice was continuous to the Canadian mainland, but strong winds opened large leads of open water by the end of the month.

The high incidence of windy days reduced total flying hours and forced much of the flying to higher altitudes than the customary 300 feet. Fresh tracks were quickly filled and old frozen-in tracks were sometimes revealed. Since winds persisted on days following the few snowfalls, drifting conditions resulted, and the additional snow was of limited help.

In marked contrast to the situation in 1966 and 1967, wintering birds were plentiful on Isle Royale this year. That is, the usual pine siskin flocks were present, but redpolls were not recorded. Purple finches and red crossbills were seen frequently at Windigo, plus a few pine grosbeaks and evening grosbeaks. There was a single record of the black-backed three-toed woodpecker. It was evident that 1967 was a good fruit year. Birch seeds were abundant, as were cones

of spruce, balsam, and cedar. Mountain ash bore well, but the fruit was nearly gone by the end of January-- probably because of icing earlier in the winter.

Moose-Wolf Relationships

That the aberrant weather conditions of February-March had important biotic effects is not to be doubted. Patterns of animal distribution and behavior with which we were familiar in other years were considerably modified-- a situation having value in that it reveals the causative influences behind habits which tend to be taken for granted as "normal." Thus, what may be termed ground-level moose browse was much more available in the past winter, since less of it was buried in snow. Moose were feeding on balsam and other kinds of reproduction in areas where usually little is available at this season. This seems to have affected their distribution, bringing them more commonly into open and higher parts of the island. Footing for the wolves was reasonably good nearly everywhere, with the result that they did not use bays and lakes for travel to the extent observed in most other years. The small packs were exceedingly difficult to find in thick cover. They move less often than a large number (a kill lasts longer), and in the absence of new snow their signs are difficult to interpret.

Moose numbers

The stratified sampling procedure described in the last two annual reports was employed again in 1968 for the winter aerial moose census. In contrast to the past two winters, however, a distinct stratification of moose density was not discernible and the animals appeared more uniformly distributed over much of the island. It was thus impossible to distinguish four well defined strata of moose density. This necessitated a modification in the sampling procedure, and only two rather than four strata were used in the count. Even these were somewhat arbitrarily defined, although it is interesting to note that the variance computed for these two strata (.4010 and .9949, respectively) was less than that in all three of last winter's higher density strata. The results of the 1968 winter moose census are shown in Table 1.

Table 1. Winter aerial census of moose, 1968

Stratum	Area (sq. mi.)	Plots	Percent of stratum	Moose counted	Moose per sq. mi.	Total moose
1	98.03	26	11.4	25	2.26	222
2	114.72	44	13.5	103	6.91	793
I.R.	212.75	70	12.6	128	4.59	1015

At the 95 percent confidence limits the actual population would lie somewhere between 785 and 1245 moose. It is difficult to account for the discrepancy between the population estimate for 1968 of 1015 and that calculated in 1967 (530). As will be seen, moose productivity last summer was by no means exceptionally high. A graphic comparison of population estimates for the Isle Royale moose herd by the above and other census procedures in six different years is shown in Fig. 1. Indeed it is obvious that the 1967 and 1968 figures represent the lowest and highest estimates of the island's moose population.

Although the plots counted and the proportion of the island sampled were nearly identical in these counts, the number of moose seen was 35 percent greater this winter than last. In 1967 no moose were recorded in over 55 percent of the plots counted, while "blanks" comprised only 31 percent in the 1968 census. It was evident that a larger proportion of the "low density" plots were frequented by moose in the winter just past.

It appears that the fraction of moose missed in counting was low in 1968 and high in 1967. This can not be attributed to more favorable counting conditions this year, but rather to differences in moose distribution. The year 1967 was one of exceptionally deep snow-- generally 30 inches or more-- while in 1968 average snow depth was around a foot for much of the work period. Deep snow tends to restrict moose to the more heavily forested lowlands, and the past winter's observations leave no doubt that light snow cover and the wider availability of low-level browse result in a more general distribution of moose over the more-open and higher parts of the island. More animals were seen on exposed ridges, burns, and non-conifer cover than had been in the case for several years.

While not all variables are subject to reliable interpretation, we must conclude that the 1967 moose count was low owing to sighting limitations and the 1968 census probably is high-- the true figure probably lies below the mean and in the lower range of our calculated confidence limits.

Herd compositions; calf production and survival

Estimates of herd composition and current productivity were calculated directly from observed sex and age ratios. As noted in previous reports this method is subject to certain limitations resulting from differences in individual moose behavior. Perhaps the most important of these is the increasing mobility of calves in late summer, which introduces the possibility of some cows being classified as not accompanied by calves, when in fact the opposite is true. To reduce the possibility of this source of error 31 August was arbitrarily selected as the date after which observations made were not used in computing current productivity. During the period from 9 May through August a total of 257 moose were classified as to sex and age. The results of these observations are summarized in Table 2.

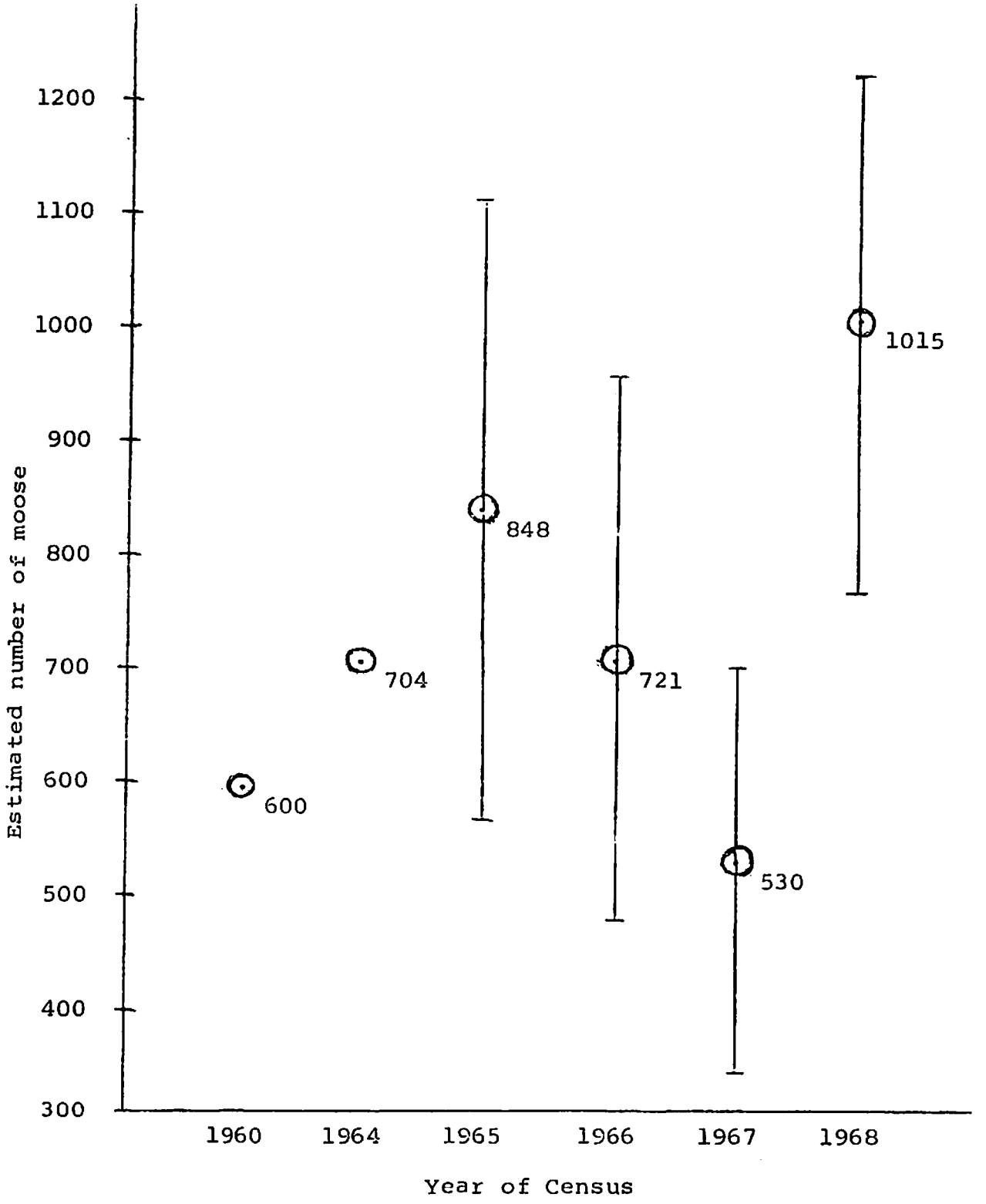

Fig. 1 Population estimates of the Isle Royale moose herd

N.B. The vertical lines represent the range defined by the 95 percent confidence limits.

Table 2. Summer moose observations, 1967

Males		Females					
Ad	Yrl*	Ad	Yrl*	Calves	Total	Cows w/ calves	Cows w/ twins
80	13	95	6	63	257	45	9

Sex ratio: 109ff/100mm
Calves per 100 adult ff: 66
Percent calves in total pop: 24.5

*Yearlings were classified as such on the basis of body size and build; males with "spike" antlers.

It is probable that the incidence (6.3 percent) of yearling, reproductively immature females is not represented adequately in the above sample. Therefore the reproductive rate of 66 calves per 100 adult females calculated from these figures must be considered conservative. Assuming the proportion of yearling females in the population to be equal to that of the yearling males (16 percent) probably provides a more realistic natality figure of 77 calves per 100 adult females.

Comparing this estimate with available data from the preceeding summer suggests that calf production was approximately 33 percent greater in 1967 than in 1966. The incidence of cows with twin calves also was higher than that observed in the previous summer: 17 and 6 percent respectively.

As in other years an aerial survey was conducted in late October to determine fall herd composition. Based on a total of 189 observations the count indicated an incidence of 49 calves per 100 adult females or 57:100 when the yearlings are excluded as above. Calves comprised 17.5 percent of the total population. Three sets of twins were seen, which represents 10.7 percent of the 28 cows with calves of the year.

The weather during the 1967 rutting season was unusually stormy with prolonged periods of high winds and rain and/or snow. As suggested in earlier reports, this may have disrupted mating activity, which might in turn be reflected in next summer's productivity. Jordan attempted to correlate fall weather and the degree of male-female association observed during the final week in October with the size of the calf crop of the following summer. Table 3 incorporates data of this nature from a similar table in the 1966 progress report with figures available for the following two years. It shows that the percentage of male-female association in the fall of 1967 was the lowest yet recorded. It is also noteworthy that, in contrast to other years, the percentage of adult females in the company of adult males was higher than vice versa in 1967. This is probably attributable to the preponderance of males (1.3:1.0) in the sample.

Table 3. Weather during the breeding season as related to mating activity and subsequent natality in Isle Royale moose.

Year	Fall weather	Adult cows accompanied by adult bulls	Adult bulls accompanied by adult cows	Calf crop the following summer (calves / 100 ad. ff)*
1963	mild	23%	28%	129
1964	stormy	42%	56%	49
1965	normal	32%	40%	49
1966	normal	--	--	77
1967	stormy	26%	18%	--

*Yearlings excluded.

On the basis of 151 moose observed in systematic aerial classification during the 1968 winter study, calves of the year comprised 18 percent of the population. Three different sets of twins were seen. In summary, it appears that in terms of natality and calf-survival last year was quite "normal." While calf production was greater than that documented in the two preceeding seasons, it cannot be considered as exceptionally high. On the other hand calf mortality due to both predatory and non-predatory causes was average or slightly below that observed in other years.

Condition of moose

The remains of three calves were found and investigated during the month of August, 1967. The death of at least one of these animals-- and possibly the other two-- was attributable to wolf predation. No visible signs of pathology were found in any of the calves.

Of the 15 moose known to have been killed by wolves this winter the carcasses of 10 were examined. The sex ratio of the nine adults recovered was 6:3, males predominating. The ages of these animals were determined by both mandibular tooth wear and cementum annulation (see below) techniques. The mean age of the adult moose as obtained by the latter method was 9.6 years. This is below the comparable figure from the previous winter of 11.2 years. The difference is due in part to the presence of both a yearling and a $2\frac{1}{2}$ year-old animal in this winter's kills.

Table 4. Moose killed by wolves, winter, 1968

Specimen Number	Sex	Age	Pathology: Jaw Necrosis	Pathology: Arthritis	No. of wolves
405	m	9	--	--	?
406	f	16	advanced	--	4
407	?	9 mo.	--	--	6
408	m	12	--	--	2
409	m	21 mo.	--	--	6
410	m	7	--	--	4
413	f	11	incipient	--	4
414	m	14	incipient	--	7
415	f	14	--	--	3
416	m	2	--	--	7
10	6:3	9.6*	3	0	

*Specimen 407, a calf, is not included in this average.

Lumpy-jaw

Varying degrees of necrotic stomatitis were found in the mandibles of three moose killed by wolves this winter. Table 5 shows the incidence of this condition among adult wolf-killed moose in the winters 1959-1968. The figures for the current winter are only tenative because all of the kills recorded could not be examined.

Table 5. Incidence of lumpy-jaw in adult moose killed by wolves on Isle Royale in the winters 1959-1968.

Year	Advanced necrosis	Incipient necrosis	None	Total kills examined	Percent with lumpy-jaw
1959	1	0	7	8	12.5
1960	2	0	6	8	25.0
1961	2	5	8	15	46.6
1962	1	5	9	15	40.0
1963	0	3	11	14	21.4
1964	0	0	13	13	0.0
1965	1	4	7	12	41.6
1966	2	1	14	17	17.6
1967	1	2	10	13	23.1
1968	1	2	7	9	33.3
Totals	11	22	92	124	26.11 (ave.)

As noted in past reports this condition has commonly been thought to be associated with an Actinomyces infection of the bone tissue in the jaw. The symptoms of the disease in moose, however, are atypical of similar infections in other animals such as livestock, where this organism has been definitely identified as the pathogen. Microbiological analyses of fresh bone tissue from several moose afflicted with the disorder were performed under the direction of O. E. Haelterman and H. C. Armstrong of the Purdue School of Veterinary Medicine. These specimens, collected by Jordan and Wolfe, were kept frozen until the time of examination. Tissue cultures failed to isolate Actinomyces in any of the specimens, which implies that it probably is not the causative organism.

Jordan inferred that the impaction of woody food material between the teeth and surrounding bone tissue may be instrumental in the iniation of necrosis in moose. One of several microorganisms or a combination of two or more may then be responsible for the ensuing infection. Since this condition is confined to older moose, the influence of age and thus of increasing wear on the molar teeth appears paramount. This is born out by the fact that the most common site of infection is between the molariform teeth P_4 and M_1 -- the location in the mandible normally showing the greatest degree of wear. Cementum annulation counts to determine the age of 15 necrotic moose jaws further support such a conclusion. The mean ages of seven animals with advanced cases of lumpy-jaw and eight showing incipient or moderately advanced stages of the infection were found to be 14.1 and 13.4 years respectively. The youngest moose in the latter group was a 10-year-old. It seems reasonable to assume that there may well be a definite "threshold" of age and hence tooth wear after which the moose become increasingly vulnerable to an infection of this nature. These investigations will be pursued during the coming year.

Other pathology

There were no signs of an arthritic condition of the joints in any of the wolf-killed moose examined during the winter study. Due to the unfavorable weather it was not possible to autopsy any animals freshly killed by wolves. The condition of one moose shot for such purposes is discussed below. The overall incidence of winter tick infestation in the island's moose herd appeared to be considerably lower this year than in the previous winter.

Fat reserves

Throughout the project's existence an effort has been made to classify the physiological condition of the moose killed by wolves by an evaluation of the fat content in the marrow of one or more of the major leg bones. The criteria used originally were those of marrow color and consistency. Although, as has been shown in the literature, this method is subject to severe limitations, it may furnish at least a gross indication of an individual moose's physical condition. Of the ten moose examined this winter three specimens (405, 410, and 416) showed extensive fat depletion in the bone marrow.

Condition of moose killed by non-predatory causes

One moose was autopsied during the 1968 winter study. The animal, a young ($3\frac{1}{2}$ years) cow, appeared to be in general good health. Body fat reserves were not great, but the bone marrow was high in fat content. Tick infestation was not excessive. Fifteen cysts of the hydatid tapeworm from $\frac{1}{2}$ to 1 inch in diameter were found in the animal's lungs but none was discernible in the liver. In addition to the calf accompanying her, the cow was carrying two foetuses (male and female) the weights of which were 2.41 kg. and 2.09 kg. respectively.

Age determination in moose by cementum annulation counts

It was mentioned in last year's progress report that the cementum annulation technique was being tested as a possible means of determining the age of moose recovered from Isle Royale more precisely than has been possible by use of the wear class method. This work has continued during the past year and a concerted effort has been made to improve the technique. Whereas molar tooth sections were originally cut, ground and polished manually, most phases of the operation have now been mechanized; the total time required to process a single tooth has been reduced to about 30 minutes. Work is currently in progress to reassess the ages of all the moose collected on the island during the 10 years of the project's existence.

A total of 124 molar sections from various teeth of 81 different moose have been processed to date. Of these animals 52 were known to have been killed by wolves. We have found that the annulations are somewhat easier to read on molar sections from an upper toothrow than those from mandibular teeth. Therefor the majority of sections prepared to date were from upper molars. In the case of 13 different moose, however, where sections of the same tooth from both upper and lower toothrows were made*, either identical or within one year. These findings substantiate the assumption that cementum annulation counts from either toothrow are valid in age determination. This is of considerable significance because upper toothrows were not always collected.

As in other cervids the first permanent tooth to erupt in moose is the first molar. This tooth was sectioned in all cases where possible. In five specimens, however, all six molariform teeth of one or more toothrows were processed. The differences in annulations observed were consistent with those expected on the basis of tooth succession. Thus it seems reasonable to assume that a reliable determination of age in moose can be made by this technique using any given molariform tooth. The results from ten calves and three yearling animals also conformed with tooth eruption and replacement in these specimens. "Known age" material from the older age groups is needed for final validation of the technique, but it has been unattainable to date.

* made, the results obtained for the respective tooth rows were

Table 6. Comparison of ages determined by tooth wear and M_1 cementum annulation counts in Isle Royale moose.

Age in years by cementum annulations	Mandibular tooth wear class (Peterson, 1955)*								
	I	II	III	IV	V	VI	VII	VIII	IX
1	3								
2		3	2		1				
3			1						
4			1	1					
5					1				
6					1	1			
7				1	1	2			
8					1		3		
9						2	1	3	
10						1	1	1	
11							1	2	1
12							1	6	
13								5	4
14								5	4
15							1	2	3
16								1	2

*North American moose, 1955. Univ. Toronto Press, 280.

The results of age determination in 70 moose obtained by cementum annulation counts and by the wear class method as described by Peterson are compared in Tables 6 and 7. It should be noted that since most of the moose in the sample were killed by wolves, the intermediate age groups are inadequately represented. This probably accounts for apparent incongruities in the 4-7 year classes. Gross discrepancies (i.e. two years or more) in the results of age determination by the two methods occurred in only two cases. The results suggest that cementum annulation counts are most consistent in the older age groups. This is precisely where age determination by the wear class method becomes arbitrary and the definition of wear classes is subject to considerable overlap.

Table 7. Age limits of the Peterson tooth wear classes for moose compared with other methods.

Wear class	Limits of wear class in years: Peterson[1/]	Sergeant and Pimlott[2/]	M_1 cementum annulation method: Mean age	95% C. L.
I	1	1	1.0	0
II	2	2-3	2.0	0
III	3	3-4	2.8	1.3 - 4.3
IV	4	4-7	5.5	0 - 24.5*
V	5-6	6-10	5.6	2.7 - 8.5
VI	6-8	8-15	8.0	6.4 - 9.6
VII	8-10	10-17	10.1	8.0 - 12.2
VIII	10-15	---	12.5	11.7 - 13.3
IX	14-20	---	14.0	13.4 - 14.6

1/ Passmore et al (1955. In Peterson, North American Moose)
2/ Sergeant and Pimlott (1959. Jour. Wildl. Mgt. 23)
* the extreme confidence limits here ~~are~~ result from small (2 specimens) sample size

Table 8. Age distribution frequency of adult moose killed by wolves

Age in years	Number of moose in respective age group: 0	1	2	3	4	5	6	7	8
1				X					
2		X							
3			X						
4		X							
5	X								
6		X							
7			X						
8			X						
9			X						
10					X				
11					X				
12							X		
13									X
14									X
15						X			
16				X					

Sample size: 52
Mean age: 10.87
95 percent confidence interval: 9.77-11.97

Table 8 shows the age distribution of 52 adult (older than one year) moose killed by wolves during the ten years of the project's existence. Almost 85 percent of the animals were seven years or older and the mean age of all the moose in the sample was calculated to be 10.87 years (95 percent C. L.: 9.77-11 97) These figures are tenative because the sample represents only one fourth of the total number of wolf-killed moose collected to date. However, they probably are indicative of results anticipated when the entire collection has been processed.

Continuation of the investigations described above will comprise a major aspect of our work in the coming year. It is expected that a reassessment of age in all moose specimens on hand will make possible the construction of a life table for the Isle Royale moose herd as well as a more precise analysis of predation trends in the past ten years. It should also be possible to describe more accurately the relationships between age and various pathological conditions in moose and their influence on vulnerability to wolf predation.

Wolf numbers

As mentioned above, adverse weather conditions of the past winter curtailed wolf-tracking efforts drastically. It was impossible to obtain more than a partial count of the island's wolf population in a single day of flying. The maximum number of wolves actually seen on one day was ten. On the other hand the wolves' social structure appeared more stable than last winter, and two of the three major packs were "marked" by the presence of melanistic animals. This facilitated recognition of the different social groups. The minimum number of wolves actually accounted for this winter was 21. However, this must be considered conservative as a census figure. It probably does not include all the single wolves and a possible additional pair. There may have been as many as 26 wolves on the island in February and March 1968. Table 9 summarizes winter estimates of the Isle Royale wolf population for the years 1959-68. It is based in part on a similar table by Jordan et al (1967. Amer. Zool. 7).

In the annual report of 1967, the appearance of four black wolves (in a pack of seven) was described. Definite conclusions as to the origin of these animals could not be reached, and the matter has been under further review and study-- in fact, certain aspects of the situation are still being investigated.

When Allen and pilot Murray first saw the "black pack" of seven (25 February 67) on Amygdaloid Channel, they both concluded initially that this group of animals (plus a wolf bloodied from fighting that was headed back across the ice* from the direction of the Sibley Peninsula some 18 miles to the north. At that time Wolfe and Murray had found an injured wolf in its bed in the Tobin Harbor area, and a week later they discovered still another. The "six pack" that had journeyed to this end of the island evidently made a kill shortly before the arrival of the black pack and was not subsequently seen. There was some question as to whether the six pack had been observed in sufficiently good light to eliminate the possibility that some were black and that the six pack and the black pack (numbering 6 and 7 respectively) were identical. Contributing

* toward Canada) had just crossed the ice

to this idea was the fact that the black pack had no fear of the aircraft, and in March they moved southward to "fraternize" about a kill with members of still another pack. Wolfe found that the black wolves were in two separate groups many miles apart at the time the winter study ended.

It will be recalled that the Isle Royale wolf population in 1967 was still evidently in a state of "social flux" and reorganization after the break-up of the large pack following the death of its alpha male in March 1966.

In February 1968 it first became possible for Allen, Wolfe, and Murray to examine together photographs taken of both the six pack and the black pack the winter before. They concluded that there was almost no possibility that these two groups were identical. Thus it appears that the six pack broke up and scattered (two injured wolves probably belonged to it) at the time the black pack arrived from Canada and invaded this area of the island.

Another aspect of this situation concerns the genetics of coat color in the wolf-- a question still being studied. Since it is quite certain that the island population included no melanistic wolves prior to the winter of 1967, if there were no immigration then the four black wolves in the black pack would necessarily be (1) all young of the year and (2) the progeny of two gray parents carrying recessive genes for black coat color. Assuming that the melanistic coat is inherited recessively according to Mendelian laws, as in the case of most mammals, the production of four black pups in one litter by heterozygous parents is a remote statistical probability. Photographs suggest that at least two of the black wolves were pups of the year, and one black animal appears to be an adult, although these judgements are by no means certain.

In view of these considerations, we must conclude that a pack of seven wolves did immigrate to Isle Royale in February 1967 and that the four black animals included a black parent. We continue to investigate the subject of coat color in Canids, on the possibility that exceptional circumstances may exist. However, the population estimates for 1967 and 1968 (table 9) are based on the above logic.

Table 9. Winter estimates of the Isle Royale wolf population, 1959-1968

Winter (Feb.-Mar.)	Known minimum	Best estimate	Possible maximum	Investigator
1959	19	20	21	Mech
1960	19	22	22	Mech
1961	20	22	23	Mech
1962	22	23	25	Shelton
1963	20	20	22	Shelton
1964 (a)	26	26	27	Jordan
1965	25	28	29	Jordan
1966 (b)	23	25	27	Jordan
1967 (c)	21	30 (d)	30 (d)	Wolfe
1968	21	23	26	Wolfe

(a) Includes one dead adult accounted for.
(b) Includes two dead, one adult & one pup.
(c) Includes two dead adults.
(d) Includes probable immigrant pack of seven.

Travel patterns and social organization

Travel routes used by the wolves during the past winter reflected strikingly the unusual snow and ice conditions. The shallow snow cover was hard crusted in many places-- either by the winds or repeated thawing and freezing-- thus facilitating inland travel. Conversely, shelf ice around the island's periphery and in some of the larger bays was, as mentioned above, poorly developed and this precluded extensive utilization of these routes. It was noted that the wolves moved inland more frequently than observed in the past. Also noteworthy is the fact that, in contrast to last winter, the center of wolf activity this year was on the southwestern half of the island. Only two sightings of wolves were made east of Moskey Basin. This corresponds generally with our observations of moose distribution in February and March.

The social structure of the island's wolf population this winter (as in 1967) was characterized by the presence of several smaller aggregations rather than a single large and dominant pack. In contrast to the previous winter, however, these social units were quite stable in their composition. Three different packs, at least one pair, and possibly 3-5 additional wolves comprised this year's winter wolf population.

A pack of six wolves, including two black individuals, was first sighted on 2 February near Grace Creek, where they had killed a calf probably two days before. This pack was observed again five days later at a new kill (yearling bull) in the Big Siskiwit Swamp but was not seen again for the remainder of the winter study. This is the longest period of time that a group of this size has been "lost" in the history of the project. Attempts to account for the disappearance of the pack invite mere speculation.

A second pack of seven wolves contained one black animal. Another large and very dark gray wolf in this group appeared to be the dominant individual. The animal in question might be the fourth black wolf from last winter. One of the original four melanistic individuals was not as distinctively black in its coloration as the other three, and it is conceivable that last summer's annual molt could have resulted in a further modification in color. Two (possibly three) members of this winter's pack of seven were believed to be pups of the current year.

This group was first seen on 12 February near Siskiwit Bay. It is probable that we accounted for all kills made by the pack between that date and the end of the winter study. These were all located on the southwest third of the island. There was thus some degree of overlap in the areas frequented by this pack and the group of six described above.

A third group of four wolves was first observed on 3 February near Lake Lesage. One member of the pack appeared to be loosely attached to the group, which was last seen at full complement two days later. Three kills were definitely attributable to this pack, and it was responsible for at least two additional kills made prior to our arrival on the island. The pack's center of activity was restricted mainly to the area around Siskiwit Lake.

Finally a pair of wolves was seen on two consecutive days during the first week of February in the Tobin Harbor-Rock Harbor area. They had apparently left a kill near Linklater Lake on the previous day. Although no wolves were observed on this portion of the island for the remainder of the winter study, a pair was seen on 19 February at a fresh kill about one mile northwest of Lake Desor. A week later the pack of seven killed still another moose a mile further west of this site. By this time, however, the two wolves had abandoned the earlier kill, although the carcass was not completely cleaned up. Possibly the two had killed a moose that had been wounded previously by the larger group. We cannot state with certainty whether both pairs described here involved the same or different wolves.

Sexual activity was observed in all three of the major wolf associations and attempted mountings were seen on several occasions in the two larger groups. However, only one incidence of actual coupling was recorded, in the pack of seven.

Predation patterns

The mean daily food (moose) consumption rates calculated for the three larger groups described above was 12.5, 14.7 and 13.3 pounds per wolf per day respectively. These figures are comparable to those obtained for the "big pack" in other years by former investigators. It appears that the overall predation efficiency of the packs of six and seven in the past two winters has been essentially equal to that of the large pack during its existence. This winter's observations furnished sufficient proof that these smaller groups had little difficulty killing moose, and there were even some suggestions of incomplete utilization of the carcasses. For example, the pack of seven spent almost a week at a kill in the Big Siskiwit Swamp, but subsequent examination of the carcass revealed that it was still largely intact. One of these groups took a moose in the intermediate age range.

Observations of the large pack in former years of this study demonstrated that commonly only part of the animals present participated in killing a moose. If this number is approximately the same in the present smaller groups, then the proportion of "free riders" is smaller, and the small packs represent more efficient economic units. Past observations also imply that the maximum number of wolves that is operationally effective under Isle Royale conditions is about 16. Strong social ties, expecially the leadership of the dominant male of long standing, probably were prime factors in maintaining the large pack at what must be regarded as a maximum, and somewhat precarious, level. Death of the alpha male in the winter of 1966 evidently resulted in immediate break-up of the large pack and subsequent reorganimation into smaller packs. The fact that the groups of six and seven include breeding individuals suggests that social changes of the past two years may have produced durable units. In any event, the composition of the island population of wolves in the future will be a subject of great interest.

Wolf mortality

Partial remains of two adult male wolves were discovered on the island during the past year. The skull, vertebral column, and pelvic girdle of one animal were found in August 1967 near North Gap by Windigo District Ranger, Zeb V. McKinney. The wolf apparently died during late winter or early spring of the same year. In February 1968 pilot Murray and Wolfe found the skull and vertebral column of another wolf near Hay Bay. This animal probably had been dead since the preceding fall and had recently been unearthed by other wolves. None of the major leg bones from either of the two specimens was found, and those skeletal portions recovered exhibited no gross signs of pathology. The cause of death was not ascertainable in either case.

Sex determination in both specimens was based on sexual dimorphism. Cranial measurements taken from each animal agreed with those given in Young and Goldman (1944. The Wolves of North America) for males of the eastern subspecies, Canis lupus lycaon.

Both animals exhibited extreme wear on the canine teeth, suggesting that they were quite old. Tentative estimates of age were made by N. Wilsman and others in the Veterinary Anatomy Department of the Purdue School of Veterinary Medicine. The criteria used were the degree of ossification of the cranial sutures and tooth wear based on large domestic dogs (Boenisch, 1913. Arch. der Tierheilkunde, 39). In each case one year was subtracted arbitrarily from the estimates obtained to compensate in some measure for the differential diet of wolves and domestic dogs. The estimates of age in the above animals by this method were two and four years respectively.

Obviously the social rank of an individual wolf in a given pack may affect its diet (amount of bone) and hence the degree of tooth wear. Likewise single wolves that are compelled to scavenge on remains left by other wolves probably wear down their teeth faster than animals associated with a group. Therefore age determination in wolves on the basis of tooth wear alone can at best be considered only an approximation. Linhart and Knowlton (1967. Jour. Wildl. Mgt., 37) have shown that precise age determination in the coyote (Canis latrans) is possible using cementum annulation counts on the canine teeth. Work is currently in progress to decalcify the canines of the wolf specimens collected on the island to date and determine their ages on this basis.

The Terrestrial Small Mammal Community

Investigations of the red fox, and three of its principle prey species, the snowshoe hare, red squirrel, and deermouse continued in the pattern established in 1966. Vegetation analyses begun in 1966 on the Bangsund, Conglomerate Bay, and Raspberry Island grids were completed in 1967. Thirty-three percent of the trap sites on the Bangsund and Raspberry Island grids and eleven percent on the Conglomerate Bay grid were analyzed.

Tree species within a circle of 17-foot radius were counted and placed in one of four height strata. Shrubs and lesser woody vegetation were counted in a circle of 7-foot radius; and groundlayer species were tallied in a circle with a 2-foot radius. The circles were concentric with the center on the trap site. Frequency percentages have been calculated for all plant species recorded.

Red fox

Summer studies consisted of making scat collections and analyses, and observing the tagged foxes in the Windigo area. During the 1968 winter study foxes were again counted in the course of aerial work on the wolves and moose, also the fox tracking lines were flown as often as possible.

Fox scat Analyses: By means of a computer program fox scat data collected since 1958 thru 1967 were re-analyzed on monthly and annual bases. Table 10 lists the percent occurrence of four of the major prey species. It appears that the increase in percent occurrence of hares from 1958 thru 1962 is correlated with the population build-up of hares. No pattern is readily apparent in the percentages of the other species listed. The monthly analysis has shown the abrupt summer change in diet from primarily small mammals to fruits.

Table 10. Partial analysis of red fox scats, 1958-1967.

Year	No. Scats	Occurrence percentage			
		Snowshoe Hare	Muskrat	Red Squirrel	Deermouse
1958	21	0.194	0.056	0.028	0.111
1959	113	0.476	0.102	0.048	0.014
1960	167	0.535	0.079	0.021	0.026
1961	128	0.378	0.043	0.137	0.047
1962	10	1.000	-	-	-
1966	79	0.094	0.042	0.062	0.073
1967	109	0.133	0.104	0.087	0.104

Fox numbers, 1967-68: Table 1 of the 1966-67 Annual Report gave a summary of foxes seen in previous winter aerial observations. In the 1968 winter study, the unusual conditions of sustained high winds and little snow both influenced fox movements. Shallow snow and solid footing gave these animals greater freedom of movement, and they were less restricted than usual to easier travel routes on the shoreline of Lake Superior and inland lakes. Thus the 1968 figure of 17.2 foxes seen per 100 flight hours is considered to be greatly biased and not comparable to similar counts of former years when these animals were more commonly in the open. As another limitation, the unfavorable weather conditions did not permit the accumulation of adaquate sample sizes on the fox tracking lines established in 1967. It is evident that this method of determining relative fox numbers is valid only under favorable operating conditions where counts can be made on new snow and where a statistically sufficient number of runs can be made. As a result of these developments, we have no new information on fox numbers.

Snowshoe hare

In an attempt to compare trends in the Isle Royale snowshoe hare population with that of the mainland, information was sought from the Michigan and Minnesota Departments of Conservation, the Ontario Department of Lands and Forests, and the Wisconsin Department of Natural Resources. These departments supplied hunting kill records and biologists' reports over a period of years that give an indication of hare fluctuations. It appears that the last low point is snowshoe hare numbers in each of these regions was as follows:

Michigan	Minnesota	Ontario	Wisconsin
1966	1966	1965	1965

Evidently Isle Royale hares have conformed to this pattern, and they remain at a low level.

Hare live trapping: Trapping was continued on the Raspberry Island grid established in 1966; however there were no recaptures, and only four animals, all adult males, were taken. Table 11 gives the population estimates in 1966 and 1967, which may be taken to represent the population for the entire 29-acre island. The sharp decline in 1967 is correlated with 1966 trap mortalities and indicates little or no immigration to the island during 1966-67 winter months. This grid will be monitored again in 1968 to determine the fate of remaining animals.

In 1967 live-trapping began on August 10 on Belle Isle. Thirteen hares were previously tagged on this study plot, which is located near a clearing that acts as a congregating area for feeding hares. Winter observations on this site indicate a relatively numerous population, considering the current Isle Royale situation.

Supplemental trapping was done at Sugar Mountain, Lake Halloran, and Windigo with the six Windigo hares being necropsied for basic natural history information. Sample sizes are not now large enough to make significant analyses and 1968 field work will be designed to fill in a picture of habitat comparisons rendered generally obscure by the scarcity of hares.

Table 11. Population estimates on the Raspberry Island grid.

Year	Schnabel	Schumacher-Eschmeyer	Lincoln-Petersen
1966	10.9 (0.02)*	12.5 (2.6)	10.0 (4.3)
1967	3.8 (0.07)	3.8 (0.28)	4.0 -

*Number in parentheses is one standard error.

Snowshoe hare live weights: Forty hares have been examined in the course of this study and live weights have been determined on most of these. Table 12 gives the weights of snowshoes in age groups and according to sex and month. The maximum adult weight was from a female taken in February, 56.7 ounces. The summer weights of adult females have not been "corrected" for pregnancy since all weights were from live animals taken on trapping grids. The smallest individual was a 3-ounce female which must have been about one day old. The preliminary indications are that adult females attain a greater average weight than males and also that hares on Isle Royale do not get as large, in general, as their mainland counterparts.

Table 12. Mean live weights of snowshoe hares (ounces).

Month	Adults		Subadults*		Immatures	
	Male	Female	Male	Female	Male	Female
February	(1)50.0**	(3)51.5	(3)39.0	--	--	--
June	(4)44.5	--	--	--	--	--
July	(11)46.3	--	--	--	--	--
August	(6)46.6	(7)51.6	--	(4)32.1	(3)21.7	(1)29.0
Sept.	(3)51.0	(2)47.2	--	--	--	(3)23.5

* "Subadult" males in February are those with abdominal testes; in August, this term designates first-litter young.

** Parentheses include number of rabbits handled.

Snowshoe hare pellet lines: An effort is being made to determine relative numbers of hares in several habitats by making spring counts of hare pellets on plots established by Jordan for a similar project on moose. These plot lines were described in the annual report for 1964-65. The summary given in Table 13 represents the winter accumulation of hare pellets in three habitats, as indicated by counts in May and June 1967. On this basis the open, early forest succession stages found in the 1936 burn are the most favorable snowshoe hare habitat. This confirms our subjective impressions based on tracks in winter and other sources.

Table 13. A comparision of hare pellet counts in three habitats.

Habitat	No. lines	No. plots	Total pellets	Pellets per plot
Boreal forest	5	60	26	0.4
Sugar maple - yellow birch forest	6	109	103	0.9
1936 burn	10.5	160	846	5.3

Red squirrel

The current studies are concerned with the demographic characteristics and habitat preferences of Isle Royale red squirrels. Three live-trapping grids were established to monitor populations. The Bangsund grid (mixed conifer and birch) has yielded data on 44 squirrels, while 42 animals have been caught on the Windigo (fir-spruce-birch) grid. Only seven individuals have been captured on the third grid (maple-yellow birch) located at the junction of the Island Mine and Greenstone trails.

Additional squirrels have been handled at Belle Isle (4). Mott Island (1), Bangsund Cabin (3), and Edisen's Cabin (10). Also, 21 squirrels have been taken in snap-traps set for deermice. In all, 132 animals have been examined, the following information being recorded: date, location, sex, age, weight, total length, tail length, hindfoot length, ear length, condition of pelage, external parasites, position of testes, evidence of lactation or pregnancy, nipple size, bait, trap time, weather, temperature, wind speed, and precipatation.

All animals are tagged in the ear with #1 monel metal ear tags which are serially numbered, and also toe tagged according to a system using both fore and hindfeet.

Breeding season and numbers: Trapping began June 7 in 1968 on the Bangsund grid and continued into October. Twenty-seven animals were captured on the area, and the population consisted entirely of adults until juveniles from the summer litter began to leave the nest in late July and early August.

Evidence of a spring litter is lacking, and this question will be examined further in 1968. The population estimate using the Lincoln-Petersen method for this grid is 24.4 animals with a standard error of 4.35. Squirrel density in the 14.9-acres of this quadrat is 1.63 animals per acre.

Twelve squirrels were caught on the Windigo area during the original trapping period in March 1967, and since then 30 additional animals have been taken. Age composition appears similar to that on the Bangsund grid with juveniles absent until August. Population density on this quadrat is the highest of any study area at 2.8 squirrels per acre.

The Sugar Mountain grid supports a much lower density of squirrels with only seven individuals caught to date. Food may be a limiting factor, as there are no cone-bearing tree species in this deciduous forest.

Survival rates: Annual survival rates may be calculated for squirrels on the Bangsund quadrat. Thirteen individuals were alive on the area when trapping ceased in early September of 1966; and five of those animals were trapped again in 1967. This gives a minimum survival rate of 38.5 percent of the 1966 animals that were alive after one year.

Results of trapping on the Windigo grid offer some measure of mortality through the year. In March 1967 twelve squirrels were trapped, tagged, and released; when trapping was resumed in August, 7(0.58%) were taken in September, and 5(0.42%) in October. This population was trapped in February 1968 and 5(0.42%) of the original animals were recaptured.

Woodland deermouse

This species occupies an anomalous position on Isle Royale, since it is the only mammal smaller than a red squirrel on the 210-square-mile island. A seed-eater characteristic of the northern boreal forest, it constitutes the entire small-mammal key industry, and thus has a vital potential relationship to the fox and to species such as hawks, owls, and weasels that may compete for the fox's small-animal prey. Winter observations indicate that the woodland deermouse is well protected by deep snow and suggest that it can live on cached food during long periods in the cold season. In the winter of 1967, deermouse tracks appeared unusually plentiful, which probably was correlated with the relatively light snow cover and/or the abundance of birch seeds that blew into windrows on frozen surfaces.

Trapping results: A trapping quadrat of 81 live-traps on 4.65 acres was established on Conglomerate Bay in 1966. In the course of the season, 17 mice were handled and toe-clipped for future identification. In 1967 the catch on this area was 26 individual animals (in 1215 trap-nights), of which only one was a survivor from the previous year. The population evidently was somewhat higher in 1967-- 6 mice per acre, as against 4 in 1966.

Snap-trapping provides the means for a much broader sampling program in the island's various habitats. In 1967, from May to October, 35 traplines were operated for deermice. In 6300 trap-nights, a total of 386 mice were caught and examined for biological information. In addition, 85 mice were collected in traps not operated in lines. As shown by the data in 1966, there was a population build-up over the summer. However, the increase was of greater magnitude in 1967. Animals caught per 100 trap-nights increased steadily from May through September, then dropped off in October (Table 14). The substantial decline in the last month of trapping (11.7 to 5.5 mice per 100 trap-nights) reflects the cessation of breeding in late August and September. The mean litter size for 45 pregnant females was 5.0.

Table 14. Deermice per 100 trap-nights (all habitats). 1966-67

May	June	July	August	September	October	Year
-	1.7	3.5	4.2	9.7	-	1966
-	(1197)*	(1620)	(720)	(186)	-	
1.5	2.6	5.9	8.7	11.7	5.5	1967
(540)	(1260)	(1620)	(1800)	(540)	(540)	

* (number of trap-nights).

In 1967 snap-trap lines were operated primarily in three major habitats: climax boreal forest, climax hardwood forest (sugar maple-yellow birch), and the early successions of the 1936 burn. A two-way analysis of variance shows seasonal differences to be significant, but indices between habitats were not significant. A further exploration of this situation will be carried out in 1968.

Deermouse foods: The examination of stomach contents of kill-trapped deermice shows that, regardless of habitat, the most important summer food of this species is insects. Plant material, especially seeds, are second in importance. During the month of August, mice of the sugar maple forest find and use a greater diversity of arthropods than those of the mixed boreal forest. There is little doubt that the diet shifts more to seeds, nuts, and fruits in winter, and more specific information is needed on the items of chief dependence. It has been noted that in the Windigo area seeds of speckled alder are gathered above snow level in February.