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Ecological Studies of the wolf on Isle Royale, 1970-1971

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Black fox
Breeding dates
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ECOLOGICAL STUDIES OF THE WOLF ON ISLE ROYALE*

First Annual Report

(Covering the Thirteenth Year in the Isle Royale Studies)

1970-71

by

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THE WOLF ON ISLE ROYALE

June 1970 marked the beginning of a new phase of these studies in Isle Royale National Park. Or it might be said that we returned to a continuation of the intensive wolf investigations that were carried out by L. David Mech from 1958 to 1961. In the intervening years we have obtained a better understanding of the numbers and community functions of species associated with the wolf. It was evident to those of us who habitually flew over the island in the sixties that beavers were increasing on new and old sites inland, especially in the large burn area. In the fall of 1969 Shelton made a re-survey and concluded that these animals had increased by about 25 percent since the termination of his intensive work in 1963. This probably means that we have well over a thousand beavers on the island as of fall and winter. Moose surveys of recent years indicate that the midwinter population of the wolf's principal prey is near 1000 animals. Winter wolf numbers averaged about 24 for the first 8 years of the work. Since 1968 the average total population has been about 18.

The above figures are a baseline for our further work on the wolf. In the several years immediately ahead we do not plan intensive inventories of prey species, although summer surveys of moose reproduction will continue to be taken, and it may become advisable to return to fall herd composition counts in 1972 and 1973.

In 1970 Ronald L. Bell, a graduating senior, was the one experienced man on hand to help give continuity to the summer work, and he went to Isle Royale on 9 June. With him was John D. Vanada, who had just finished his junior year. Peterson, who will be our full-time investigator in 1970-73, arrived on 14 June. Bell left the island on 8 July, Peterson on 27 August, and Vanada on 4 September. During the summer Allen and Dr. Charles M. Kirkpatrick (Department of Forestry and Conservation, Purdue) were in the field with Peterson and Vanada from 15 to 23 August.

For the past year, John Vanada has been investigating the use of incisiform teeth for aging moose. This is a technique that has been successful in aging deer. His results are included in this report.

Since Peterson needed to be on campus for course work in the fall and spring semesters, 1970-71, he could not participate in the full period of the winter field work. This winter he was able to spend 12 days on the island, between semesters. Dietz came to Purdue in September 1970 as a graduate student with primary interest to Wildlife physiology. Since he had not yet begun work on a problem, he decided to join the Isle Royale studies on a temporary basis for valuable field experience. Thus he is on a research assistantship from January through

August 1971. He participated, with Allen, in the full period of winter field work and submitted a report covering winter activities of the wolf packs. During the spring he analyzed bone-marrow specimens collected in three winters, the results of which are reported here.

The uniqueness of Isle Royale as a research area inheres in the fact that we have a major game species and a major predator finding their natural relationship free from attrition by man. This makes possible such studies as that reported by Jordan and Wolfe, former post-doctorals on this program, collaborating with statistician Botkin of Yale:

Jordan, Peter A., Daniel B. Botkin, and Michael L. Wolfe
1971 Biomass dynamics in a moose population.
Ecology 52(1):147-152.

Dependent on this same natural-area feature is Wolfe's paper, now in preparation, covering a life table and survivorship curve for the Isle Royale moose herd. A manuscript by Wolfe and Allen on four years of wolf studies is ready for submission to an editor. Wolfe and Jordan have a paper in manuscript on moose population trends.

Portions of a howling chorus by 18 wolves taped by us at Windigo in the winter of 1966 were included in a hi-fi reocrd assembled by Natural History Magazine and distributed to subscribers. Plans are now being made for this to be marketed by a large recording company.

The past winter was the thirteenth in which Donald E. Murray has piloted his Aeronca Champion and applied his great interest and skill to our studies of the wolf and its prey. Again, William J. Martila transported personnel and brought in supplies in the Cessna 180. Successively we were ably helped by five exchanges of park staff members during the winter period: William E. Dohrn, 26 Jan. - 7 Feb.; Charles F. Atwood, Jr., 7-15 Feb.; Alan D. Eliason, 15-24 Feb., (Superintendent) Hugh P. Beattie, 24 Feb. - 3 Mar.; Frank J. Deckert and Irving L. Dunton, 3-11 Mar.

Summer Observations, 1970

Although the summer was unusually hot and dry, the crop of blueberries and most other wild fruits was good, including beaked hazel. Mountain ash fruited abundantly, and the crop carried over to winter. In January and February trees were still well fruited on the south shores, although we noted that trees were stripped locally (such as in Washington Harbor) on north-facing exposures, suggesting that icing early in the winter may have been involved. Fruit brought down by ice probably is utilized quickly by the foxes, since we do not find it stratified in the snow profile.

Although June is too late to run moose pellet lines efficiently, the field party ran approximately half the lines previously set up by Jordan, and this information was turned over to Jordan and Wolfe for purposes of their moose paper.

A particular effort was made to cover every part of the island in last summer's survey of moose reproduction. In addition, it was desirable that Peterson become thoroughly acquainted with his study area. Hence a total of 440 miles were hiked by parties or individuals during the summer.

Two moose kills seen from the air in the winter of 1970 had not been examined on the ground, and these were located and specimens collected. In addition, the remains of 10 other moose were found. Of 7 adults, there were 5 males, 1 female, and 1 unknown. The other 5 were calves from the 1969 generation.

Our sex-age sampling of the moose herd probably represents the best distribution and least repetition in such statistics that we have ever obtained. The 197 individual records were summarized as follows:

Bulls: 64 Cows: 91 Calves: ~~35~~ 40 Unknown: 2

Thirty of the cows were observed with one calf and 5 had twins. A cow seen with twins between Windigo and Huginnin Cove in late August had open wounds on the right ham and in the anal area. There is little doubt that these were evidence of wolf attack. However, the calves appeared unharmed.

It was well established by observations in 1970 that the white vulval patch of cows sometimes does not show in summer. In two cases the patch could have been obscured by a smear of fecal matter, and the prevalence of this condition will be a point for further checking.

The sighting of only one wolf, by a hiker, was reported during the summer. Signs and howling indicated the presence of wolves in the Siskiwit-Feldtman area and also in the northeast sector of the island. Remains of a summer-killed moose were found near the Lane Cove trail in late June. Most of the skeleton and hair of a middle-aged wolf were found south of Lake Richie in early September. The animal appeared to have died in late fall or winter of 1969-70. The canine teeth had been removed from the skull.

For the first time in recent history, the great aspen leaf roller (Archips conflictana) appeared on Isle Royale and defoliated much of the aspen. A new growth of leaves was evident by the end of July, although aspen on Greenstone Ridge showed less vigor than elsewhere.

In line with Shelton's observations in 1969, great activity was noted in beaver colonies inland.

Winter Conditions, 1971

Weather during the period 26 January to 11 March was characterized by deep, soft snow, many days of high wind, and temperatures consistently cold but not extreme for the first half of February. For comparative purposes principal weather statistics are given for the past five winters in Table 1. The lowest temperature recorded this year was -25°F. on 13 February. The highest daily minimum was +25°F. on 27 February.

Table 1

Weather Conditions and Flying Time in Winter Field Work

	1967	1968	1969	1970	1971
Period	2 Feb.- 21 Mar.	30 Jan.- 17 Mar.	31 Jan.- 14 Mar.	29 Jan.- 14 Mar.	26 Jan.- 11 Mar.
Temp. F. Mean max.	+19.6°	+26°	+28°	+22.3°	--*
Mean min.	-4.9°	+4.9°	+4.5°	-1.3°	-1°
Snow depth** at Windigo	23-31"	9.3-14.3"	44"	23.2-23.4"	20.3-36"
Hours flown	169	140	131	90	99

* Maximum temperatures unavailable because of the failure of equipment.

** First figure is depth at beginning of period. Second is the maximum, if greater.

As in 1969, total flying hours for the winter (Table 1) were severely restricted by the prevalence of high winds, which often prevented effective low-level work even on days of no precipitation. There were 46 half-days when flights of at least 90 minutes were possible. In the first two weeks of the study period slush was common on inland lakes, but consistent sub-zero temperatures considerably improved conditions for landing and take-off by the middle of February. On 26 February heavy rains again caused slush to form. The combination of rain and no new snow limited tracking to an extent that during the last week of the study wolves were leaving little sign on the crust.

At the time of the flight to Isle Royale on 26 January, there was new ice between the main portion of the island and the Canadian shore. This was steadily solidified and extended until by 13 February it reached east of Passage Island and far to the west beyond Rock of Ages Light. The ice was exceptionally smooth and white with snow, making visibility good. West winds were breaking it up by 21 February, at which time there was open water to a curving line from Hugginin Cove to the Canadian islands. A week later this had been extended east to Lake Desore. When the work terminated on 11 March much of the channel was open, with interrupted ice floes between the east end of Isle Royale and Thunder Bay.

Although snow depth averaged 23-27 inches for much of the winter, the 36 inches recorded after a new fall of 16 inches on 4 and 5 ~~March~~ February was the second greatest depth we have measured in the 13 winters of this work. It had settled to 27 inches by the time the rains came on 26 February. What was probably more significant than total depth, it appeared that the light and fluffy character of the snow cover produced the most extreme conditions yet witnessed in affecting moose-wolf relationships.

During the past two winters both smog and odor from the Thunder Day paper mill have been evident over Isle Royale when wind was from the north.

Status of winter birds

It has been noted in past winters that an abundance of seed on the birches (white and yellow) is accompanied by large flocks of three closely related small fringillids, the redpoll, pine siskin, and goldfinch. Usually either the redpoll or siskin has been predominant, with a few of the other species and only occasionaly goldfinches. These three species appear to occupy the same environmental niche in winter on Isle Royale. They feed mainly on birch seed, although some alder is taken, and always from the tree. They do not pick up seed from the surface of the snow.

In 1970 a new variation in these winter bird flocks was observed. Although birch seed was not actually abundant, there appeared to be sufficient for aggregations of birds commonly numbering from 50 to more than 100, of which more than 90 percent were wintering goldfinches. Siskins were the secondary species this year, although a few purple finches sometimes were with them. No redpolls were seen. A flock of 10-12 purple finches was found frequently in the Windigo area, and up to 6 evening grosbeaks appeared every few days. We saw no pine grosbeaks or crossbills. This was surprising, considering the abundance of mountain ash fruit available.

For the first time this year we saw ravens making heavy use of the mountain ash. Ravens appeared to be more plentiful than we had seen them previously, and around most kills their droppings, red-stained and containing seeds, were in evidence. These birds frequently carried heads of the fruit out onto the ice of lakes to pick them apart. As usual, they followed the large wolf pack and fed on wolf droppings.

Usual numbers of chickadees, nuthatches, whiskeyjacks, and downy and hairy woodpeckers were seen. Occasional pileated woodpeckers were heard. Two horned owls could be heard on quiet nights from the Windigo shack. An immature bald eagle was sighted on 20 February and a pigeon hawk on 21 February. On several occasions flocks of up to 200 mergansers and goldeneyes were observed off the south shore of the island.

Secondary species of mammals

Based on general abundance of tracks, we judge that the snowshoe hare built up in the late sixties to a peak in 1970 and was somewhat less plentiful in 1971. However, the species was still conspicuously abundant on Mott Island during the past winter-- a carry-over from unusually large numbers in the summer of 1970.

Red squirrels probably were present in usual numbers. They exhibited little activity during most of February, although they were heard occasionally and tracks were sometimes observed. Squirrels were much more active in early March.

We believe that the otter is slowly increasing from year to year. This winter tracks were observed in the following locations: Stockeley Bay, Whittlesey Lake, Conglomerate Bay, Herring Bay, Francis Point, and Robinson Bay.

In all years but one, beginning in 1961, we have recorded fox observations in the course of our aerial field work and calculated the number of foxes observed per 100 hours of flying. It is now evident that in some winters these figures are so biased by field conditions that they do not reflect the status of the fox population with any satisfactory degree of accuracy. It appears that foxes built up with hares in the past several yaars, and the peak of foxes probably came during the past winter-- a year later than that of hares. However, Foxes could hardly have increased as much as observations increased from 1970 to 1971.

The most fox observations previously recorded per 100 hours of flying was 51.9 in 1963. In 1970 we saw 20 foxes per 100 hours. In 1971 this figure was 141!

As will be shown later, the softness of snow brought about a prevalence of moose kills by the wolves near lake edges and shorelines. In addition, mountain ash fruit was most plentiful along shores. Both of these factors caused foxes to frequent the edges that we regularly follow in flights. It was common to see 3 to 5 foxes at one time in the vicinity of a kill. On individual days of flying we recorded 17, 16, 15, and fewer foxes. As another factor, it may well be that for several weeks snow conditions made hares particularly difficult to capture, and this could account for the unusual territorial tolerance shown by the foxes that aggregated to scavenge on moose remains.

At the shack on Washington Harbor we recognized a dominant male and associated female that also occupied this territory in 1969. A new subordinate male was there regularly, as well as an occasional visitor, thought to be a female. The "cross fox" seen at times during the 1970 winter period was on Washington harbor near Beaver Island several times. It visited the shack once and was last observed on the ice along the west side of Barnum Island on Grace Harbor, 9 March. Two other foxes showing partial melanism were seen during the winter. The young, socially subordinate silver fox seen at Windigo in 1970 was located 22 miles away, where it appeared to be established in a range on Whittlesey Lake. There it was one of five foxes that fed on two kills and was seen repeatedly from 18 February to early March.

The pair of foxes at the shack were seen less often in late February and early March and gave evidence of sexual behavior. This winter we obtained two copulation dates for foxes, 3 and 9 March. A fox was killed on Lake Mason by two wolves on 21 February. It was not fed upon by the wolves. In different parts of the island we made three observations of the agonistic behavior and chasing by which foxes organize and maintain their territorial arrangements.

Wolf Packs and Population, Winter 1971

The principal wolf pack of the island carried over from 1970, when it numbered 8. This winter the maximum number was 10, observed only twice, 27 January and 7 February. Counts of 9 were made occasionally through the winter period, and between times the pack more commonly numbered 8, or even 7. It continued to occupy approximately the western half of the island, being observed as far east as Malone Bay.

In 1970 the dominant male of this pack was a large gray, who was obviously paired with a small, sharp-nosed ("foxy headed") female. This pair was closely attended by a large black wolf, assumed to be the beta male of the pack. In 1971 the gray male previously dominant could not be identified and probably had disappeared. This year the black male was obviously dominant, and it was paired with the small female, with whom it was seen coupled on 7 and 8 February.

The largest number of wolves seen in one day was 16, on 8 February. The individual groups were 9, 3, 2, 1, and 1. Our summary for the year was made on 6 March as follows:

Big pack	9
West end loner	1
Siskiwit Bay duo	2
Malone Bay loner	1
North side loner	1
Moskey Basin duo	2
Tobin Harbor duo	2
East end loner	1
Probable total population	19

The presence of two pups in the large pack was well established. It is probable that a female with an exceptionally dark back and tawny markings on the underparts also was a member of this pack but was a drop-out for most of the winter. Such a wolf was one of the original 4 black individuals that immigrated in 1967, and it has been seen occasionally, but not regularly. Except under the most favorable light conditions, it probably can not be distinguished from other members of the pack, so its presence has often been a matter of uncertainty. This winter's observations are of particular interest in this respect.

On 7 February, 10 animals were counted in the Big Pack, which was traveling west along Houghton Peninsula from Fisherman's Home. Farther east on the peninsula there was a duo of males. On this date and the day after, the alpha female was at the height of estrus and bred. On 8 and 9 February the count in the Big Pack was 9. There were several kills in this general area of Houghton Peninsula and the South Shore. On both of these dates, near a kill on the north side at the tip of the peninsula, we saw a dark-backed female with tawny markings on the venter attempting to join-- or at least approaching closely-- the Siskiwit Bay Duo

of males. One male was interested and approached her closely, often with sidewise body-slams. She replied with snaps and evasive action, often sitting on the ice, and always holding her tail tightly tucked under the body.

We theorize that, at a time of peak sexual activity, this subordinate female was not permitted to pair and breed in the large pack, from which she dropped out for ad hoc purposes. The duo was seen several times on Siskiwit Bay in late February, but we were unable to locate the female. For three weeks the large pack numbered 8 or 7, but it was back to 9 again on 3 March. During the earlier part of the winter period-- the time of high sexual activity-- the dominant male of the Big Pack carried his tail flagged. It was notable that this animal was toward the rear of the pack and not flagging his tail on 26 February while traveling south across the mouth of Washington Harbor and Grace Harbor. This was also observed later in the study, at which times the alpha female might be displaying dominance by flagging her tail.

Distances traveled by the Big Pack were correlated with snow conditions. All major inland expeditions made by this group were late in the study after warm weather had caused the snow to settle. Dietz summarized distances traveled for three principal periods in Table 2. The first period represented the time when snow was deepest and most fluffy, producing extremely difficult traveling conditions inland. Wind-blown shores, lakes, and ridgetops were preferred by both moose and wolves for moving around.

Table 2

Travels of the Big Pack in Three Periods

	Miles Traveled	Miles Per Day
2-15 February	46	3.5
15-26 February	54	4.9
26 February - 9 March	96	8.7

The loner at the west end of the island appeared to be definitely a scavenger in the wake of the Big Pack, and we doubt that it was ever included in any counts of this pack. On 26 February it came within sight of the large group, who were lying on the ice of Grace Harbor nearly a mile away. The pack arose immediately and trotted toward the loner, who headed quickly away toward Cumberland point, gaining distance steadily. This loner was a rough, large-headed animal-- probably an old male. It should not have been malnourished, since it was feeding on generous leavings at several kills.

Moose Distribution and Predation Relative to Snow Depth

As noted previously, snow conditions of the past winter brought about a striking modification of moose distribution and age-specific vulnerability to wolves. For a comparison with previous years, Peterson studied the distribution of 99 moose carsasses examined during the winters 1967-71, nearly all of which undoubtedly were wolf kills. In addition to reflecting moose distribution, the locations of these kills are a function of wolf travel routes. The data were analyzed by the use of two-way contingency tables, and the following conclusions appear justified:

1. In periods of high average snow depth (greater than 27 inches and usually greater than 3 feet) the vulnerability of calves to wolf predation is increased. Under these conditions 21 (54 percent) of 39 carcasses found were calves. During periods of "low" average snow depth (less than 15 inches), 2 (17 percent) of 12 carcasses were calves.

2. During periods of low average snow depth, proportionately more moose were killed away from the shores of Lake Superior and inland lakes, reflecting the better travel conditions inland for both moose and wolves when there is less snow.

3. Under conditions of great snow depth, proportionately more moose kills were made in the dense cover of spruce and cedar swamps, whereas during periods of least snow cover more kills were made in more open cover types, such as the 1936 burn.

Table 3 summarizes figures on moose remains found and the proportion of calves in the (presumed) kills by wolves during the past 5 years. For this purpose all moose remains located are considered to be "kills," although an occasional animal might have been severely injured, or actually killed, by accident.

Table 3

Predation on Moose Correlated with Snow Depth

	Max. Snow Depth	Kills Located	Kills Examined	No. Calves
1967	31 inches	12	12	2 (17%)
1968	14	15	10	1 (10%)
1969	44	30	19	9 (47%)
1970	23	22	15	6 (40%)
1971	36	36	34	19 (56%)

The extent to which carcasses are immediately utilized is a function of both the size of a particular pack and the rate of killing, the later being determined in part by the vulnerability of moose. For calves vulnerability depends largely on snow depth and for adults it probably depends largely on physical condition.

To speak of "the extent of utilization" involves the time element in large degree, since all carcasses are eventually totally utilized by the wolves and various scavengers. In the winters of 1964 and 1965 the original "Big Pack" commonly numbered 18 to as many as 22. Under these conditions carcasses were totally dismembered and practically all flesh, skin, and soft bony parts were eaten. This included skin from the lower segments of the legs, which usually were left covered with skin in earlier years when the Big Pack numbered 15 or 16.

It was in the winter of 1969 that the incomplete use of carcasses was first observed. The big pack then was comprised of 8 or 9 animals, and frequently they would move on when a carcass was only partially consumed. It appeared that the slow rate of utilization permitted an adult moose, while still warm, to melt down into the deep snow, where the lower half became firmly frozen into a layer of ice and practically unavailable. All such carcasses would, of course, become available when the snow melted in March.

Figures for 1971 in Table 3 show clearly that the rate of killing was up. We were able to examine such a high proportion of the kills because many of them were on shorelines near to where the plane could be landed. The kill of calves was the highest yet observed, and the incomplete utilization of carcasses was striking. The specific mechanisms involved in this predation record for 1971 were impressively demonstrated as the work progressed, the details of which follow.

Predation on Moose, 1971

During the 1971 study period, or immediately before, the wolves of Isle Royale killed at least 32 moose. Since a total of 36 remains were located, this means we have excluded from this current-kill record 4 specimens, which bear our field numbers as follows:

71-1 A calf previously floating and found frozen into the ice south of Belle Isle.

71-4 Not examined on ground. From air judged to be a few bones of an old kill 2 miles west of Island Mine Trail.

71-13 Remains of old cow dating from last fall-- totally beneath snow, near Whittlesey Lake.

71-17 A few bones of a calf, evidently killed and completely eaten in early winter.

Specimens on which such evaluations could be made have been few in former years and have been included as "kills" in compilations. This record for 1971 is made for possible future comparisons. Following is a summary of the moose remains found:

Moose remains located	36
Not examined	2
Examined	34
Adults	14
Male	7
Female	7
Unknown	0
Calves	19
Male	3
Female	10
Unknown	6
Probable non-kill	1

The character of the snow cover in 1971 was an obvious factor in causing moose to frequent the more favorable conditions found on shorelines and lakes. Wolves also favored the better footing of these areas, and this brought wolves and moose together. Calves were at a three-way disadvantage under these conditions: They had particular difficulty in moving about; the shorelines were heavily browsed by adult moose, putting them under a nutritional penalty; and they were poorly protected by their mothers. We established two cases of "orphaned," or temporarily abandoned, calves, which suggests that their mothers had left them to travel inland

to feed. In two cases calves separated from their mothers were attacked and severely injured by a single wolf. Probably both should be called "kills" but one was not found subsequently.

Our best quantification of this distributional phenomenon is in the location of kills. Of 36 moose remains, only 3 were more than half a mile from a shoreline, and only 8 were more than a quarter-mile from a shoreline.

It is fairly certain that a complete kill record was obtained for the Big Pack after 1 February. Its kills are listed in chronological order in Table 4. They total 19 moose in 37 days, of which 11 were calves and 1 was not yet determined-- this kill will be examined in spring, if possible.

This rate of predation, about a moose every 2 days, is the highest we have ever observed. The under-utilization of carcasses took different forms. An adult moose might be abandoned (for future reference) after a quarter or less of the meat was gone. Several calves were literally skinned, with meat used and skin and bones (usually with the spine still articulated) remaining for further treatment by ravens, foxes, and scavenger wolves. Several calves were killed on lake ice and evidently abandoned after only one or two feedings. The skeletons were largely intact, incl including the rib cage, with viscera and meat eaten out of the skin. It is evident that in March enough meat remained on various carcasses to provide substantial further support for the island's wolves. Previously we have thought that this could be a factor in the successful rearing of a litter of pups, but there is no evidence of this.

In the thirteenth winter of the work, we witnessed a form of moose killing not previously seen, or at least not recognized. Borrowing a term from the early buffalo hunting of Indiana, we have called it the "moose jump." There were five kills where it was clearly evident that moose had been put over cliffs or shelves of rock and killed or immobilized by the fall (Table 5). It appears that the tops of wind-blown ridges, like open lakes and shores, provide somewhat better footing under the conditions experienced in 1971. Thus, moose and wolves are more likely to have a confrontation in such areas. Where a moose is brought to bay at the edge of a cliff, it might easily be backed over the edge. The fact that at least two groups of wolves used the moose-jump technique during the past winter, suggests strongly that it was conditions, rather than wolf strategy, that brought it about.

It is notable that among the moose killed in this manner there were two young adults-- an age group not usually vulnerable to the wolves. It is possible that this can be appraised to better advantage after all of this winter's specimens have been aged by the tooth-sectioning method.

Table 4

Moose Killed by the Big Pack in Winter Period

Date	Approx. Age	Sex	Autopsy No.
(21 Jan)*	Middle age	F	536
(1 Feb)	(Not yet examined)		
(5 Feb)	Calf	F	540
7 Feb	Calf	?	541
8 Feb	Calf	?	542
9 Feb	Calf	F	553
10 Feb	Calf	M	543
12 Feb	Middle age	M	545
14 Feb	Calf	?	546
17 Feb	Young adult	M	547
21 Feb	Old adult	F	557
(23 Feb)	Young adult	F	558
25 Feb	Young adult	F	563
(26 Feb)	Calf	F	565
27 Feb	Old adult	M	564
2 Mar	Calf	F	562
(3 Mar)	Calf	M	567
5 Mar	Old Adult	F	566
(7 Mar)	Calf	M	569
9 Mar	Calf	F	568

* Dates in parenthesis are approximate.

Table 5

Summary of Moose-jump Kills

Kill No.	Autopsy	Age and Sex	Fall in Feet	Pack
71-11	543	Calf, male	30	Big Pack
71-12	545 - 5yrs.	Old male	30	Big Pack
71-16	547 - 4yrs.	Young male	15	Big Pack or Sisk. Bay Duo
71-18	554	Calf, female	12	Moskey Basin Duo
71-24	558 - 3yrs.	Young female	40	Big Pack

Further Studies of the Fat Content of Bone Marrow

Since the beginning of these investigations we have routinely examined the leg-bone marrow of moose remains found in the field and of moose collected. Fat depletion has often been extreme, especially in the older animals. This is sometimes the only evidence that a moose killed by the wolves was not in good physical condition. Field inspection of marrow is a technique long used in deer research, and quantitative measurements have been made, with marrow fat content expressed as a percentage. We have not favored this kind of an expression, since it is confused by the loss of water through evaporation. In the leg bones of moose that have lain in the field for some weeks, the marrow is shrunken and desiccated, even though most or all of the fat is still present. In such a specimen the percentage of fat by weight is almost meaningless.

It has appeared to us that a valid comparison of the condition of marrow fat from one moose to another could be made on the basis of grams of fat per cubic centimenter of bone marrow cavity-- the specimen being taken near the middle of the bone. By making a preliminary appraisal based on appearance and "feel" of a series of specimens, then following up with a laboratory analysis, it appeared that we could standardize our records and validate a qualitative method that could be used quickly when a carcass is examined in the field. This was the objective of a study that can now be reported.

A total of 143 samples of bone marrow from 49 moose (29 adults and 20 calves) were used. These represent carcasses examined in 1968, 1970, and 1971. A section, usually about 2 inches in length, was sawed from the mid-portion of a leg bone in the field, placed in a plastic bag, and kept frozen until the laboratory analysis. After being thawed, the marrow was removed from the cylinder of bone and the fat content estimated by inspection and given a rating from 1 (highest, undepleted) to 5 (lowest, or totally depleted). The marrow sample was then weighed, and the crude fat separated by ether extraction in a Goldfisch apparatus (courtesy Biochemistry Department, Purdue University). The volume of the marrow cavity was measured by sealing the end of the bone section to a glass plate with petroleum jelly and filling the empty cavity with water from a calibrated burette. Thus, the grams of crude fat per cm^3 could be calculated.

The results indicate that we need only three classes for our field test. These are indicated in Table 5, with the mean fat content as determined quantitatively for each. The characteristics to be used in field inspection are described.

Table 6

Fat Content of Three Bone Marrow Classes

Class	Description	Mean fat content and 95% confidence interval (gms fat/cm^3)
1 - Not depleted	Solid consistency; feels waxy when squeezed between fingers; opaque	.580 ± .060
2 - Partially depleted	Semi-solid (like liver tissue tissue); feels somewhat fatty when squeezed; opaque	.432 ± .074
3 - Very depleted	Gelatinous; feels watery when crushed between fingers; translucent	.017 ± .007

With one exception, all calves from which specimens were collected in 1970 and 1971 had "very depleted" bone marrow. In young calves there is a predominance of blood-forming tissue in the marrow, and as the animal matures this tissue is replaced by fat. Until this stage, there is little fat in the bone cavity. Fat deposition in the marrow of white-tailed deer is known to take place at 4 to 6 months of age, when the deer begins to acquire its winter supply of fat. We do not know the age at which fat is originally deposited in the bone marrow of moose. The extent to which the low fat ratings of calves in the past two winters is due to malnutrition or other secondary cause can not be appraised at this time. It could be a "normal" condition (though not without exception) for moose 8 to 9 months of age. This will be a particular point of interest in winters to come.

Seventeen of 100 marrow samples taken from adult moose were classed as "very depleted," and for some animals specimens were collected from several bones. A preliminary inspection of results indicates that in moose the depletion of fat progresses from proximal to distal bones, as has been reported in deer. Further analysis of information on hand and the collection of more specimens should confirm or modify our present impression that, while proximal bones provide the most sensitive test, any bone of any leg may be useful in diagnosing an extreme degree of fat depletion.

Aging Moose from Cementum of Incisiform Teeth

In these studies Michael Wolfe found that moose could be aged with satisfactory accuracy by counting cementum annulations on the root of the first molar and that this was the best molariform tooth to use for the purpose. In Ontario Sergeant and Pimlott found that the first incisor also could be used for aging, and in studies of the deer in Indiana extensive collections of deer have been aged by the collection of first incisors. It was of particular interest whether the technique could be extended to other incisiform teeth in moose, and in particular whether the outer tooth of this type (the incisor-like canine) offered aging possibilities. Conceivably, this tooth could be removed from an immobilized live moose at little or no physical liability and thus permit aging animals that had been marked in the field.

A project was carried out this year by John D. Vanada to compare the aging potential of incisiform teeth. He used teeth from 12 moose remains picked up on the island during winter and summer, 1970. An age was determined for each moose using Wolfe's method of grinding the root of the first molar. The three incisors and one canine were decalcified, sectioned, stained, and read under a microscope.

Results of the study indicate no significant difference in the number of annulations shown by M_1, I_1, I_2, I_3, and C_1. Thus, the age of a moose may be determined by the use of any one of the incisiform teeth. As with the molar technique, a confidence interval of $\pm$ 2 years is adopted because of errors in reading the cementum lines and our continuing lack of known-age material. Relative to the latter point, we expect to begin some method of tooth-marking moose by the use of a dart-gun in the winter of 1972.

Vanada's work is the basis of other conclusions of interest: All of the incisiform teeth had the same number of annulations, implying that they all begin growth and calcification at approximately the same time, even though they do not all erupt together.

Paired lines, resembling "rut lines," were found in several of the females, and these were especially prominent in one specimen. Rut lines have been reported only in males previously, and in a study of reindeer they were definitely absent in females. It is not certain whether the paired lines in moose are associated with the rut, but this is a possible explanation.

OUTLINE OF PROPOSED RESEARCH, 1971-72

Work of the past 10 years has provided reasonably good information on the status and interrelationships of mammalian species closely associated with the wolf on Isle Royale and, more generally, the dynamics of this island ecosystem. Thus the work of Rolf Peterson for his doctorate may now logically intensify our research on the behavior, socialization, and food economy of the wolf. This will include new departures in research on the moose, and it will also continue some of our routine procedures of years past, especially with a view to making them more efficient.

Summer work schedule

Field activities for spring and summer will be initiated by Dietz on 18 May and will probably be terminated in the first week of September. Peterson will arrive on the island 7 June.

The first assignment before the dense growth of vegetation will be to locate and collect specimens from two kills that were found during the winter but not examined on the ground. A re-check will be made on at least one other of the winter's kills.

From mid-June through August, Peterson and Dietz will systematically traverse the island on foot from the hiking trails by running cross-country lines. They will have two principal objectives: to search for signs of wolves, especially a breeding den, and to discover moose remains not previously examined. In addition, by this method they should be getting the best possible coverage in our annual calf count of the moose herd. Experience has shown that a cow-calf index has little value unless a widely scattered sampling is possible. This cross-country sampling was suggested by the interesting findings of a team of geologists who were engaged in much off-trail travel two years ago.

Long-continued and intensive field observations are the chief dependence in improving our limited knowledge of calf dependency and habits in the neonatal period, the rate of summer losses, and such new problems as the obscuring of the vulval patch in some cows during summer. In the course of the field work, as usual, routine records will be made on many kinds of wildlife, the annual fruit crop, the condition of vegetation, and other points of significance.

It is not anticipated that any extensive field work can be done during the fall of 1971, since this will be Peterson's last semester of course work on the campus. If possible, Allen will spend a week on the island in October. It is anticipated that Dietz' association with this project will be terminated in late August.

Winter study, 1972

It is expected that the winter camp will be opened about 24 January and closed about 12 March. Peterson will be in the field for the full 7 weeks and Allen for approximately 5 weeks. The winter routine that has proved highly productive in recent years will continue to be followed, with emphasis on several new problems. Pertinent phases of the work or questions to which we will address ourselves are:

1. A wolf census, including the numbers and relationships of packs.

2. Observations of wolf behavior and socialization, including breeding.

3. Moose herd composition by sex and age.

4. Location and examination of wolf-killed moose.

5. Collection and autopsy of at least one moose.

6. Collection of teeth, marrow bones, rumen contents, and other appropriate specimens from moose remains.

7. Preliminary trials of the immobiliaation, marking, and aging of moose by the use of a dart gun.

8. Study of moose distribution relative to snow depth, especially calf vulnerability to wolves.

9. Continued observations on fox numbers and behavior.

10. Status report on major wildlife species of Isle Royale.

More explicit to some of the above points, we will be particularly interested in continuing our record of the individual wolves in the Big Pack. Will the black male continue to be dominant, and will he be paired again with the small female? Will any pups survive as a result of last winter's mating of these two animals, and if so what color will they be? Has the large pack actually learned a "moose jump" technique, and will they practice it again?

Beginning with January 1972, and the completion of course requirements, Rolf Peterson looks forward to two years of field work, including fall periods in 1972 and 1973. It is hoped that one of these can also be a sabbatical half year for Allen, permitting more work in September and October than has heretofore been possible.