MOOSE RESPONSE TO HUNTING AND 1 KM² BLOCK CUTTING

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ABSTRACT: In Ontario, overharvesting of moose (*Alces alces*) is often associated with extensive access for hunters and lack of cover for moose in recently logged areas. The effect of increased cover was examined on a 110 km^2 area which had alternate cut and leave blocks averaging about 1 km^2. Road density exceeded 1.3 km/km^2. The area was open to moose hunting each year, but some roads were closed to vehicle travel. The moose population declined from about 0.40 $moose/km^2$ before extensive cutting and road access to about 0.27 $moose/km^2$ after the cutting and roads were completed. Hunting pressure became high when the area became road accessible, and the harvest was about 0.2 $moose/km^2$. Pressure then declined to a moderate level, and harvest declined to about 0.1 $moose/km^2$. The moose population in the block cut area after hunting was much higher than in nearby continuous cutover areas. Moose were strongly associated with standing timber. Leave blocks of 0.7 km^2 and larger were used more than smaller blocks, and leave blocks greater than 5.0 km^2 were used more than medium sized blocks. Total leave area and leave block size appear to be important in protecting moose from hunters. Road closures did not seem to increase moose density. The calf component of the block cut area was low at 0.03 $calves/km^2$, indicating high predation and low sustainable yield. Actual sustainable yield appears to be higher, so immigration may be important. Optimum cut pattern is discussed.

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The vulnerability of moose to hunting appears to be directly related to the amount of access for hunters and inversely related to the amount of cover for moose. These factors appear to result in overharvesting of moose in recently logged areas where road networks are extensive and cover for moose has been greatly reduced by clearcutting (Timmermann and Gollat 1982, Girard and Joyal 1984, Eason 1985). Overharvesting, in this context, is a large unsustainable harvest which results in an extended period of substantially reduced population size and very low harvests.

Moose will also move out of cutovers by late winter in response to snow conditions (Welsh *et al* 1980). However, early winter populations in cutovers protected from hunting do not show large reductions or actually increase (Welsh *et al* 1980, Eason 1985, Payne et al 1988). Therefore, moose movements do not seem to be the main cause of the large reductions in early winter populations observed in hunted cutovers.

Overharvesting of moose in cutovers appears to be common in Ontario. Cutting affects 2 to 3% of the moose range in Ontario each year (Thompson and Euler 1987) and moose populations in cutovers remain depressed by hunting for at least 8 to 10 years (Timmermann and Gollat 1982). Therefore, it is possible that 16 to 30% of the moose range could be overharvested and producing low yields in any year. This could result in large reductions in the moose yield available to hunters - particularly where parts of the moose range and yield are not accessed by hunters and clearcuts make up a large portion of the area that is accessible and providing yield.

The present hunting regulations in Ontario do not appear to adequately regulate the moose harvest on heavily cutover areas (Eason in preparation). The number of bull and cow tags is regulated on Wildlife Management Units (WMU's) which are many times larger than cutover areas. Although the tag quota is calculated for the entire WMU, the hunters concentrate in recent cutovers and have more than enough tags to overharvest these smaller areas.

We have been experimenting with hunting controls (Eason *et al* 1981, Eason 1985) and cut pattern (this study) to prevent the overharvesting of moose and increase long term moose yields in cutover areas. This paper examines the moose population response to hunting in the DREE Road cutover - a 110 km^2 area which has been cut in roughly 1 km^2 alternate cut and leave blocks. The DREE Road cut is very close to the cut pattern recommended in provincial guidelines to provide habitat for moose, including late winter habitat (OMNR 1988). This pattern has much more cover for moose than the large contiguous clearcut pattern that has been typical in this part of Ontario.

The purposes of this paper are to: 1) describe the moose population, harvest, and habitat use in the DREE Road block cut area before and after cutting; 2) compare the DREE Road moose population with the moose populations in contiguous clearcut areas; and 3) discuss optimization of cut pattern for moose.

STUDY AREA

The study area lies 60 km north of Wawa in the boreal forest region of north-central Ontario (Fig. 1). A LANDSAT image showing the study area has been published (Banks 1989). Climate is primarily continental with minimal local effect from Lake Superior. Topography is mostly rolling to hilly with elevations of 345 to 520 m. There are many small lakes and streams making up about 10% of the area. The forest is a very even mixture of conifer, mixed, and hardwood stands which provides a good distribution of food and cover for moose. Jack pine (*Pinus banksiana*) and upland black spruce (*Picea mariana*) are the dominant conifers, with some lowland black spruce, white spruce (*Picea glauca*), balsam fir (*Abies balsamea*), and white cedar (*Thuja occidentalis*). The dominant deciduous trees are trembling aspen (*Populus tremuloides*) and white birch (*Betula papyrifera*).

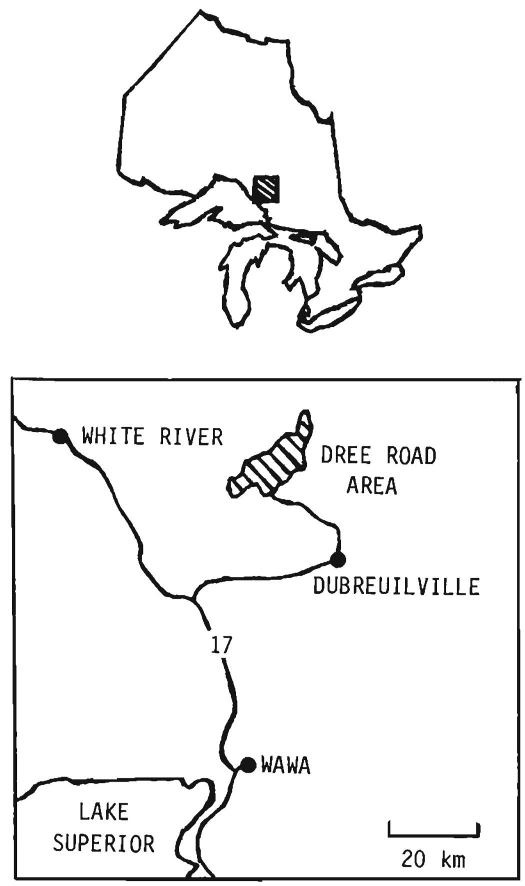

Fig. 1. Location of the DREE Road block cut area.

The 110 km^2 DREE Road area is part of WMU 22 which is 8000 km^2. The area was cut by Dubreuil Brothers Ltd. from 1984 to 1988 in a roughly 1 km^2 (100 ha) alternate cut and leave block pattern (Fig. 2). The cut blocks were clearcut for conifer and aspen with only a few inoperable areas and patches of birch left within the cuts. The 30 cut blocks total about 30 km^2, average 1.0 km^2, and range from 0.1 to 1.6 km^2 with most from 0.6 to 1.4 km^2. The cut blocks are well separated in most of the study area; however, some of the blocks in the south-central section are separated by smaller leave areas of 0.1 to 0.2 km in width. Most cuts were greater than 0.5 km wide, with some up to 1.0 km wide. Road clearings and gravel pits not within cut blocks add about 1 km^2 to the cleared area. Intensive

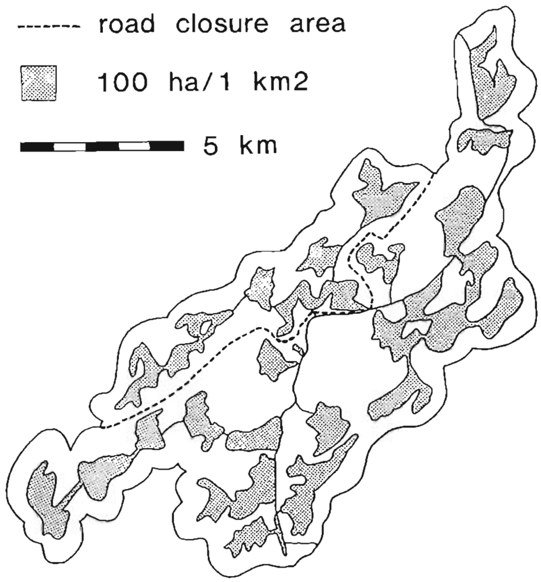

Fig. 2. DREE Road block cut area showing cutovers.

silviculture to regenerate conifer and eliminate deciduous trees is occurring on about 3/4 of the area in the cut blocks. This consists of mechanical site preparation, some prescribed burning, planting, and spraying. Roads, rocky areas, and thick hardwood residual make up the 1/4 of the cut area which is not treated.

The uncut portion of the study area includes: the leave blocks between the cuts; an uncut zone along the outside edges of the cuts on the periphery of the study area; and residual uncut patches within the cuts. Leave blocks are bounded on at least 3 sides by cuts or roads, and connections to adjacent blocks or to the surrounding forest can be no wider than 1.5 km. Moose in these blocks are clearly within the cutover pattern and not in the surrounding forest. There are 41 leave blocks which total about 45 km^2, average 1.1 km^2, and range from 0.1 to 7.3 km^2 - much wider than the range for cut blocks. Many of the leave blocks are small (0.1 to 0.3 km^2), particularly in the south-central area, and 3 are quite large (over 5 km^2). The ratio of cut block area to leave block area is 40:60, but about 50% of the conifer was in the cut blocks. Therefore, the leave blocks have a slightly lower conifer component than the original forest. The peripheral zone is 0.5 km wide and totals about 27 km^2. This zone includes any moose in the surrounding forest that are closely associated with cut blocks. There are also 10 cut blocks with 1 or 2 residual patches from 0.1 to 0.3 km^2 for a total of just over 1 km^2. Lakes and marshes from 0.1 to 0.4 km^2 total about 6 km^2 and are not included in cut or uncut areas.

The road network is extensive, totalling about 147 km. This is about 4.8 km/km^2 of cut area, 1.8 km/km^2 of cut and leave block area, and 1.3 km/km^2 of the total study area.

The DREE Road area has been open to hunting in all years. However, since its construction in 1985, vehicle travel has not been permitted on the Anahareo road system along the northwest side of the study area (Fig. 2) to prevent road access to a fly-in outpost camp lake. This covers about 23% of the study area. Cut size and forest type is similar inside and outside the Anahareo gate, but the amount of large leave block area inside the road closure area is small. During the 1987 hunt only, vehicle travel was also restricted on the other secondary roads and only the main DREE road was open to travel.

Cutting continues immediately to the northeast of the study area and 5 km to the southeast. Hunting pressure is heavy in these areas. There is 1 fly-in outpost camp on Anahareo Lake on the northwest side of the study area and 3 fly-in lodges and 2 outpost camps on Esnagi Lake to the east of the study area. Hunting pressure from the lakes is moderate. The remainder of the surrounding area is uncut with low hunting pressure.

Wolves (*Canis lupus*) are common in the area. Aerial surveys indicate that the range of 1 pack overlaps the study area; 5 wolves were seen in 1988 and 4 in 1989. Black bears (*Ursus americanus*) are also common, but the population size is unknown.

METHODS

Aerial surveys were used to collect the moose population data. Surveys were flown prior to cutting in 1982 and 1984, during cutting in 1986 and 1987, and after cutting in 1988 and 1989. In 1982 and 1984, only the northern 50 km^2 of the study area were flown; 86 km^2 were flown in 1986; 98 km^2 in 1987; and 110 km^2 in 1988 and 1989. A similar sized area outside the study area was also flown each survey year.

A total census of the survey area was conducted using flight transects 0.5 km apart. All moose and tracks seen were circled until observers were confident of an accurate count of the moose present. Surveys took place from January 9 to February 25. Only the 1982 survey took place after February 15 when moose are generally in late winter habitats. The surveys required 1 to 3 days to complete. No more than 2 days elapsed between flights, and an overlap area was flown to ensure that moose groups were not missed or counted twice. Snow depths varied from 47 to 84 cm at White River and Dubreuilville and were likely between 45 and 70 cm in the study area. Snow was deepest in 1982, 1986, and 1989. Snow crust varied from none in 1988 and 1989 to medium in the other years. However, moose movements did not appear to be impeded in any year. Recent snow provided good tracking conditions in all years except 1982 and 1984. Surveys were conducted in bright, mid- day conditions in all years. A Turbo-Beaver airplane with 4 people was used in 1982, 1984, and 1988, and a Twin Otter with 4 people in 1986. A Bell 47 helicopter with 2 people was used in 1987, and a Bell 206 helicopter with 4 people in 1989. Moose detection rates are thought to be similar for all of these aircraft because the ability to see tracks and follow them to the moose is good for each of the machines in the mixed habitat and medium moose densities of the study area. Observation time averaged 1.9 minutes/km^2, ranged from 1.4 to 2.4 minutes/km^2, and was higher when the helicopters were used because more time was spent sexing animals. All personnel had considerable previous experience on aerial moose surveys. After the 1984 survey, the habitat became more open as logging occurred, and this may have improved observability of moose. The counts are thought to be quite accurate from 1986 on because of good tracking conditions and more open habitat. Poorer tracking conditions and heavier cover may have resulted in under- estimates in 1984 and particularly in 1982 when the survey was in late winter. An attempt was made to identify the age and sex of all moose seen (Oswald 1982, Eason 1986).

Moose harvest information for the study area was obtained from several sources: the provincial voluntary jaw collection program which records kills by 100 km^2 mercator blocks; a mail and telephone survey of adult validation tag holders from WMU 22 in 1986 and 1988 respectively; a check station covering the first 9 days of the hunt in 1987 and 1988; and estimates of Conservation Officers, local hunters, and outfitters.

To examine moose population changes in relation to cutting, the mean of the moose densities prior to cutting was compared with the mean of the densities after cutting using a t-test. Densities were used because the survey area increased during the study. This method was also used to compare calf numbers before and after cutting and moose numbers inside and outside the road closure area.

To examine the relationship of moose numbers to leave block size, a chi^2 test was used to compare the observed and expected number of moose in the small (<0.7 km^2), medium (0.7 to 2.6 km^2), and large (5.1 to 7.3 km^2) leave blocks. Observed moose numbers were obtained from the 1988 and 1989 surveys when the cut pattern was complete. Expected moose numbers were obtained by applying the average moose density for the 2 years to all 3 size categories. The small size category includes blocks smaller than expected in a 1 km² alternate cut and leave pattern; the 3 atypically large blocks make up the large category.

RESULTS

The moose densities observed on the DREE Road area declined by at least 1/3 from before cutting to after cutting (Fig. 3, Table 1). Precut densities were 0.36 moose/km² in 1982 and 0.38 moose/km² in 1984. The 1986 density was 0.47 moose/km². Only 5 km² or 6% of the 1986 survey area was cut, so this survey is also considered representative of precut conditions. Because of the possible under-estimates of the 1982 and 1984 surveys, precut density was likely above the 0.40 moose/km² average for the 3 precut years.

By 1987, just over half of the cutting was complete - about 17 km² or 17% of the survey area was cut and the moose density was 0.28 moose/km². By 1988, cutting was complete at 31 km² or 28% of the survey area. There were 0.25 moose/km² in 1988 and 0.28 moose/km² in 1989. The mean precut density (1982, 1984, 1986) of 0.40 moose/km² is significantly higher ($P<0.01$) than the mean density after cutting (1987, 1988, 1989) of 0.27 moose/km².

Moose were strongly associated with standing timber. During the surveys, only 1 moose was observed in a cut, and it had just come from a leave block.

Within the uncut areas, moose numbers were positively related to the size of residual and leave blocks (Fig. 4). In 1988 and 1989, moose densities averaged 0.26 moose/km² on residual and leave blocks less than 0.7 km², 0.45 moose/km² on leave blocks from 0.7 to 2.6 km², and 0.75 moose/km² on leave blocks from 5.1 to 7.3 km². The number of moose in these categories was significantly different ($\underline{P}<0.05$) from the number expected if the moose were evenly distributed over the uncut areas.

Closing roads to vehicle traffic was not related to higher moose densities. Moose densities behind the Anahareo gate after cutting in 1987 to 1989 averaged 0.29 moose/km², not significantly greater than the area outside the gate which averaged 0.26 moose/km². Precut densities in the surveyed portions of these same areas averaged 0.74 and 0.30 moose/km². Following the 1987 closure of all secondary roads to vehicle travel, the 1988 density remained low and similar to the 1987 and 1989 densities.

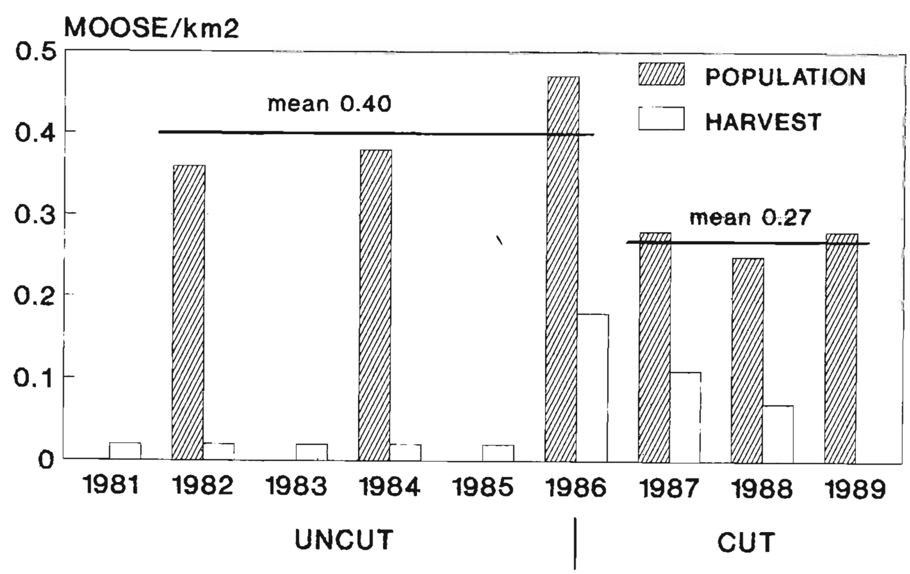

Fig. 3. Moose population and harvest densities in the DREE Road block cut area.

Table 1. Moose population characteristics of the DREE Road block cut area.

Year	Total Moose	Bulls	Cows	Unsexed Adults	Calves	Bull:Cow:Calf Ratio
1982	18 (.36)[1]	3	5	9	1 (.02)[1] (6%)	
1984	19 (.38)	8	4	6	1 (.02) (5%)	
1986	40 (.47)	14	9	14	3 (.03) (8%)	
1987	27 (.28)	12	12	0	3 (.03) (11%)	1.00:1:0.25
1988	28 (.25)	10	5	8	5 (.05) (18%)	
1989	31 (.28)	14	13	1	3 (.03) (10%)	1.08:1:0.23

1. Density of moose/km^2 on surveyed area

The adult sex ratio was accurately determined only in 1987 and 1989 when helicopters were used on the surveys. Bulls and cows were similar in number in both years (Table 1). In addition, large numbers of adults were sexed in the other years, and there is no indication of abnormal sex ratios.

The calf component of the population was very low prior to cutting, varying from 5 to 8% (Table 1). As the moose density declined following cutting, the calf component ranged from 10 to 18% but is still considered low. Actual calf densities were not significantly different before and after cutting, averaging just under and just over 0.03 calves/km^2.

The moose harvest data available on the study area is summarized in Table 2. The voluntary jaw returns are for the four 100 km^2 blocks enclosing the study area. The jaw returns indicate a low moose harvest prior to cutting and a much higher harvest following road construction and cutting. A survey of 1986 adult validation tag holders in WMU 22 determined the harvest location, if any, for 91% of the tag holders, and a harvest of 10 moose was recorded from the study area. A 1988 survey determined the harvest location of 97% of the tag holders, and a harvest of 7 moose was reported from the study area. The check stations conducted on the study area recorded a moose harvest of 11 in 1987 and 10

Table 2. Moose harvest in the DREE Road block cut area.

Year	Jaw Returns[1]	Postcard Survey[2]	Check Station[3]	Fly-in Camps[4]	Illegal[5]	Estimated Total[6]
1981	1			0-3	0	0-3
1982	0			0-3	0	0-3
1983	7			0-3	0	0-3
1984	4			0-3	0	0-3
1985	3			0-3	0	0-3
1986	11	10		0-3	2	20
1987	12		11	0-3	2	12
1988	8	7	10	0-3	2	8

1. From 100 km^2 blocks FJ 67,68,77,78
2. From known harvest locations WMU 22 tag holders
3. From first 9 days of hunt
4. Estimated by outfitters
5. From Conservation Officer reports
6. See text for explanation

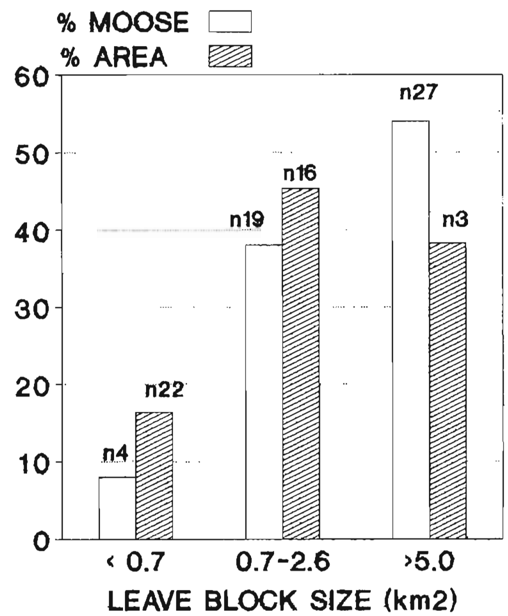

Fig. 4. Moose distribution in relation to leave block size in the DREE Road block cut area in 1988 and 1989.

in 1988 for the first 9 days of the hunt. From discussions with the fly- in camp operators, from 0 to 3 moose are harvested by their hunters in the study area each year. Illegal harvest is not well known; no illegal kills were reported prior to 1986 in the vicinity of the study area, but about 2 pre-season kills per year were reported to Conservation Officers for 1986 to 1988.

A combination of the harvest information was used to estimate the total moose harvest from the study area each year (Table 2). Prior to cutting, virtually all of the harvest was from the fly- in camps. The increase in jaw returns beginning in 1983 reflects access and cutting to the south of the study area. Therefore, the annual harvest prior to 1986 is estimated at 0 to 3 moose (average 0.02 moose/km^2).

In 1986, the known harvest on the study area was 14 moose: 10 from the mail survey of adult tag holders and 4 other moose from jaw returns (3 calves and 1 adult taken by a non-resident). It is estimated that another 4 moose were also taken by hunters: 2 of 9 moose in the mail survey with unknown harvest location; 1 moose by extrapolation to tag holders that did not respond to the mail survey; and 1 more calf, based on the proportion of calves in the known harvest. In addition, 2 moose were probably poached. Therefore, the harvest in 1986 was likely about 20 moose (0.18 moose/km^2).

In 1987, some of the 11 moose recorded at the check station and some of the 12 jaw returns recorded for the 400 km^2 block were likely taken outside of the study area because of the extension of roads to the north. A realistic estimate seems to be about 8 moose taken in the study area during the check station, perhaps another 2 moose after the check station, and probably 2 poached moose. Therefore, the harvest in 1987 was likely about 12 moose (0.11 moose/km^2).

In 1988, a minimum harvest of 10 moose was reported from the study area: 7 from the telephone survey and 3 additional jaw returns. The check station also reported 10 moose taken in the study area. However, as in 1987, some of these moose were likely taken outside the study area. It is estimated that about 6 moose were harvested in the study area during the moose season, with probably 2 moose poached before the season. Therefore, the harvest in 1988 was likely about 8 moose (0.07 moose/km^2).

Hunting pressure on the study area was rated subjectively as low prior to 1986, high in 1986 and 1987, and moderate in 1988. Hunting pressure or harvest did not correspond to changes in the number of adult validation tags issued for WMU 22, which declined steadily from about 800 in 1983 to 240 in 1989.

DISCUSSION

Moose Density in Relation to Cutting and Hunting

The precut moose density on the DREE Road area of about 0.40 moose/km^2 was similar to densities observed for many unhunted populations thought to be limited by predation from wolves and bears (Crête

1987). The hypothesis of limitation by predators, as opposed to food or hunters, is also supported by good abundance of browse in the uncut areas, good condition of the moose, low hunter harvest, and low calf component.

The decrease in the moose population following cutting corresponds closely to the changes observed in hunting pressure and harvest (Fig. 3). The population now appears to be limited by hunting and predation at about 0.27 moose/km^2. Moose movements in relation to food and cover do not appear to be responsible for the population changes - there continues to be a good abundance of browse and ample conifer cover in the study area, and the moose density in the area surrounding the study area did not increase as populations in the study area declined. Large movements of moose have been identified out of a nearby unhunted cutover area into surrounding uncut areas as winter progressed (Welsh *et al* 1980), but this cutover area did not have large blocks of conifer cover and early winter densities were good.

The closure of roads to vehicle travel did not seem to result in higher moose densities. This could be related to difficulty in enforcing such a ban - hunters often drove the closed roads and moose shot during the day were often picked up by vehicle late at night. In addition, Conservation Officers and hunters thought that hunting success was actually better for hunters that walked. The effect of the Anahareo gate may have been masked by differences in the leave block size inside and outside the gate; but the results of the 1987 hunt seem to indicate that road closures had little effect inside or outside the gate. Alternatively, the effects of road closures may have been masked by moose movements after the hunt but before the surveys.

Importance of Leave Blocks

Although the moose density in the DREE Road block cut area declined by at least 1/3 following cutting, this is much better than the 75% decline in typical hunted cutovers with large contiguous clearcuts and much less leave area. Densities in these typical cutovers decline to 0.10 moose/km^2 or less after hunting, which appeared to be the main cause of the decline (Eason 1985 and in preparation). Moose density in these hunted areas appears to be related to the proportion of uncut forest remaining in the areas (Fig. 5). This suggests that the smaller cut area and larger leave area in the DREE Road block cut may offer substantially more protection to moose from hunting than normal clearcutting practices.

The relative role of reduced cut size versus increased leave block sizes in retaining moose is of interest to both forest and wildlife managers. In recent cutover areas, moose primarily use residual uncut areas and uncut edges because it takes some time for food and cover to regenerate in the cuts. It is these uncut areas which screen moose from hunters. Moose in small leave blocks will encounter surrounding cuts and roads more frequently than moose in large leave blocks because of the larger edge to area ratio in small blocks. Therefore, moose in small

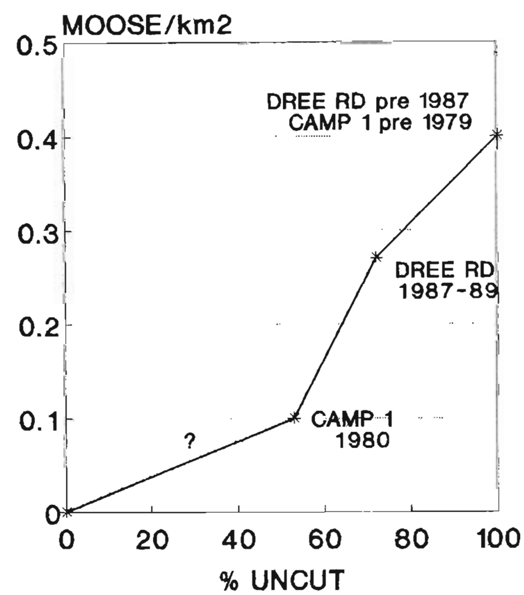

Fig. 5. Moose density in relation to forest cover for hunted areas near Wawa, Ontario (Camp 1 data from Eason 1985).

leave blocks are likely to be exposed to hunters more often than moose in large blocks, since hunters concentrate on roads and cut edges. This implies that cutover areas with small leave blocks may have fewer moose after hunting than cutovers with the same leave area in larger blocks. It also implies that cutovers with small leave blocks will have fewer moose even if clearcuts are also small. Therefore, increased leave block size is probably more important than reduced clearcut size in retaining moose in cutover areas.

How big should the leave blocks be to adequately protect moose from hunters? In the DREE Road area, small leave blocks of less than 0.7 km^2 had an average density of 0.26 moose/km^2 in winter, which should result in an overall density of 0.13 moose/km^2 in a 50:50 cut and leave pattern. However, the sample size of blocks 0.4 to 0.6 km^2 is small. In the nearby Camp 1 area, moose were not found in leave blocks 0.6 km^2 or less after hunting (Eason 1985). Medium sized leave blocks from 0.7 to 2.6 km^2 in the DREE Road area had a density of 0.45 moose/km^2, which should result in an overall density of about 0.23 moose/km^2 in a 50:50 cut and leave pattern. Large leave blocks of greater than 5.0 km^2 had a density of 0.75 moose/km^2, which should result in an overall density of about 0.38 moose/km^2 in a 50:50 cut and leave pattern. However, the sample size of leave blocks greater than 1.5 km^2 is small. In the Camp 1 area, all of the moose observed after hunting were in a very large leave block measuring 10.5 km^2 (Eason 1985). At some point, increasing leave block size will not increase moose density because large areas of uncut forest in this area generally have no more than 0.4 to 0.5 moose/km^2.

The DREE Road data seem to suggest that leave blocks should be at least 0.7 km^2 and that blocks greater than 5.0 km^2 are most valuable in retaining moose in cutover areas. However, any shift in the division between the small and medium categories or the medium and large categories removes the statistical significance of the density differences between the size categories. Therefore, more data are needed from other cut patterns to clarify the relationship between leave block size and moose density.

Population Characteristics

The block cut pattern retained much higher densities of bulls than typical clearcut areas nearby (Eason 1985 and in preparation). This is advantageous because bulls are often very susceptible to overharvesting which can lead to reduced breeding (Crête 1987). The cut pattern, rather than the selective harvest system, seems to be responsible for protecting bulls; enough tag holders were hunting in the study area to take many more bulls (check station data), and the bull numbers were low in typical clearcuts with the tag system in place (Eason in preparation).

The block cut pattern also retained higher cow densities than typical clearcuts. This is particularly important because most population growth in heavily hunted areas is usually from the reproduction of the resident survivors, not from immigration (Gasaway *et al.* 1980, Goddard 1970).

The very low calf component of 5 to 8% prior to logging is indicative of a predator limited population. There is a good abundance of browse, so reproduction does not appear to be a problem. Following cutting, the calf component increased to 10 to 18% as the population declined. However, actual calf densities were not significantly higher, averaging just under 0.03 calves/km^2 prior to cutting and just over 0.03 calves/km^2 after cutting.

This low calf component results in a low sustainable yield of adults - no more than 0.03 moose/km^2. Allowing for some natural mortality, an adult harvest of probably no more than 0.02 moose/km^2 can be sustained. With the calf harvest averaging about 0.01 moose/km^2, total sustainable yield is likely about 0.03 moose/km^2. Maximum sustainable yield (MSY) of hunted moose populations with 2 predators is thought to occur at about 0.6 to 0.7 of the equilibrium density without hunting, or from about 0.2 to 0.3 moose/km^2 (Crête 1987). The density in the DREE Road area falls within this range, but the yield of about 0.03 moose/km^2 appears to be less than the proposed MSY of 0.05 moose/km^2 for populations with predation (graph in Crête 1987).

The low calf density suggests that calves remain very vulnerable to predation after block cutting. Because the calf density after cutting was lower than expected for a population at this density, predation pressure appears to be higher than normal. Higher predator numbers may be responsible or the block cut pattern may actually make moose more susceptible to predators. This may support the view that leave blocks can concentrate moose and make them more easily available to predators (Bergerud 1981). Perhaps a more homogeneous pattern would be more difficult for predators to search than a heterogeneous pattern in which predators can predict where moose will be. Homogeneity may also increase with time as cutovers regenerate. However, our sample size is small, and more information from other leave block patterns is needed before we can determine how cut pattern influences predation on moose.

The actual sustainable harvest from the study area appears to be close to the 1987 and 1988 harvests which average 0.09 moose/km^2. The increase of 0.06 moose/km^2 above the estimated sustainable yield based on calf component appears to be from immigration. This would make immigration more important in the block cut area than generally observed in other hunted areas (Goddard 1970, Gasaway *et al.* 1980, Eason 1985). Perhaps the increased leave area keeps more immigrating moose in the area. However, immigration would be less if harvest was overestimated or if the surrounding area was also heavily hunted. Also, if any immigration occurred between the hunt and the survey period, the post-hunt density would be lower than the survey density - indicating that the block cut pattern provides less protection for moose from hunting. Again, information from other cut patterns is needed to determine if block cutting enhances immigration.

Optimum Cut Pattern

Very little quantitative information exists on the interspersion of food and cover for moose (Allen *et al* 1987, Thompson and Euler 1987, Timmermann and McNicol 1988). Nevertheless, moose habitat management is carried out in many areas. In Ontario, the emphasis is on limiting clearcut size to about 1 km^2 and 0.4 km in width to provide cover near food, and on protecting late winter areas by retaining half of the conifer in leave blocks equal in size to the cut blocks (OMNR 1988). However, food does not seem to be a limiting factor for moose in most parts of Ontario (Crête 1988, Thompson and Euler 1987). Similarly, there is no evidence that late winter areas are limiting because moose can walk long distances to reach this type of habitat (Welsh *et al* 1980).

Predation and hunting are thought to be the main limiting factors for most moose populations in Ontario (Crête 1988, Thompson and Euler 1987). The critical periods for these populations are spring and early summer when many calves are killed by predators, and fall when many adults are killed by hunters. This implies that the habitats moose occupy in the spring, early summer, and fall are also critical. That is, if these habitats can be managed to provide more protection for moose from predators and hunters, the moose population will increase. Conversely, if escape habitat is reduced the population will decline. Therefore, optimum habitat or cut pattern should include important needs, such as escape habitat, along with the more traditional requirements for food and cover.

The DREE Road area provides some

information on optimum cut pattern. This area closely approximates the alternate 1 km^2 cut and leave block pattern recommended in the provincial guidelines to provide adequate cover near food and retain late winter cover for moose (OMNR 1988). These objectives appear to have been met because moose are not limited by food and they continue to use the area in late winter. This cut pattern also appears to provide optimum protection from hunting because it maintained the moose density at the theoretical level for MSY; however, this may be related to the large leave blocks (>5.0 km^2) in the study area. Immigration may have been enhanced by the block cut pattern, but predation on calves remained high. Sustainable harvest appears good, but would be low if immigration was reduced.

To determine the optimum cut pattern, many cutover areas with a variety of cut and leave block sizes need to be examined over time. This should clarify the relationships of amount of uncut forest and leave block size with moose density, hunter harvest, predation, and immigration. This information could allow the design and scheduling of cut patterns which would maintain moose populations at MSY.

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