THE RELATIONSHIP BETWEEN HUNTER ACCESSIBILITY AND MOOSE CONDITION IN NEWFOUNDLAND

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ABSTRACT: To test whether hunter accessibility correlates with moose condition, the similarity of two classifications of Moose Management Units (MMU's) in Newfoundland were compared for the years 1974 to 1987. The two classifications based on seven indices of moose condition and mean distance to roads as a measure of hunter accessibility, were not independent. Moose condition may also be related to the productivity of the land for moose and therefore a second comparison of two classifications of MMU's based on moose condition and land types was also done. Hunter accessibility was better correlated with moose condition than land types and possible explanations for these relationships are discussed. The relationship between hunter accessibility, percent forest cover and moose condition was described using the linear function of the log of the first principal component of seven measures of moose condition. Two measures of moose condition, mean age of females and mean antler points for males best correlated with hunter accessibility while percent yearlings in the harvest and mean antler points for males best correlated with land cover. MMU's that require greater harvest were identified and proposed management include increasing resident and/or non-resident license quotas as well as winter hunts. Methods of monitoring the success of suggested management practices are discussed.

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Newfoundland's moose (*Alces alces*) management situation differs from most areas of North America since natural predators do not limit moose density and control of moose population growth depends on hunter harvest (Bergerud and Manuel 1962; Bergerud *et al.* 1968). Black bear (*Ursus americanus*) predation affects moose population growth in some areas of Newfoundland through predation of calves (Mahoney 1984), but in most Moose Management Units (MMU's), a controlled hunter harvest has up until now largely determined moose densities (Mercer *et al.* 1988). In contrast, natural predators, i.e. wolves (*Canis lupus*) and bears (*Ursus* sp.), combined with uncontrolled native hunting limit moose populations in many areas of North America (Hauge and Keith 1981, Gasaway *et al.* 1983, Bergerud *et al.* 1983, Messier and Crête 1985, Larsen *et al.* 1989).

Moose were introduced to Newfoundland at the turn of the century just before the extermination of wolves (Pimlott 1953). Potential predators of moose on the island include black bears, lynx (*Lynx canadensis*) and recently coyotes (*Canis latrans*). By the 1950's moose occupied most of the potential moose habitat in Newfoundland and Pimlott (1959) made note of the need to harvest more moose in the inaccessible southern portion of the island (Fig. 1). This region has little hunting pressure, low moose densities (0.5 moose/km^2) and sparse forest cover (21%; Mercer *et al.* 1988). From 1960 to 1972 aerial survey results and harvest statistics suggested a general decline in the moose population attributed by Mercer and Manuel (1974) to overhunting in accessible areas and to range deterioration through overbrowsing in areas of poor hunting access. In 1973 an island-wide quota system was introduced in an effort to maintain moose numbers in balance with their food resource (Hancock and Pike 1980).

Mercer and Manuel (1974) suggested that moose populations in areas inaccessible to hunters were in poor condition (i.e. low productivity and small size) because population growth was restricted by food limitation

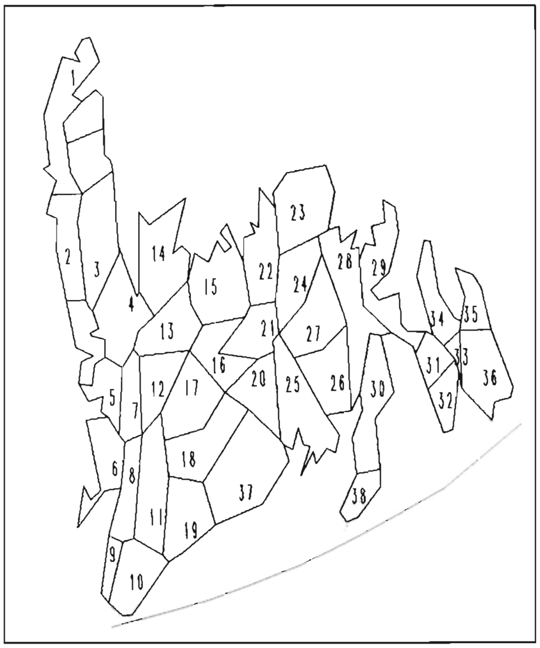

Fig. 1. Thirty eight Moose Management Units in Newfoundland.

rather than predation. Moose lack efficient density dependent life history strategies for regulation of population growth since they have evolved with efficient predatory regulation (Keith 1974). Without predators, managers use human hunting to simulate density dependent predation to support optimal density for maximum sustainable yield while maintaining moose in good condition (McNab 1985). Maintaining optimum moose densities in these inaccessible areas has posed a unique problem for moose managers in Newfoundland.

The vegetative carrying capacity is related to the productivity of the land for moose and the amount of forest cover best defines this relationship (Ferguson *et al.* 1988). Forested regions of the province support the highest moose densities (2.9 moose/km^2; Mercer *et al.* 1988) set by vegetative carrying capacity. Also these regions generally contain the best road systems developed for logging operations.

The objectives of this investigation were to describe the relationship between hunter accessibility, land types (forest cover) and moose condition in a conceptual model and apply this information to better manage Newfoundland moose populations. We hypothesize that moose mortality from hunting in inaccessible MMU's has since 1974 not been sufficient to maintain moose population densities below the habitats carrying capacity set by food availability.

We further hypothesized that insufficient harvesting is correlated with poor condition of moose: lower productivity and recruitment, smaller animals and an older-aged population. We predicted that since 1974 resident hunters in inaccessible MMU's, relative to accessible MMU's, have: (1) observed fewer calves and killed fewer calves and yearlings; (2) reported fewer antler points from the bulls shot; (3) shot smaller moose, as indicated by the length of yearling mandibles; and (4) shot older animals as indicated by the age of harvested females.

METHODS

The following seven variables were used to measure moose condition in Newfoundland from 1974 to 1987: (1) productivity and recruitment measured as (i) percent calves observed by resident hunters, (ii) percent calves observed on aerial surveys, and (iii) the percentage of calves and (iv) yearlings represented in the resident harvest (harvest is the sample of mandibles returned by hunters); (2) size of animals as indicated by (i) the length of yearling mandibles and (ii) by the mean number of antler points of bulls; and (3) relative age of the population as shown by the mean age of harvested females. We considered these seven variables together to measure moose condition.

Hunter Questionnaires

Hunt statistics were obtained from license questionnaires. Hunters successful in the draw were obligated to complete questionnaires attached to their licenses. About 50% of the hunters returned the questionnaire within a week of the end of the season

(Ferguson *et al.* 1988). Follow-up returns were used to obtain information from non-respondents. Hunter information included: hunter name, address, MMU hunted, length of time hunted, number and types of moose and other wildlife observed, and for successful hunters, the date of kill, location of kill, age (adult or calf), sex, and number of antler points for males.

Land Cover Types

Hancock (1981) calculated composition of land types for MMU's from the 'global inventory' conducted during the 1960's and 1970's by the Newfoundland Department of Forestry (Delaney and Osmond 1977). The Department of Forestry defined forest cover as land carrying tree growth of stocked forest types.

Mandible Collections

Lower mandibles were collected from hunters at check stations, via the mail, or from hand deliveries. Age of moose was determined from eruption pattern for calves and yearlings and by counting cementum annuli of the first incisor from older animals (Sergeant and Pimlott 1959). Percent yearlings (Y) and percent calves (C) were calculated (%Y=Y/C+Y+Ad or %C=C/C+Y+Ad). Mean age of females was calculated using the total hunter harvest for MMU's and included calves and yearlings. For each MMU, the mean yearling mandible length was used as a measure of relative size of moose.

Aerial Surveys

Aerial moose survey methods since 1972 have been done using helicopters, primarily Bell 206A and B, to count moose on 4 km square quadrants with systematic-random block sampling (Ferguson *et al.* 1988). Moose were classified according to age (calf, yearling or adult) and sex.

Statistical Analyses

Standard parametric two-tailed tests with F and t-statistics were used (Sokal and Rohlf 1969) and analyses (cluster, principal component, correlation, regression and canonical discriminant analysis) were performed on an AT microcomputer using SAS statistical packages (SAS/STAT Guide: 1987).

For frequency comparisons, we used G Tests of independence since like the analysis of variance, it permits investigation of whether the effects of two independent variables interact (i.e. whether the relationship between two classifications differs across the range of MMU's).

Cluster analysis was used as a mathematical method to find out which objects (MMU's) in a set are similar (Ferguson and Mercer 1989). The standardized data matrix (objects and attributes) were used to compute the values of the Euclidean distance (resemblance coefficient). Average linkage clustering method (UPGMA) processed the values of the resemblance coefficient to create a diagram called a tree, or dendrogram, that showed the hierarchy of similarities among all pairs of objects (Romesburg 1984). From the tree the clusters were read off so that 3X3 contingency table analysis could be used to test the research hypothesis using the hypothetico-deductive method (Romesburg 1981). We coupled the use of cluster analysis with discriminant analysis to obtain a secondary validity of the classifications of MMU's based on moose condition.

Hunter accessibility was defined as the mean distance to access roads. We used a systematic point census method by sampling at the intersection points of the mercator grid lines on 1:50000 topographic Big Game Hunting Area Maps. We defined inaccessible MMU's as areas that hunters cannot access easily because of the lack of roads and this includes MMU's with the mean distance to roads greater than 2 km.

The objects used in the analyses were 38 MMU's in Newfoundland that range in size from 800 to 7402 km^2 (Fig. 1). These MMU's were originally delineated subjectively on the basis of accessibility, vegetation, geography, size, and characteristics of the moose population (Mercer and Manuel 1974). The number of MMU's in Newfoundland increased from 36 in 1974 to 45 in 1987. Because of small sample sizes, we used information for 38 MMU's of a possible 40 delineated in 1978. Since 1978, MMU's have been subdivided but the outer boundaries have remained intact.

Principal component analysis was used as a multivariate technique to derive a small number of linear combinations (principal components) of a set of condition variables that retain as much of the information in the original variables as possible. We used principal component analysis to summarize the seven measures of moose condition by reducing the number of variables (first and second principal components) used to detect linear relationships in regression analysis against the measure of mean distance to roads and percent forest cover. Regression analysis was used to describe the relationship between moose condition and hunter accessibility.

RESULTS

Classification Based on Moose Condition

Hierarchical cluster analysis of MMU's based on seven measures of moose condition suggested three clusters (Fig. 2). MMU34 clustered separately as an outlier and was therefore eliminated from contingency table analysis.

We labelled the largest group to a cluster of MMU's having moose in "good" condition (Table 1). Twenty six moose MMU's classified as "good condition" were characterized by (1) the greatest percentage of calves observed by hunters, observed on aerial surveys, and shot by hunters; (2) highest percent yearlings represented in the harvest; (3) largest body size as represented by greatest length of yearling mandibles and greatest number of antler points; and (4) lowest age of females.

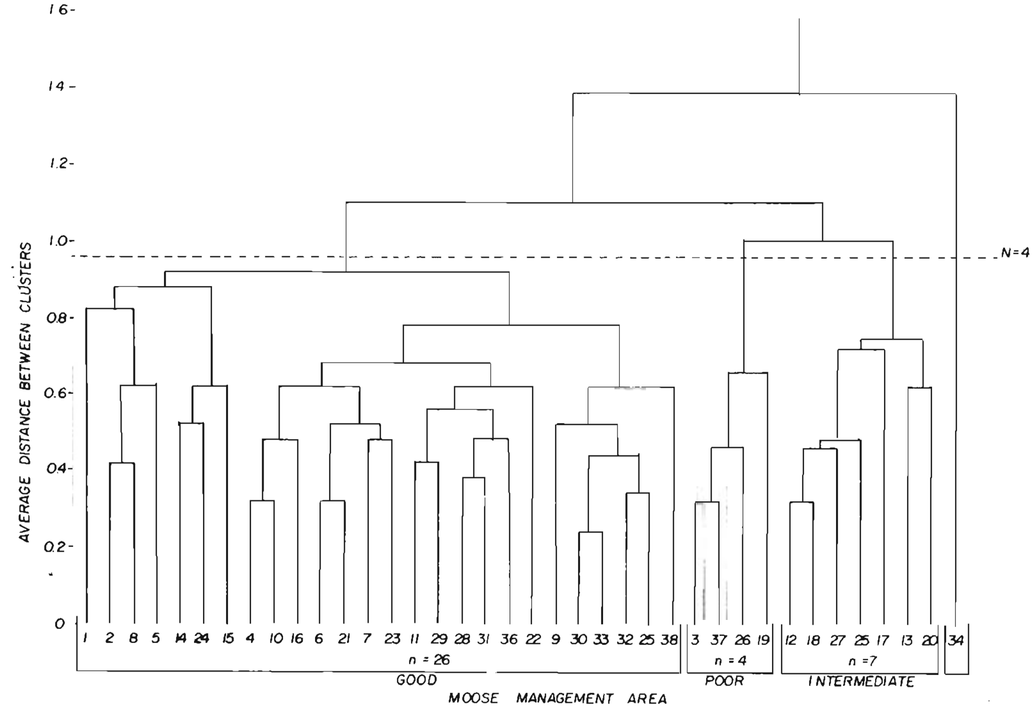

Fig. 2. Hierarchical cluster analysis of seven measures of moose condition for 38 Moose Management Units in Newfoundland.

Table 1. Class means for seven measures of moose condition for three clusters of 38 Moose Management Units in Newfoundland.

CLUSTER	Measure of Moose Condition						
	% Calves Seen by Hunters	% Calves Observed on Aerial Surveys	% Calves Shot by Hunters	% Yearlings Shot	Mean No. Antler Points (>4 yr)	Mean Length Yearling Mandible	Mean Age of Females (years)
Good (n=26)	13.2	24.1	7.2	33.5	16.2	407	3.4
Intermediate (7)	11.1	16.4	3.9	29.6	14.7	381	3.7
Poor (n=4)	12.9	13.3	3.2	19.2	13.0	400	5.3
Unit 34	15.6	23.3	18.9	32.2	16.5	418	2.2
Mean	12.8	21.5	6.5	31.3	15.6	402	3.6

These MMU's included most of the area of Newfoundland and all of the island's forested regions (Fig. 3).

We labelled the next cluster of MMU's as representing moose in "intermediate" condition. Moose harvested from these 7 areas were characterized by (1) a lesser percentage of calves observed by hunters, observed on aerial surveys and shot by hunters; (2) a somewhat lower percent yearlings in the harvest; (3) smaller yearling mandible lengths and lesser number of antler points; and (4) somewhat higher age of females. These areas are located in the south-central region of the island where forest cover is reduced and intermittent.

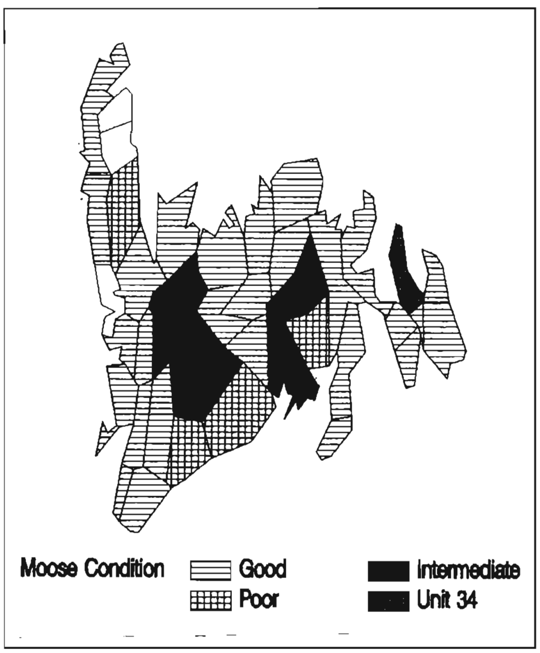

Fig. 3. Clusters of 38 Moose Management Units in Newfoundland according to moose condition.

The four MMU's labelled as having moose in "poor" condition were located in the southern part of the island and on the Northern Peninsula (Fig 3). The moose in these MMU's were characterized by (1) the lowest percentage of calves observed by hunters, observed on aerial surveys and shot by hunters; (2) lowest percent yearlings in the harvest; (3) small mandible lengths of yearlings and least number of antler points; and (4) highest age of females. MMU 34, clustered separately as an outlier, was characterized by moose in "excellent" condition with a high percent of calves and yearlings, very large yearling mandibles, a great number of antler points and a very low mean age of females.

Canonical discriminant analysis was used as a secondary test of the validity of the classifications obtained by hierarchical cluster analysis of moose condition. This second multivariate method verifies the classification by cluster analysis (Fig. 4). The three clusters identified appear distinct but some MMU's could be grouped differently. MMU 19, although clustered as having moose in "poor" condition, 'approaches' the cluster of MMU's having moose in "good" condition while management unit 11, although clustered as having moose in "good" condition, 'approaches' the cluster of MMU's having moose in "poor" condition. Also, MMU's 2 and 30 approach management unit 34 that clustered separately as an area with moose in "excellent" condition as indicated by large animals, young females and high productivity and recruitment.

Correlation Among Condition Variables

Most of the measures of moose condition were correlated (Table 2). Mean age of females in the harvest was used as a measure of overall mean age of the moose population and this measure was negatively correlated with the other six variables. Percent calves observed by hunters, calves observed on aerial surveys and calves shot by hunters were all correlated and these three measures were used to represent productivity. Percent yearlings in the harvest was correlated with calves observed during aerial surveys, mean antler points and mean age of females and was considered to represent recruitment. Mean length of yearling mandibles and mean antler points were not correlated, although these two measures were used to represent morphological condition or size of moose. Only two variables, mean age of females and percent yearlings in the harvest approached the high level of correlation (r>0.70) where Bowyer *et al.* (1988) recommended eliminating one variable from model building because of multicollinearity. Principal component analysis remedies multicollinearity and this technique is used to describe the relationships between the dependent variables, hunter accessibility and forest cover, with moose condition.

Tests of Independence

Three major clusters of 38 MMU's were identified according to (1) moose condition; (2) mean distance to roads as a measure of

Table 2. Correlation matrix for seven measures of moose condition for 38 Newfoundland Moose Management Units as observations. Pearson's correlation coefficients/ probability.

Variable	Percent Calves Seen by Hunters	Percent Calves Observed Surveys	Percent Calves in Harvest	Percent Yearl-ings in Harvest	Mean Number Antler Points	Mean Length of Ylg Mandible	Mean Age of Females
Percent Calves Seen by Hunters	- -						
Percent Calves Aerial Surveys	0.221 0.183	- -					
Percent Calves in Harvest	0.393 0.015	0.387 0.016	- -				
Percent Yearl-ings in Harvest	-0.167 0.315	0.468 0.003	0.052 0.757	- -			
Mean Antler Pts. For Males >4 yrs	-0.124 0.459	0.325 0.046	0.008 0.962	0.456 0.004	- -		
Mean Length of Ylg Mandibles	0.483 0.002	0.469 0.003	0.373 0.021	0.103 0.538	0.110 0.510	- -	
Mean Age of Harvested Females	-0.154 0.356	-0.513 0.001	-0.462 0.004	-0.633 0.0001	-0.285 0.082	-0.270 0.101	- -

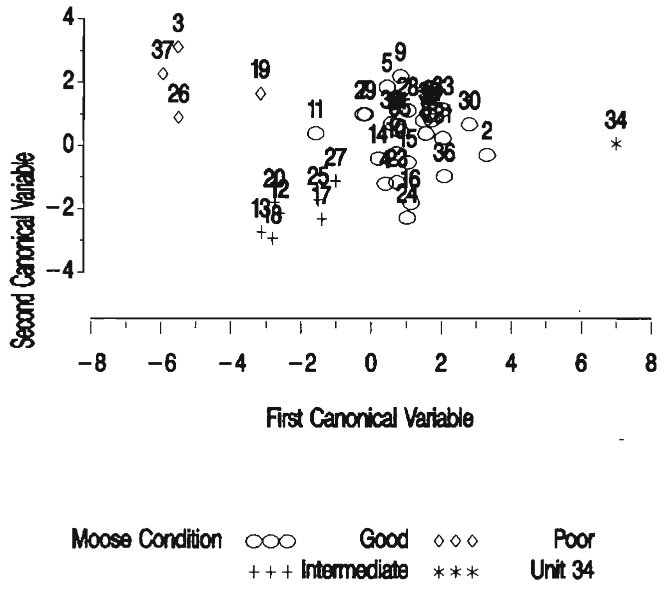

Fig. 4. Canonical variables identified by four clusters of 38 Moose Management Units in Newfoundland based on moose condition.

hunter accessibility; and (3) land types as a measure of productivity of the land for moose. The three classifications appear similar (Fig. 3, Fig. 5 and Fig. 6). The three methods of hierarchical classification based on measures of hunter accessibility, land types and measures of moose condition were not independent. The best correlation of two classifications was between hunter accessibility and moose condition suggesting that condition of moose was related to hunter accessibility (G-Test Likelihood Ratio = 28.5, P=0.0001). This test supports the hypothesis that moose mortality from hunting in inaccessible MMU's has not been sufficient to maintain moose population densities below their habitat's carrying capacity set by food availability. The next best correlation was between classifications based on moose condition and land types (G-Test Likelihood Ratio = 18.1, P=0.001). Also, the two classifications of MMU's based on hunter accessibility and land types were correlated (G-Test

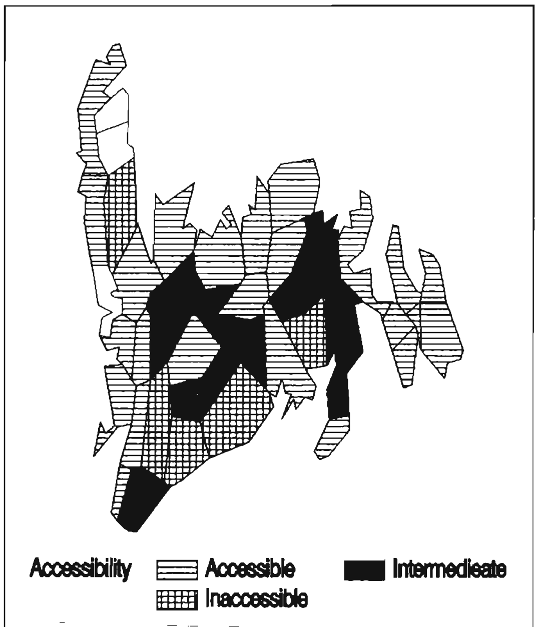

Fig. 5. Clusters of 38 Moose Management Units in Newfoundland according to mean distance to roads.

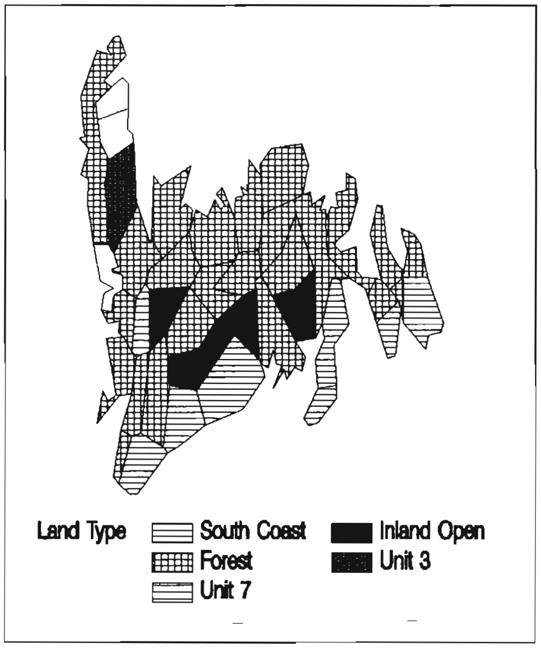

Fig. 6. Clusters of 38 Moose Management Units in Newfoundland according to land types.

Likelihood Ratio = 12.1, P=0.017).

Relationship Between Moose Condition and Hunter Accessibility

Principal component analysis was used to reduce the number of moose condition variables for regression. The first principal component accounted for 40 percent of the standardized variance and measured overall moose condition. The interpretation of the second component is not obvious and therefore only the first component was used in regression analysis with the measure of hunter accessibility, (mean distance to roads) and productivity of the land (percent forest cover).

The relationship between the first principal component of moose condition and distance to roads was best described by the log of the component (log model F=94.6, df=37, P=0.0001; Fig. 7). This plot is curvilinear and indicates that areas greater than 2 km start to show characteristics of moose in poor condition. The MMU's, 3, 26 and 37 appear to provide a major contribution to the significance of this relationship yet removal of these three MMU's did not substantially reduce the significance of the relationship (log model F=14.5, df=34, P=0.0006).

The relationship between the first principal component of moose condition and forest cover was best described by the square of the component (squared model F=11.4, df=37,

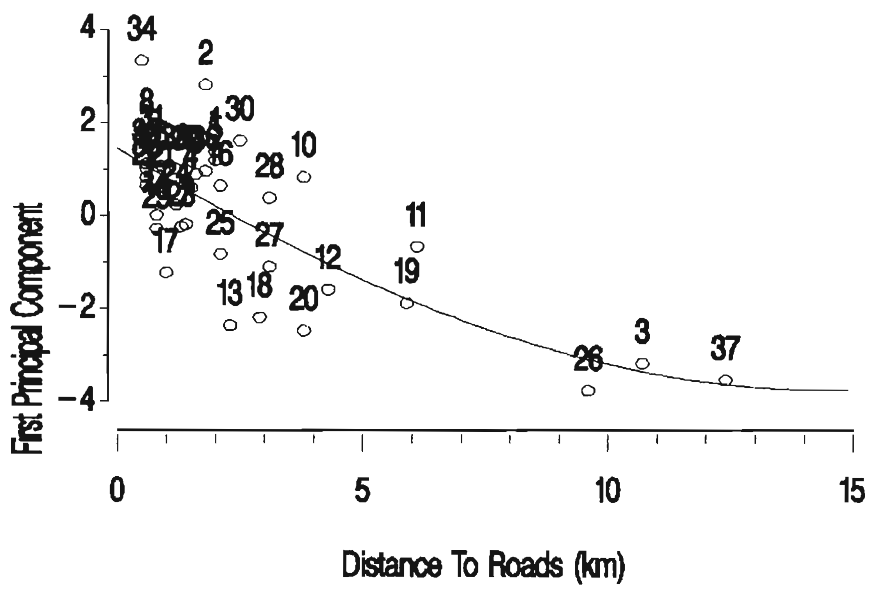

Fig. 7. Relationship between moose condition, according to the first principal component of seven variables, and mean distance to roads for 38 Moose Management Units in Newfoundland.

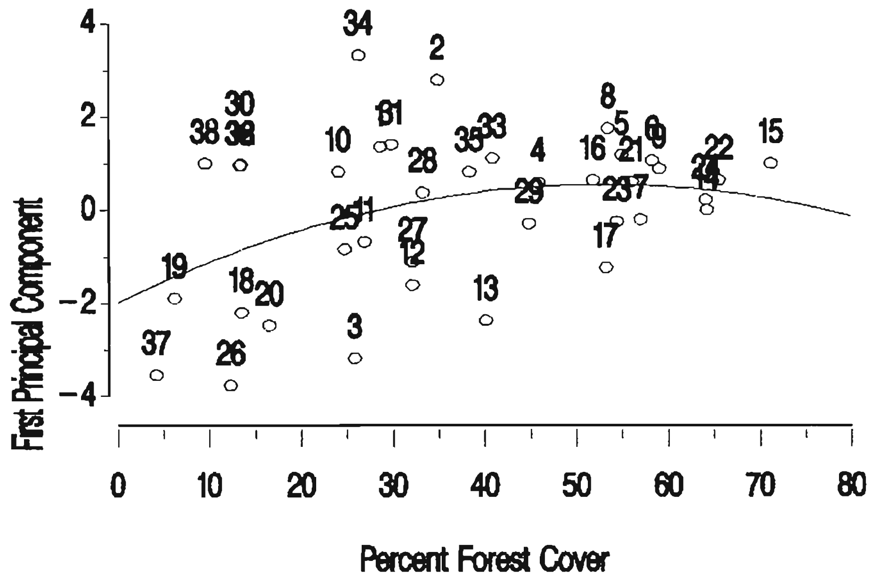

Fig. 8. Relationship between moose condition, according to the first principal component of seven variables, and percent forest cover for 38 Moose Management Units in Newfoundland.

P=0.0018; Fig. 8). This plot is also curvilinear and indicates that areas with less than 20% forest cover may start to show moose in poor condition. The exceptions to this pattern are MMU's 30, 34 and 38 where moose have recently colonized.

Multiple regression analysis was used to determine which of the seven measures of moose condition together best correlated with the measure of hunter accessibility and forest cover. The two condition variables that best correlated with hunter accessibility were mean age of females harvested and mean antler points of males harvested (df=37, R^2=0.68, F=37.3, *P*=0.0001) while the two condition variables that best correlated with forest cover were percent yearlings in the harvest and antler points of males (df=37, R^2=0.42, F=12.6, *P*=0.0001).

DISCUSSION

We hypothesized that moose in inaccessible MMU's in insular Newfoundland presently are in relatively poorer condition than moose in accessible areas because moose in inaccessible areas have been limited by vegetation rather than natural or hunting predation. Clustering MMU's according to good, intermediate and poor for moose condition and hunter accessibility showed that the two classifications were more similar than a classification of MMU's based on land types. The relationship between hunter accessibility and moose condition is curvilinear and the model formulated indicates that MMU's with most of their area greater than 2 km from roads are inaccessible to most resident hunters. Also the relationship between forest cover and moose condition is curvilinear and areas with less than 20% forest cover generally have moose in poor condition.

The results of this investigation can direct management decisions since the basic classifications of MMU's according to moose condition, hunter accessibility and land type can delineate different harvesting regimes. For example, the inaccessible south coast area is sparsely forested and Mercer and Manuel (1974) suggested that less than 20% of the total area contained suitable moose winter habitat, the remaining area being maritime barrens. Subalpine and maritime barren habitats are at best poor habitats for moose and they are fragile habitats where vegetative disruption can occur fairly quickly while recovery would be very slow. It may be necessary to maintain low densities in these areas for a long period of time (>10 years) to allow for regeneration of shrub and forest cover and thereby increasing the vegetative carrying capacity.

MMU's grouped as having moose population in poor condition, inaccessible to hunters and with little forest cover (3, 11, 18, 19, 26 and 37) require an increased hunter harvest. The MMU's 30, 32, 36 and 38 are located within the southern maritime barrens. Although moose populations in these MMU's are in good condition according to the measured variables, moose have only recently colonized these areas and densities should be kept low to prevent deterioration of the habitat in future. Vegetative plots would help establish if there are herbivorous competitors (caribou [*Rangifer tarandus*], hares [*Lepus sp.*]) to moose that are complicating the relationship between moose density and vegetative carrying capacity.

The MMU's grouped as intermediate in hunter accessibility, forest cover and moose condition require a different management solution. These MMU's were identified as 12, 17, 20, 25, 27 and also parts of MMU's 10, 13, 16, 28 and 30. The inaccessible areas within these MMU's need to be delineated and a computerized mapping system (GIS) can identify these areas from forest classification information and detailed road system maps.

We propose three approaches: (1) increase license quotas for residents and through additional enforcement ensure that these hunters hunt in the inaccessible MMU's; (2) increase license quotas for winter hunts when snow cover allows easier access by snowmachine to inaccessible MMU's; and (3) increase nonresident license quotas, including allowing a harvest of females, for outfitting camps located within these inaccessible MMU's. Information on the moose harvested from these MMU's can help identify specific outfitting camps. For extreme MMU's we recommend all three solutions. For intermediate MMU's we recommend the first two solutions, of increasing resident quotas and allowing winter hunts. We need better mapping of inaccessible and accessible areas, a restructuring of MMU's and a harvest that will ensure food supplies and a maximum sustainable yield.

An important part of management would be to monitor the success of proposed management practices. We recommend that annual measures be taken of the three variables determined by regression analysis to best represent moose condition: (1) mean age of females harvested, (2) mean antler points for male moose greater than 4 years old; and (3) percent of the harvest represented by yearlings. We recommend caution in using mean age of females because this measure was correlated with both percent calves and yearlings in the harvest and productivity of females varies with age. These three measures can be used with the derived regression functions to calculate a measure of moose condition that can be used to monitor success of the implemented management program. We plan to include measurements of fecal nitrogen and fat content of mandibles in future to better measure changes in moose condition over the short term. We intend to continue managing moose in Newfoundland using a conceptual model that combines the three interacting systems of population demography, hunter behaviour and habitat productivity.

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