HOW MANAGEMENT UNIT LICENSE QUOTAS RELATE TO POPULATION SIZE, DENSITY, AND HUNTER ACCESS IN NEWFOUNDLAND

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ABSTRACT: We recommend introducing habitat-based moose density as a management tool to be used in annual quota setting. We illustrate our recommendation with the case of Newfoundland, where moose densities are much higher than elsewhere in North America, and have led to local areas of habitat deterioration and subsequent population decline. We suggest more emphasis be placed on relationships between local densities of moose and reported hunter kill locations to stabilize populations. We calculated both moose density and moose-kill density using estimates of forest and "scrub" cover in management units surveyed between 1985 and 2001, comparing aerial surveys with license sales for the same year to hunter success. In the first part of our study period, license quotas were often well below 10% of population size estimates calculated by management unit, especially in central Newfoundland. In the latter part of our study period, a strong relationship between license quotas and population estimates ($r^2 = 0.81$) existed, in which quotas averaged about 15% of a population size estimate; however, moose kills and population size were less well correlated. Overall during this period, kill density increased, while moose density decreased, sometimes below target.

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Effective management of moose (*Alces alces*) populations requires on-going assessment of their size and productivity, ideally along with habitat assessments. It also requires consideration of the feasibility of implementing various hunting strategies, based on hunter demand and capability, and further on the ability of wildlife managers to understand moose population dynamics. Spatial variation in moose population dynamics and in hunter success within a management unit may demand an analysis finer than what is incorporated in a sequence of unit-by-unit comparisons of aerial survey summaries and hunting objectives. Unfortunately, innovative licensing strategies within a management unit are rarely undertaken (one example is described in McLaren et al. 2000), even though to undertake a fine-scale, habitat-based approach to management has long been a recommendation to managers (Timmermann and Buss 1998). Unlike the usual approach to moose management, carried out by estimating population size and assigning a sustainable "share" or "quota" to hunters, we recommend approaching moose populations by introducing habitat-based density measures as the basic management parameter. This paper is directed to illustrating our recommendation using the case of moose management on the island of Newfoundland, Canada.

An interesting perspective granted by Newfoundland moose also comes from our

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experience that for game species, much focus is spent by managers on cases of declining populations, which are the short-term interest of the hunting public. Much less is understood about overpopulations, even though the situation ironically also leads in the long term to declining populations (McLaren et al. 2004). Overpopulation, or overabundance, usually occurs following introduction into unexploited habitat and persists in situations without natural predators (McShea et al. 1997). This is the case for Newfoundland, where wolves (*Canis lupus*) are absent due to their extirpation in the 1920s, and as a result, moose densities are much higher than elsewhere in Canada. Active control strategies to optimize condition of moose and moose habitat then arguably become a primary responsibility of managers (McLaren et al. 2004). Several decades ago, Pimlott (1953) suggested that inadequate hunting was the most pressing issue facing moose management, particularly in Newfoundland. Associated with his argument were concerns for inaccessibility of large areas, refusal of logging companies to permit hunter access to their licensed lands, public pressure against liberalizing hunting seasons and against the killing of females, and the lack of inclination and/or inability of most hunters to penetrate into a hunting area from an established road. Another concern recognized during the 1960s was the inaccuracy of many moose aerial surveys (Bergerud and Manuel 1969). Mercer (1995) and Mercer and McLaren (2002) reviewed some of these same concerns and determined that problems still exist regarding the access by hunters of remote areas and the ability of moose surveys to detect local overpopulations in certain management units.

Current stated goals for moose in Newfoundland include a target density of 2 moose / km^2 of forested habitat in each moose management unit. Yet, achievement of this goal is assessed only as an average for an entire management unit. Mercer (1995:92) presents the position that more emphasis be placed on relationships between densities of moose and hunter moose-kill to achieve this target and also to stabilize populations. This paper considers these variables explicitly and reviews moose management in Newfoundland in two periods, before and after Mercer's (1995) recommendation. We will focus our discussion on local moose overabundance in Newfoundland.

STUDY AREA

The island of Newfoundland, 112,000 km^2, is situated off mainland Canada in the North Atlantic, near 50° N latitude and 55° W longitude (Fig. 1). About two-thirds of the island is forested, in an area roughly bisected by the route of the Trans Canada Highway, plus in additional areas of the Northern Peninsula, Avalon Peninsula, west coast, and in river valleys along the south coast. Most forests consist of a combination of balsam fir (*Abies balsamea*) and spruce (*Picea* spp.), with a mix of pioneer (*Betula* spp. and *Populus tremuloides*), and tolerant (*Acer* spp. and *Sorbus* spp. and other) hardwoods.

Moose (*A. a. andersoni*) were introduced to central Newfoundland in 1878 with the release of a male and female from nearby Nova Scotia (Pimlott 1953). A second release of two males and two females from New Brunswick, into western Newfoundland, followed in 1904. The arrival of moose to the Avalon Peninsula appears to have been delayed by several decades due to slower migration across a narrow isthmus (Broders et al. 1999). The island-wide population increased to record high numbers, about 150,000, by 1986 (Mercer 1995), after which populations decreased, to a 1999 post-hunt estimate of 125,000 animals (Mercer and McLaren 2002). Moose now occupy all parts of the island of Newfoundland, with higher densities in forested than in non-forested areas.

More than half a million Newfoundland moose have been taken by licensed hunters since 1945. The majority of licenses are sold

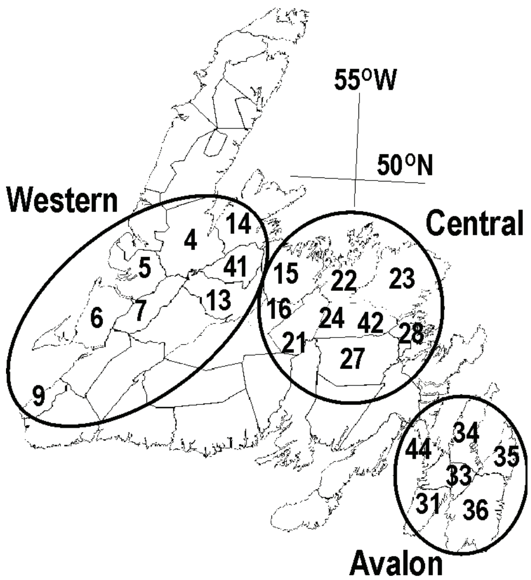


Fig. 1. Location of 23 moose management units along the Trans Canada Highway in Newfoundland, for which aerial survey data are available for two periods, 1985-1991 and 1993-2001.

to residents, from access linked to the Trans Canada Highway (Ferguson et al. 1989). License sales offer limited-entry opportunities to hunters, with a combination for most units of a selective hunt by sex (mostly male-only and some female-only tags) and a more restrictive draw for either-sex moose tags. Young of the year (calves) can be taken on both license types. Calculation of the combined license quota for each management unit begins with a population estimate from the last available aerial survey and a management objective (i.e., an increasing, decreasing, or stable population). For each year since the last aerial survey, an estimate of population recruitment is based on observed productivity (i.e., the number of calves) at the time of the survey. Recruitment is adjusted by estimates of natural, late-winter mortality. Mortality estimates in the population also include the number of moose killed by hunters based on hunter information (submitted mandibles and a mandatory report of success on individual licenses), and losses to poaching, crippling, and moose-vehicle collisions (Mercer 1995). Recruitment and mortality estimates are combined with reports of the number of moose seen by hunters with either-sex tags. The reconstructed population is used to create a "quota." Quotas are most often changed when a management unit is periodically resurveyed (about once every 5-10 years) and found to be above or below "target." Hunters provide in many cases a written description of their kill location, as well as information on maps attached to their license returns as to the 5 km × 5 km area where they took their animal.

Demand for resident hunting in Newfoundland has historically been high, and the number of licenses sold in most management units is very near to the quota. Allocations to non-resident hunting vary by management unit, are often given special consideration in more remote areas, and usually complete the filling of the quota for any area. Non-resident, outfitter-based hunting currently accounts for 10% of license sales as an average for Newfoundland. There is no special consideration for First Nations hunters in this part of the province. Resident hunter success varies considerably both among and within Newfoundland management units and is correlated both to the variability in moose density (Ferguson and Messier 1996) and to road accessibility (Ferguson et al. 1989). In 2002, 26,360 moose licenses were sold for insular Newfoundland. An average resident license success rate of 69% was achieved during a season approximately from September to December.

METHODS

Twenty-three sample moose management units, ranging in size from ca 700 to ca 4,500 km^2, were selected from among those in insular Newfoundland considered most accessible to resident hunters. This selection, chosen to represent a standardized level of access to hunting, excluded special management units (created in a few remote locations) but included any management unit intersecting the Trans Canada Highway, plus two management units on the Avalon Peninsula less than a 30 minute drive from the highway and less than an hour from metropolitan St. John's (Fig. 1). Choice of management units was also based on availability of aerial population estimates in our two periods of interest, 1985-1991 and 1993-2001, roughly before and after management recommendations made in the early 1990s (Mercer 1995). These two periods also correspond to the last peak moose density recorded and to the most recent population estimates for most areas (Mercer and McLaren 2002). Only two management units adjacent to the highway, units 8 and 10 in western Newfoundland, were excluded from our analysis due to lack of data.

Moose population estimates were obtained from calculations (Inland Fish and Wildlife Division, 1985-2001, unpublished) made following a modification of the stratified random block survey (Gasaway et al. 1986), usually conducted from mid-January to late March. Area stratification for these surveys was typically from Cessna-185 aircraft at an altitude of 50-150 m. Census blocks ranged from 2-4 km^2 and moose were counted by 3 observers and a pilot in a helicopter (typically Bell 206B and 206-L). Search intensity was usually 4-5 minutes / km^2. An estimate of 50% visibility has been used in all calculations to account for observer bias (unseen moose), based on averages from a set of calibration efforts in the 1980s (Oosenbrug and Ferguson 1992). Moose density was calculated from estimates of the area of merchantable forest and non-merchantable ("scrub") cover from forest inventory maps of each management unit.

License sales and estimates of moose kill were obtained for the same years as the moose survey, within the two study periods as available, from files of the Department of Tourism, Culture and Recreation. Kill density was calculated using estimates of forest and "scrub" cover in each management unit as a suitable range for hunting; i.e., using the same factor as in the calculation of moose density. Kills were estimated from the reports of hunters responding to a questionnaire and adjusted for all non-respondents by the reports obtained in one mailed questionnaire reminder. Kill estimates, then, are calculated as a proportion of license sales. Thus, sales rather than quotas are reported in our correlations, although the difference between license sales and license quotas is insignificant (Table 1). In comparisons of license sales and kill density with population estimates, all correlations significant at $P > 0.05$ were reported.

RESULTS

During the first study period, 1985-1991, moose license quotas in eastern Newfoundland were well below 10% of population size calculated by management unit, especially in central Newfoundland (Table 1, Fig. 2). By 1993-2001 this situation changed, with quotas > 10% of the population in all sampled management units, and >20 % of the population in 15 of the 22 management units we sampled, including all but unit 44 on the Avalon Peninsula (Table 2). Aerial survey data became available for western Newfoundland during the second period, and in this area, all units except unit 14 were assigned a quota > 20% of the moose population estimate. Thus, a strong relationship between license quota and population size developed over time for the management units in our survey, with quotas averaging close to 15% of the estimated moose population size ($r^2 = 0.81$) in the 1993-2001 period (Fig. 2). A consistent and strong relationship existed between the number of licensed kills and the moose population in management units on the Avalon Peninsula, $r^2 = 0.99$ ($n = 3$) during 1985-1991, and $r^2 = 0.91$ ($n = 6$) during 1993-2001 (Fig. 3). However, for central Newfoundland, the same relationship was stronger during 1985-1991, $r^2 = 0.94$ ($n = 4$), than during 1993-2001, $r^2 = 0.66$ ($n = 8$). In a comparison of the earlier and the later periods, kill density increased while moose density decreased in most management units on the Avalon Peninsula and in central

Table 1. Data references and calculations used in this study for the first of two periods in Newfoundland moose management, 1985-1991. Target moose density in Newfoundland is 2 moose / km^2 of forested habitat; our estimate of density combines forested and non-forested portions of a management unit.[1]

Unit	Survey Year	Population Estimate	Density[1]	Quota	License Sales	Percent Hunter Success	Kill Density	Percent of Population Killed
Central Newfoundland (4 Management Units Surveyed)								
22	1990	6270	3.86	180	180	71.9	0.08	2.1
23	1991	8557	3.00	340	340	61.9	0.07	2.5
24	1985	3663	6.45	350	350	53.6	0.33	5.1
27	1989	6032	3.00	180	180	58.0	0.05	1.7
Avalon Peninsula (3 Management Units Surveyed)								
33	1987	1680	3.48	170	170	63.3	0.22	6.4
34	1986	2100	2.56	100	100	86.1	0.10	4.1
36	1986	5738	5.34	950	950	60.5	0.54	10.0

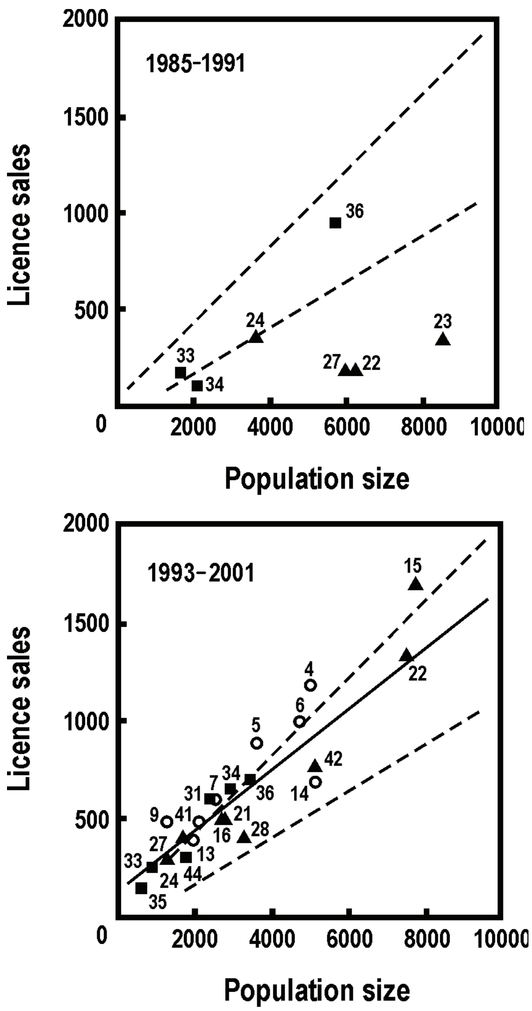
[1] Our estimate of density is based on forest and "scrub" cover from forest inventory maps for each unit; our calculation is an overestimate because moose use areas outside these cover types; on the other hand, if moose use forest preferentially, then their density in forest cover alone would have a higher expected value than in our average for forest and "scrub" cover.

Newfoundland (Tables 1 and 2). Kill density was only weakly (not significantly) correlated with population density in our sample from western Newfoundland, $r^2 = 0.39$, where data were available only for 2001.

DISCUSSION

Our Recommendation to Set Quotas Using Density and Habitat Information

For effective moose management that incorporates a "biodiversity" approach, data from aerial surveys must be combined with habitat information both before periodic aerial survey (during stratification of the management unit for survey purposes) and in the intervening time between surveys (when we argue that both moose density and habitat be given consideration during a quota-setting exercise). The easiest calculation of density might be termed a "coarse filter" approach: in our calculation, to arrive at density from a measure of available habitat from forest inventory maps. We recognize that closer attention to habitat might distinguish categories of forest types and forest age, known to have very different carrying capacities (e.g., Parker and Morton 1978). Variation in moose density, alternatively variation in carrying capacity, is important and is regrettably too often ignored after survey stratification. It is informative from our review that the density of moose appears to be highly variable among Newfoundland management units Fig. 2. Moose quotas, expressed as license sales, relative to population size in management units in western Newfoundland (open circles), in central Newfoundland (triangles), and on the Avalon Peninsula (squares), in 1985-1991 and 1993-2001. Management units were selected along the Trans Canada Highway, as shown in Fig. 1. The dashed lines indicate a range, in which quotas fell between 10 and 20% of the population size. The solid line indicates the correlation between license sales and population size during 1993-2001 for all units, $r^2 = 0.81$. even in a coarse measure of habitat availability. This variation is acknowledged by managers during survey stratification, but perhaps less recognized for its potential to lead to overpopulation and habitat deterioration unless it



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is given special attention during quota setting.

In the Newfoundland example, moose management during 1985-1991 failed to address overpopulation by even a simple approach to proportional quota setting for management units 22, 23, and 27, an apparent failure particular to central areas (Fig. 2). These management units, while recognized as containing some of the more remote hunting areas, do not actually have the highest moose densities. According to our calculations, they are nevertheless above target, like all areas during 1985-1991 (Table 1). Areas above target density should be managed for higher hunter kill, which has generally occurred, but with more apparent success on the Avalon Peninsula (Fig. 3). During the period after recommendations to address density in management, closer correlation occurs between license sales (quotas) and population size (Fig. 2). However, during the same period, less correlation occurs between kill density and population density, particularly in western Newfoundland (Fig. 3). The proportion of moose killed by hunters ranges from < 7% to > 32% (Table 2). The differences between periods and the variation in hunter success and activity that we report suggest that management has improved in terms of a simplistic and proportional approach to population size, a goal probably typical of ungulate management. At the same time, there is no apparent effort to assign quotas to manage kill density proportionally to moose density.

Differences in kill density in a perfect management system would be due only to specific objectives like targeting a population for reduction. However, manipulation of license quotas to achieve an increase or decrease in hunter kill is always a “best guess,” considering the accuracy and currency of data on moose and on hunting. Moose population estimates are always inaccurate, especially given observer bias equivalent to 50% visibility, as in our example. Population estimates also have wide confidence limits, often over 20%, especially within a density stratum. Lag time between surveys of up to 10 years creates further difficulty in assessing population size. Hunter kill is imperfectly estimated, because hunters do not completely or accurately report their kill activity or location. Moreover, directing

Table 2. Data references and calculations used in this study for the second of two periods in Newfoundland moose management, 1993-2001. Calculations are as in Table 1.

Unit	Survey Year	Population Estimate	Density	Quota	License Sales	Percent Hunter Success	Kill Density	Percent of Population Killed
Western Newfoundland (8 Management Units surveyed)								
4	1997	4992	1.69	1200	1198	57.8	0.23	13.9
5	1993	3548	2.75	900	899	82.0	0.57	20.8
6	1994	4674	3.03	1000	999	72.2	0.47	15.4
7	1994	2478	2.48	610	610	70.6	0.43	17.4
9	1996	1217	2.07	500	500	78.2	0.66	32.1
13	1997	1870	1.55	400	399	62.4	0.21	13.3
14	1997	5117	1.89	700	700	79.5	0.21	10.9
41	1997	2039	2.24	500	500	62.8	0.34	15.4
Central Newfoundland (8 Management Units surveyed)								
15	1996	7759	3.02	1700	1694	65.9	0.43	14.4
16	1994	2695	2.37	500	495	54.4	0.24	10.0
21	1997	2736	1.92	500	500	61.6	0.22	11.3
22	2000	7490	4.61	1350	1334	71.9	0.59	12.8
24	1991	1237	2.18	300	300	53.6	0.28	13.0
27	1997	1600	0.80	400	399	58.0	0.12	14.5
28	2001	3226	1.80	400	400	62.4	0.14	7.7
42	1997	5106	4.65	800	764	45.3	0.32	6.8
Avalon Peninsula (6 Management Units surveyed)								
31	1996	2319	4.48	600	600	65.1	0.75	16.8
33	1995	833	1.72	250	250	63.3	0.33	19.0
34	1997	2876	3.5	650	650	86.1	0.68	19.5
35	1995	548	0.91	150	150	45.4	0.11	12.4
36	1995	3402	3.17	700	700	60.5	0.39	12.4
44	1997	1710	6.13	300	300	82.3	0.88	14.4

hunter kill to target geographically isolated overpopulations will create a lower overall hunter success, contrary to normal management objectives. All the same, we present the case that optimal management will certainly not be achieved if quotas are assigned by assuming that a maximum sustained yield exists proportional to all population sizes. Problems are certain to arise if hunter success is not viewed and monitored as a spatial variable, especially as overall hunter success declines with demographic changes and busier lifestyles.

Our very feasible recommendations are to factor habitat into an explicit measure of moose density, and further to acknowledge and account for spatial variation in hunter success that influences kill density. Interestingly, this approach has a few precedents in Newfoundland, where management objectives to target overpopulations met with success. For example, in the 1960s, a small area of central Newfoundland, located within management unit 16, had experienced failure in forest regeneration due to moose overabundance. The situation was confirmed by forest survey and by a moose aerial census (Bergerud and Manuel 1969). The area was then specifically targeted for a reduction of moose using special hunting licenses (Bergerud et al. 1968). In a contemporary example, McLaren et al. (2000) described the creation of a management subunit, within unit 15, to direct additional hunter effort where the central Newfoundland forest industry was also sustaining losses. It seems unfortunate to us that examples have not arisen outside of forest economic concerns, when, as we stated in the introduction, negative ecological effects associated with habitat and subsequent moose declines can be avoided by addressing any case of overabundance. Furthermore, sufficient information exists in a modern, updated forest inventory as to classification of disturbed areas and predictions about moose habitat, which can be combined with fairly accurate reports by hunters of locations of moose seen and killed, to create a sophisticated, annual review of predicted moose density between aerial survey years.

Specific Recommendations for Newfoundland

Discrepancies between the comparisons of license sales and population size (Fig. 2) and of kills and density (Fig. 3) may for any moose management unit or larger area indicate an explicit management objective, a failure to manage hunter success, or a failure to address overpopulation. Reductions in moose density in Newfoundland seem to have been typical between 1985 and 2001, as shown by increased license quotas (Tables 1 and 2) and by changes to the relationship between kill density and population sizes (Fig. 3). Whether these reductions were part of an explicit or implicit management strategy is unclear. Here we present more specific conclusions from our review of moose management in Newfoundland between 1985 and 2001.

A difference in management of central Newfoundland and the Avalon Peninsula is easily apparent. In both time periods, central Newfoundland experienced a lower proportional number of moose taken by hunt-

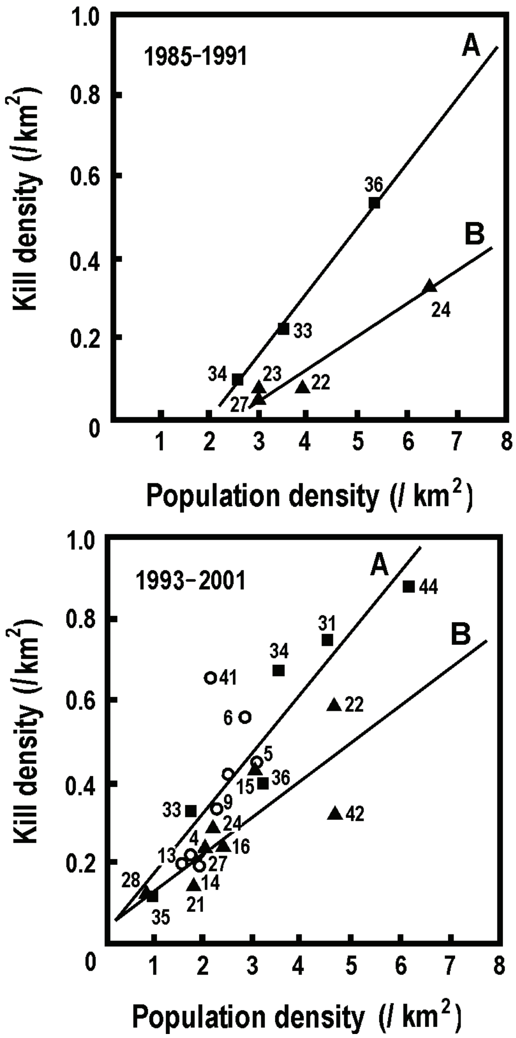

Fig. 3. Moose kill density calculated from license sales and adjusted success rates, relative to population density in management units in Newfoundland, in 1985-1991 and 1993-2001 (management units as in Fig. 1, symbols as in Fig. 2). The solid lines, A, indicate the correlations between moose kill density and population density for the Avalon Peninsula, $r^2 = 0.99$ in 1985-1991 and $r^2 = 0.91$ in 1993-2001. The solid lines, B, indicate the correlations between moose kill density and population density for central Newfoundland, $r^2 = 0.94$ in 1985-1991, and $r^2 = 0.63$ in 1993-2001. Kill is only weakly correlated with population size in western Newfoundland, $r^2 = 0.39$ (data are available only for 1993-2001).

ers. Moreover, this difference was larger for management units of higher moose density. A general explanation of the trend may lie in the fact that road access is much more limited in central Newfoundland than on the Avalon Peninsula, where about half the residents of the province have their permanent homes. For example, in 1985 license sales in unit 24 were proportional to the population estimate, similar to management units on the Avalon Peninsula (Table 1, Fig. 2). Yet a density calculation illustrates an apparent failure to address overpopulation in the habitat-limited unit 24, relative to the apparently more intensive management approach that was possible on the Avalon Peninsula (Fig. 3). The overpopulation in unit 24 appears partly rectified by 1991 (Table 2, Fig. 3), but this change is actually the result of creating a new unit, 42, by subdividing unit 24. Unit 42 is not only smaller in area with more moose than the revised unit 24, but also has proportionally less forested habitat and was, up until recently, less accessible (Table 2). Thus, by a concerted effort to direct the quota to a less accessible area, license sales in both management units fell near the expected value proportional to the two population estimates (Fig. 2), but hunter success was low and calculated kill density in unit 42 fell well below the regression line predicted by moose density (Table 2, Fig. 3). Recent resurvey of unit 42 (Inland Fish and Wildlife Division, unpublished data, 2004) indicated a 70% decline in population since 1997 and corroborates our suggestion of an unaddressed overpopulation that led to decline.

On the Avalon Peninsula, where hunter accessibility is relatively high, moose management strategies have generally been quicker to respond to overpopulations. Examples of this principle come from reviewing both the more and less accessible management units within the region. In the more accessible category are units 31, 33, 34, 35, and 44; in the less accessible category is unit 36. (Unit 31, like unit 36, is not accessed directly from the Trans Canada Highway but has a direct highway route created for island ferry access; area 36 has only regional highway access and contains a large wilderness area, where motorized vehicles are prohibited.) Unit 36 was among the most densely moose populated management units in the first period, but supported a population estimated at about a one-third reduction in density by the second period (Fig. 3). While some of this change may have been due to a density-dependent decline resulting from overpopulation, we believe much is attributable to higher kill density documented even for the earlier period (Table 1). In the other management units where high moose density occurs, for example, in units 31, 34, and 44, managers responded by increasing license quotas that resulted in higher kill density (Table 2).

In western Newfoundland, kill density and moose density are not correlated (Fig. 3), and the highest proportional quotas occur (Fig. 2). Because management units in this area are similar in density to the target for Newfoundland (Table 2), we argue that they are actually managed inconsistently and in some cases hunted unsustainably toward population reductions. Specific cases in point are units 6 and 41, which are among the highest in kill density despite near target moose density. We view these cases as further examples of failure to use specific information about moose density in assigning quotas.

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REFERENCES

BERGERUD, A. T., and F. MANUEL. 1969. Aerial census of moose in central Newfoundland. Journal of Wildlife Management 33:910–916.

______, ______, and H. WHALEN. 1968. The harvest reduction of a moose population in Newfoundland. Journal of Wildlife Management 32:722–728.

BRODERS, H. G., S. P. MAHONEY, W. A. MONTEVECCHI, and W. S. DAVIDSON. 1999. Population genetic structure and the effect of founder events on the genetic variability of moose, *Alces alces*, in Canada. Molecular Ecology 8:1309–1315.

FERGUSON, S. H., W. E. MERCER, and S. M. OOSENBRUG. 1989. The relationship between hunter accessibility and moose condition in Newfoundland. Alces 25:36–47.

______, and F. MESSIER. 1996. Can human predation of moose cause population cycles? Alces 32:149–161.

GASAWAY, W. C., S. D. DUBOIS, D. J. REED, and S. J. HARBO. 1986. Estimating moose population parameters from aerial surveys. Biological Papers of the University of Alaska, Number 22. Fairbanks, Alaska, USA.

MCLAREN, B. E., S. P. MAHONEY, T. S. PORTER, and S. M. OOSENBRUG. 2000. Spatial and temporal patterns of use by moose of pre-commercially thinned, naturally-regenerating stands of balsam fir in central Newfoundland. Forest Ecology and Management 133:179–196.

______, B. A. ROBERTS, N. DJAN-CHÉKAR, and K. P. LEWIS. 2004. Effects of overabundant moose on the Newfoundland landscape. Alces 40:45-59.

MCSHEA, W. J., H. B. UNDERWOOD, and J. H. RAPPOLE, editors. 1997. The Science of Overabundance, Deer Ecology and Population Management. Smithsonian Institution Press, Washington, D.C., USA.

MERCER, W. E. 1995. Moose management plan for Newfoundland. Report on file with Inland Fish and Wildlife Division, Newfoundland and Labrador, Corner Brook, NL, Canada.

____, and B. E. MCLAREN. 2002. Evidence of carrying capacity effects in Newfoundland moose. Alces 38:123–141.

OOSENBRUG, S. M., and S. H. FERGUSON. 1992. Moose mark-recapture survey in Newfoundland. Alces 28:21-30.

PARKER, G. R., and L. D. MORTON. 1978. The estimation of winter forage and its use by moose on clearcuts in northcentral Newfoundland. Journal of Range Management 31:300–304.

PIMLOTT, D. H. 1953. Newfoundland moose. Transactions of the North American Wildlife Conference 18:563–581.

TIMMERMANN, H. R., and M. E. BUSS. 1998. Population and harvest management. Pages 559–616 *in* A. W. Franzmann and C. C. Schwartz, editors. Ecology and Management of the North American Moose. Smithsonian Institution Press, Washington, D.C., USA.