AN EVALUATION OF MOOSE HARVEST MANAGEMENT IN CENTRAL AND NORTHERN BRITISH COLUMBIA

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ABSTRACT: Moose (*Alces alces*) harvest strategies employed within 19 Game Management Zones (GMZ's) of central and northern British Columbia during the mid-1990's were reviewed and evaluated. Passive harvest controls, including long bull-only seasons, were primarily used in northern GMZ's where moose densities and hunting pressure was low, and predator populations were lightly exploited. A mix of passive and active harvest controls for bulls, cows, and calves were used in most of the remaining GMZ's where moose densities and hunting pressure were higher. The effectiveness of the various harvest controls were evaluated from 5 performance indicators. Overall, the harvest strategy that sustained the greatest hunting pressure, harvest density, and harvest rates, while maintaining desired hunting effort and post-season bull/cow ratios, was the strategy employed within the Omineca Sub-Region. This strategy provided a general open season to harvest spike-fork or "immature" bulls and calves, combined with a limited entry hunting season for mature bulls and cows. Several preliminary yield-density curves were proposed. Where predator populations were reduced through hunting and trapping, moose harvests ranged from 22 kills/1,000 km^2 at a post-season density of 300 moose/1,000 km^2 to 53 kills/1,000 km^2 at 700 moose/1,000 km^2. Moose harvest management was hindered by insufficient survey data, lack of reliable estimates of non-hunting mortality rates, and incomplete information on unregulated harvests. In British Columbia, moose management objectives should focus on maintaining appropriate adult sex ratios, providing a diversity of hunting opportunities, and optimizing recreational days per moose harvested, as opposed to traditional objectives associated with population size, harvest, hunter numbers, and hunter days which have either not been achievable or measurable.

ALCES VOL. 35: 91-103 (1999)

Key words: active controls, *Alces*, harvest strategy, passive controls, population management, yield-density curves

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British Columbia (BC) has developed a variety of moose harvest strategies in response to varying population characteristics and ecological conditions, hunting pressure, and regional stakeholder desires. These strategies have been used to regulate harvests, distribute hunting pressure, and control success rates. Timmermann and Buss (1998) indicated that harvest strategies can be classified as either "passive" or "active" controls. Passive controls usually affect all hunters equally, do not directly impact individuals, and allow unlimited numbers of hunters. Active controls directly affect individuals by limiting hunter numbers and hunting opportunities. In BC, passive controls include a general open season (GOS) which manipulates the season length and timing, and may also include area closures and access restrictions. Active controls include limited entry hunting (LEH) where hunters must successfully draw a permit in a lottery to hunt a specified sex and age class of animal in a designated area. The objective of both active and passive controls is to affect or control the number of moose harvested, and thereby the population through selective harvest of a predetermined annual allowable harvest.

In this paper, I review the moose harvest strategies employed during the mid-1990's in central and northern BC, and evaluate the effectiveness of these strategies from 5 performance indicators. Preliminary yield-density curves are presented and new management objectives for moose are proposed.

STUDY AREA

Central and northern BC comprises approximately 700,000 km^2, of which about 550,000 km^2 are occupied by moose. The area is ecologically diverse and incorporates a variety of climatic, physiographic, and ecological factors that affect moose productivity, habitat requirements, and consequently, management prescriptions. In recognition of this diversity, 6 moose ecotypes or geographic regions were identified by Eastman and Ritcey (1987) to facilitate management. Administration is currently through 4 regions and sub-regions comprising 19 Game Management Zones (GMZ's, Fig. 1). GMZ's (range: 13,727

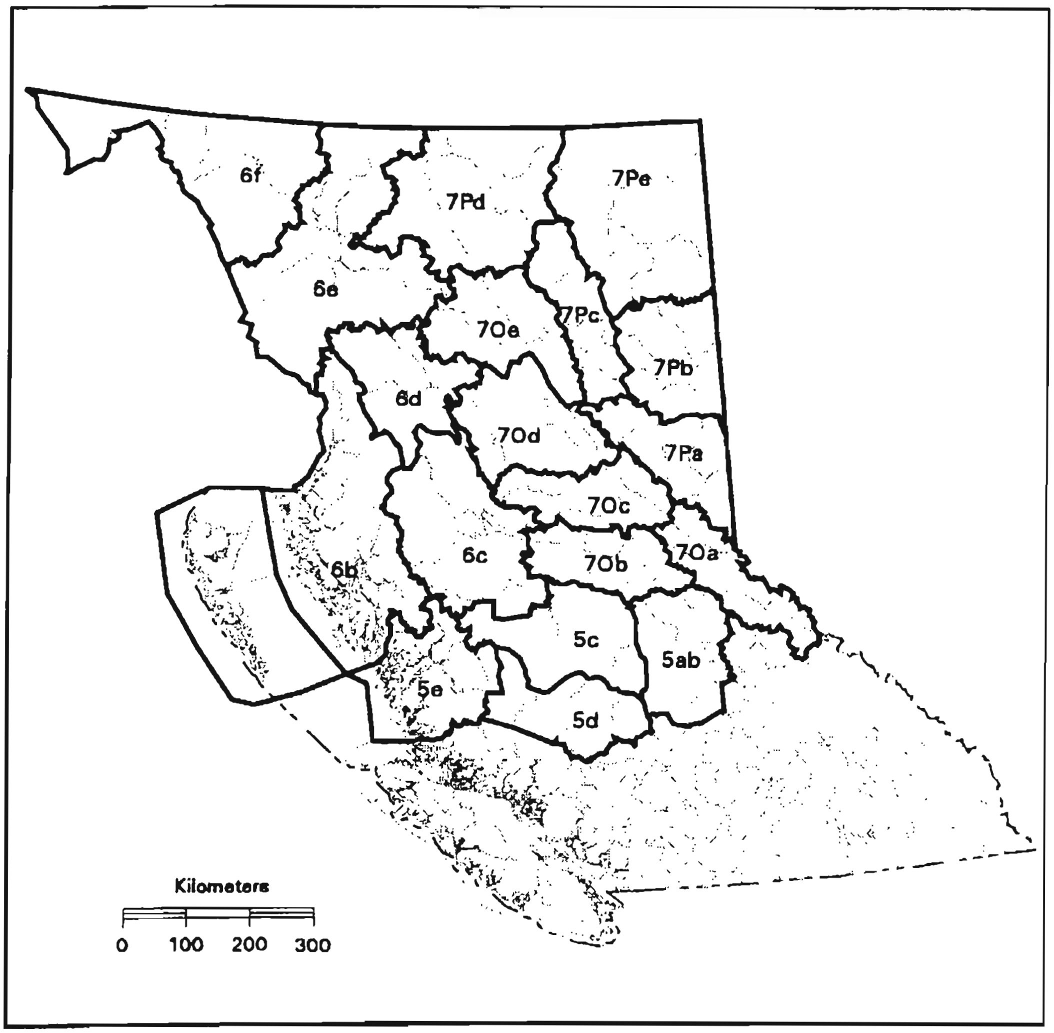

Fig. 1. Game Management Zones (GMZ's) in central and northern British Columbia. GMZ's prefixed with a 5 (e.g., GMZ 5c) occur within the Cariboo Region, while a 6 refers to the Skeena Region, 7O to the Omineca Sub-region, and 7P to the Peace-Liard Sub-region. Bold lines delineate GMZ's and thin lines indicate Wildlife Management Units (WMU's).

km^2 - 61,269 km^2) are amalgamations of Wildlife Management Units (WMU's, range: 788 km^2 - 18,983 km^2) which share similar ecological characteristics (consisting predominately of 1 ecotype) and hunter harvest patterns, and thus provide a suitable geographical framework for implementing management strategies.

Moose hunting is important provincially for sustenance, cultural, and recreational needs. The priorities for allocation of moose in British Columbia are: first priority - aboriginal use as prescribed in law; second priority - resident use; third priority - non-resident use (MELP 1996). Moose are also important economically. In 1995, the value of resident moose hunting was estimated to be $15,822,940 (Reid 1997).

In recent years, moose harvests and hunter days have declined in central and northern BC. From 1988-1990, an average of 12,070 moose were harvested annually which provided an average of 276,291 hunter days of recreation each year. During 1991-1993 the harvest averaged 10,242 (250,918 days) and from 1994-1996 it averaged 9,111 (209,902 days). Current populations are generally depressed from peak levels in the 1960's, primarily because of the declining incidence of wildfire, unregulated harvests, and predation (Hatter, *unpubl. report*). Both past and present forestry practices have affected moose habitat, but the benefits and extent of these effects have varied throughout the province.

METHODS

Estimation of Harvest and Population Size within WMU's

Hunter harvest. - Harvest statistics, including total harvest, sex-age composition, hunter numbers, and hunter days have been estimated annually for each WMU since 1976. These variables were derived from a moose harvest questionnaire mailed to a random sample of hunters, with a follow-up second questionnaire sent to non-respondents. Approximately 50% of the moose hunters received the questionnaire, with an initial compliance rate of about 60% and a 15% compliance rate for the second mailing. Hunting pressure was calculated as resident hunter days/1,000 km^2 of habitable moose range (DPUA) while harvest density was resident and non-resident kill/1,000 km^2 (KPUA). Hunting effort was resident hunter days/moose (DPK). Kill per unit effort (KPUE) was calculated as the number of moose harvested by resident hunters/100 hunter days. The annual rate of population change (λ) was calculated from $\log_e$(kills/100 days) versus year (Van Ballenberghe 1983) and incorporated a harvest vulnerability exponent to account for a non-linear relationship between KPUE and abundance (Hatter 1998).

Moose population surveys. - Winter (Dec - Mar) surveys of absolute abundance were conducted periodically, based on an aerial stratified random block (SRB) sampling design for moose (Gasaway *et al.* 1986). Moose survey areas (SA's) generally ranged from 1,000 to 5,000 km^2 and included one or more WMU's. Since 1990, about 65 SRB surveys have been conducted. Classification included identification of bulls, cows, and calves. Most surveys did not include an independently derived sightability correction factor (SCF) to correct for under-counting bias, although SCF's were subjectively estimated to range between 1.1 and 1.5 (Hatter *unpubl. report*). Rate of change from repeat surveys was calculated as $\lambda=(N_t/N_0)^{1/t}$, where N_t is the number of moose in year t, and N_0 is the number of moose in the initial or first survey year (Van Ballenberghe 1983). In the Omineca Sub-region, only 3 SRB surveys were conducted. Consequently, annual herd composition surveys were also used to estimate winter sex ratios (bulls/100 cows) and calf recruitment (calves/100 cows).

Estimation of Population Status within GMZ's

Numerous WMU's were not surveyed for density and composition. Thus, moose densities from SA's were extrapolated to estimate the density within a GMZ. The reliability of these extrapolations was variable depending upon the number of WMU's surveyed and homogeneity in moose population parameters within a GMZ.

Moose population model. - A simple balance model or "annual life equation" was developed to estimate post-season population size, rate of change, and harvest rate for moose within each GMZ. The population model was partitioned into post-season bulls (*B*), cows (*C*), and calves (*Ca*). The model consisted of the following interdependent equations:

$$B_{t+1} = B_t Sa_b + 0.5(Ca_t Sj) - H(B)_t,$$

$$C_{t+1} = C_t Sa_c + 0.5(Ca_t Sj) - H(C)_t,$$

and

$$Ca_{t+1} = [C_t Sa_c + 0.5(Ca_t S_j)](Ca/C) - H(Ca)_t,$$

where $H(B)_t$, $H(C)_t$, and $H(Ca)_t$ were the average bull, cow, and calf harvests respectively. Sa_b, Sa_c, and Sj were the bull, cow, and calf winter survival rates. Sa_c was estimated from repeat SRB surveys on SA's, where available, using the method described by Hatter and Bergerud (1991). Sa_b was assumed to be either 0.85 or 0.88. Sj was estimated as $0.95 \times Sa_c$ (Larsen *et al.* 1989). *Ca/C* was the pre-season calf/cow ratio. An equal calf sex ratio was assumed (Boer 1992). Harvest estimates were increased by 20% to incorporate additional losses due to wounding (Fryxell *et al.* 1988).

The population model was used to check the inventory-extrapolated population estimates by determining if the known harvests produced post-season sex and age ratios and an annual rate of change that were consistent with SA and KPUE results. If the inventory estimate failed to provide a reasonable fit it was iteratively adjusted by the model until the above parameters more closely matched those from the SA's and KPUE. The harvest rate (*Mh*) was harvest/(harvest + post-season population). The population density was post-season moose/1,000 km². Due to errors in estimation of λ, and because of natural population fluctuations, harvests or "yields" were considered sustainable if the modelled estimate of λ ranged between 0.97 and 1.03.

Evaluation of Harvest Strategies

Five performance indicators were used to evaluate moose harvest strategies. These included hunting pressure (days/1,000 km²), harvest density (kills/1,000 km²), hunting effort (days/kill), adult sex ratio (bulls/100 cows), and harvest rate (*Mh*). In the following comparisons, the average values from 1994 - 1996 were used, except for the Peace–Liard, where 1993 - 1995 averages were used. This was because a new harvest strategy was introduced in 1996, which markedly changed these parameters from previous years.

RESULTS AND DISCUSSION

Review of Regional Harvest Strategies

Harvest controls varied between GMZ's, but generally were consistent within a GMZ (Table 1). Passive harvest controls, which included long bull open seasons, were primarily used in northern GMZ's where moose densities, calf recruitment, and hunting pressure were low and predator populations were lightly exploited (Table 2). A mix of passive and active harvest controls for bulls, cows, and calves were used in most of the remaining GMZ's where moose densities and hunting pressure were higher; and predator population's were more heavily exploited through hunting, trapping, and problem animal control on agricultural lands. More opportunities for antlerless

Table 1. Harvest controls used in Wildlife Management Units (WMU's) within Game Management Zones (GMZ's) in 1996, except for GMZ's 7Pa - e which are for 1995.

	General Open Season			Limited Entry Hunting	
GMZ	Class	Season Dates	WMU's	Class	WMU's
5ab	Bulls:	Oct 15 - Oct 31	501,502,515	Antlerless:	501,502,515
				Bulls:	501,502,515
5c	Bulls:	Oct 15 - Oct 31	510,512-514	Antlerless:	513
				Bulls:	510,512-514
5d	Bulls:	Oct 15 - Oct 31	503-504,505-506	Bulls:	503-506
5e	n/a		511	Bulls:	511
6b	Bulls:	Sep 10 - Nov 15	603,611,614,616		
	Bulls:	Oct 20 - Nov 5	610,615	Bulls:	610,615
6c	Bulls:	Oct 20 - Nov 5	601-602,604-606, 608-609	Bulls:	601-602,604-606,608-609
				Antlerless:	604-606,608-609
				Calf Only:	604-606,608-609
6d	Bulls:	Oct 20 - Nov 5	607,630	Bulls:	607,630
	Bulls:	Aug 15 - Nov 15	617-618	Antlerless:	607,630
6e	Bulls:	Aug 15 - Nov 15	619-624	n/a	
6f	Bulls:	Aug 15 - Nov 15	625-629	n/a	
7Oa	SF Bulls:	Sep 10 - Nov 5	701-705,717-718		
	Calves:	Oct 10 - Oct 25		Antlerless:	701-705,717-718
				Bulls:	701-705,717-718
7Ob	SF Bulls:	Sep 10 - Nov 5	706-713,715	Antlerless:	706-713,715
	Calves:	Oct 10 - Oct 25		Bulls:	706-713,715
7Oc	SF Bulls:	Sep 10 - Nov 5	714,716,723-726	Antlerless:	714,716,723-726
	Calves:	Oct 10 - Oct 25		Bulls:	714,716,723-726
7Od	SF Bulls:	Sep 10 - Nov 5	727-730,738	Antlerless:	727-730,738
	Calves:	Oct 10 - Oct 25		Bulls:	727-730,738
7Oe	Bulls:	Aug 15 - Nov 5	737,739-741	Bulls:	739 (Zone E)
7Pa	Bulls:	Aug 15 - Sep 20	719-722,731	n/a	
	Bulls:	Oct 15 - Oct 31	719-722,731		
7Pb	Bulls:	Aug 15 - Sep 20	732-735,744-746	Antlerless:	732-735,744-746
	Calves:	Oct 4 - Oct 11	732-734,744-745		
7Pc	Bulls:	Aug 15 - Sep 20	736,743	Antlerless:	743
	Bulls:	Oct 15 - Oct 31	736,743		
	Bulls:	Aug 15 - Sep 20	742,757-758		
	Bulls:	Aug 15 - Oct 31	750		
7Pd	Bulls:	Aug 15 - Oct 31	751-754	n/a	
7Pe	Bulls:	Aug 15 - Sept 30	747-749,755-756	n/a	
	Bulls:	Oct 15 - Oct 31	747-749,755-756		

Table 2. Summary of average moose population and harvest parameters by Game Management Zone (GMZ) from 1994-96 (1993-95 for GMZ's 7Pa-e). Post-season density and composition were estimated from population models.

GMZ	Post -season Moose/ 1,000 km^2	Post -season Bulls/ Cow	Post -season Calves/ Cow	% Harvest Composition Bull:	Cow:	Calf	Resident DPUA[1]	Resident DPK[2]	Harvest KPUA[3]	% Harvest (*Mh*)	Growth Rate (λ)
5ab	346	0.29	0.50	95	5	0	766.5	30.0	27.6	7.3	0.97
5c	206	0.37	0.40	97	3	0	342.7	26.3	15.3	6.8	0.99
5d	140	0.30	0.40	99	1	0	207.9	27.3	8.9	5.9	1.05
5e	26	0.56	0.40	-	-	-	0.0	0.0	0.0	0.0	1.02
6b	88	0.40	0.50	100	0	0	98.8	20.8	4.8	5.1	0.91
6c	379	0.35	0.33	73	13	13	498.4	20.2	28.8	7.0	0.98
6d	180	0.40	0.30	89	10	1	71.4	18.1	4.6	2.5	1.00
6e	172	0.66	0.30	100	0	0	115.2	20.2	7.7	4.2	0.93
6f	214	0.65	0.35	100	0	0	66.2	16.5	6.8	3.0	0.99
7Oa	308	0.44	0.30	63	22	15	668.3	33.4	21.5	6.4	1.00
7Ob	730	0.44	0.40	56	18	26	1973.8	32.3	66.5	8.2	1.03
7Oc	689	0.49	0.25	65	18	17	988.9	27.5	40.0	5.4	0.99
7Od	182	0.31	0.30	70	16	14	464.3	27.7	17.4	8.6	0.97
7Oe	148	0.45	0.30	100	0	0	101.6	19.8	7.7	4.9	0.96
7Pa	360	0.22	0.27	100	0	0	535.2	24.4	22.0	5.7	0.97
7Pb	510	0.30	0.32	67	9	24	546.3	14.5	38.0	6.9	1.02
7Pc	566	0.27	0.20	98	1	1	517.0	19.7	35.4	5.8	0.90
7Pd	200	0.49	0.25	100	0	0	48.1	16.7	4.9	2.4	0.98
7Pe	216	0.58	0.25	100	0	0	98.0	16.6	6.4	2.9	0.99
$\bar{X}$	298.0	0.42	0.33				426.9	22.9	19.2	5.2	0.98
SD	217.8	0.13	0.08				470.0	5.8	16.9	2.2	0.04

[1]DPUA = hunting pressure (resident hunter days/1,000 km^2 of habitable moose range)

[2]DPK = hunting effort (resident hunter days/moose)

[3]KPUA = harvest density (resident and non-resident kill/1,000 km^2)

hunting were provided within those WMU's where calf recruitment was higher.

Cariboo Region (GMZ's 5ab, 5c - 5e). - The Cariboo adopted a harvest strategy in 1993 to recover low density moose populations and improve bull/cow ratios. Passive controls included a short post-rut (Oct 15–31) GOS for bull moose in GMZ's 5ab, 5c, and 5d. There was no GOS for moose within GMZ 5e, as moose densities were extremely low (~25 moose/1,000 km^2). Active controls included pre-rut (Sep 10 - 26), rut (Sep 27 - Oct 14), and early winter (Nov 1 - 15) limited entry hunts for bulls.

Antlerless seasons were reduced, although GMZ's 5ab and 5c continued to provide some antlerless LEH opportunities. In 1993, resident harvests were reduced by 48% (GMZ 5ab) - 57% (GMZ 5d) but harvests steadily increased thereafter. The harvest proportion averaged 97% bulls and 3% cows. Moose numbers appeared to stabilize in GMZ 5ab and 5c, while numbers may have increased in GMZ 5d. SA's within GMZ 5ab showed some improvement in bull/cow ratios, although sex ratios in most SA's remained below 30 bulls/100 cows. Modelled estimates of bull/cow ratios, however, were slightly higher (Table 2).

Skeena Region (GMZ's 6b - 6f). - Skeena maintained relatively constant hunting regulations from 1993-96, although different controls were employed within different GMZ's. On the coast, GMZ 6b employed relatively short to long GOS's (Oct 20 - Nov 5 or Sep 10 - Nov 15), depending on access and hunting pressure within individual WMU's. Due to very low densities (<100 moose/1,000 km^2), there was no antlerless season in this zone. GMZ 6c was the most heavily hunted zone. In 1993, a relatively short GOS for bulls (Oct 26 - Nov 5) in this zone, combined with pre-rut/rut (Sep 10 - Oct 19) and early winter (Nov 1 - 15) LEH seasons, were implemented to improve bull/cow ratios. WMU's with moose densities on winter ranges exceeding 800 moose/1,000 km^2 maintained a short antlerless and calf LEH season. This strategy initially reduced resident moose harvests by 43%, but harvests steadily increased thereafter. The harvest proportion averaged 73% bulls, 13% cows, and 13% calves. Despite the harvest controls, winter bull/cow ratios remained relatively low (33-35 bulls/100 cows) while calf/cow ratios declined from 38/100 in 1992 to 33/100 in 1997. GMZ's 6e and 6f were lightly hunted and had a long GOS for bulls (Aug 15 - Nov 15). Winter bull/cow ratios consistently exceeded 50 bulls/100 cows within these SA's. Moose numbers appeared stable in GMZ 6c, 6d, and 6f, while numbers appeared to have declined in GMZ 6b and 6e (Table 2).

Omineca Sub-region (GMZ's 7Oa - 7Oe). - Omineca initiated a selective harvest strategy in 1981 that utilized both active and passive controls within GMZ's 7Oa - 7Od. This strategy was comprised of a GOS for spike-fork bulls (predominately yearling bulls having no more than 1 or 2 points on 1 antler) with an any-bull LEH season, a calf GOS, and an antlerless LEH (Child 1983). The antlerless LEH season included both an early (Oct) and late (Nov - Dec) season. With the exception of 1986 - 1990 when a short, post-rut GOS for bulls was offered, this strategy appears to have sustained high harvests (comparable to pre-1981 harvest levels in GMZ's 7Ob and 7Od), high hunting pressure, and stable moose numbers within most GMZ's. The harvest composition averaged 64% bulls, 19% cows, and 18% calves. Moose density was lower in GMZ 7Oe (148/1,000 km^2), but was lightly hunted and offered a bull-only GOS extending from Aug 15 - Nov 5. Moose numbers appeared relatively stable in GMZ's 7Oa - 7Od, although herd composition surveys in 1996 indicated a drop in calf recruitment in 7Ob (32 calves/100 cows compared to previous surveys of 40-50 calves/100 cows) and low calf recruitment in 7Oc (20 calves/100 cows). Despite the recent decline in recruitment, there was no harvest-related evidence (e.g., declining hunter success or kill per unit effort) to suggest population size had changed substantially over the last decade.

Peace-Liard Sub-region (GMZ's 7Pa - 7Pe). - Prior to 1996, the basic bull harvest strategy employed within the Peace–Liard was a GOS starting Aug 15 with the length of the season dictated by hunting pressure. From 1991 - 1995 the bull moose season extended from Aug 15 - Sep 21 in most WMU's of GMZ 7Pb; while GMZ's 7Pa, 7Pc, and 7Pe also included a post-rut season (Oct 16 - 31). In GMZ 7Pd, where hunting pressure was light (4.9 kills/ 1,000 km^2), the season extended from Aug 15 - Oct 31. A GOS for calves was available for a limited number of WMU's (primarily within GMZ 7Pb), but was eliminated in 1996, following an unusually severe winter in 1995–96. The harvest composition in GMZ 7Pb, where some WMU's had a GOS for calves and a LEH season for cows, was 67% bulls, 9% cows, and 24% calves. Moose numbers appeared stable in GMZ 7Pa, 7Pb, 7Pd, and 7Pe while numbers were declining within GMZ 7Pc. Adult sex ratios were relatively low in GMZ 7Pa (22 bulls/100 cows), 7Pb (30 bulls/100 cows), and GMZ 7Pc (27 bulls/100 cows). Moose densities were lowest within GMZ 7Pd (200 moose/ 1,000 km^2) and 7Pe (216 moose/1,000 km^2), but because of light hunting pressure, had higher bull/cow ratios (Table 2).

In 1996, a new bull harvest strategy (Spike-Or-Fork-Tripalm or SOFT) was implemented throughout the sub-region. Under this strategy, any bull moose was available for harvesting from Aug 15 - 31. Spike-fork bulls (bulls with no more than 2 points on 1 antler) and tri-palm bulls (bulls having 3 or more points on 1 brow palm) were legal from Sep 1 - Oct 31, except within the more heavily hunted WMU's where a rut closure (Oct 1 - Oct 15) was maintained. Resident hunter days declined by only 4% from 1995 (47,364 days) to 1996 (45,673 days), even though the harvest declined from 2,500 to 1,365. This slight reduction in hunter days indicated that resident hunters spent more timing hunting for each moose harvested under the first year of the SOFT strategy. In the second year of the SOFT strategy (1997), hunter days declined to 35,054 while the moose harvest increased slightly to 1,434.

Evaluation of Moose Harvest Strategies

Hunting pressure. - Hunting pressure increased linearly with moose density (R^2=0.67, F=36.7; 1, 18 df; P<0.001, Fig. 2). The greatest hunting pressure occurred within GMZ 7Ob (1,974 days/1,000 km^2) and GMZ 7Oc (989 days/1,000 km^2). GMZ 5ab produced 767 days/1,000 km^2, followed by GMZ 7Oa (668 days/1,000 km^2), 7Pb (546 days/1,000 km^2), 7Pa (535 days/1,000 km^2), and 7Pc (517 days/1,000 km^2). The high hunting pressure within GMZ 7Ob and 7Oc indicated that the "Omineca" strategy was effective in maintaining a high level of recreational hunting. This was partially because approximately 3 times as many days were required to harvest a spike-fork bull or calf during a GOS than a bull or cow during a limited entry hunt (Child and Aitken 1989).

Harvest density. - Harvest density also showed a strong relationship to moose density (R^2=0.87, F=115.4; 1, 18 df; P<0.001, Fig. 3). As with hunting pressure, the Omineca Sub-region produced the highest harvests in 7Ob (67 kills/1,000 km^2) and 7Oc (40 kills/1,000 km^2). GMZ's 7Pb and 7Pc produced 38 and 35 kills/1,000 km^2,

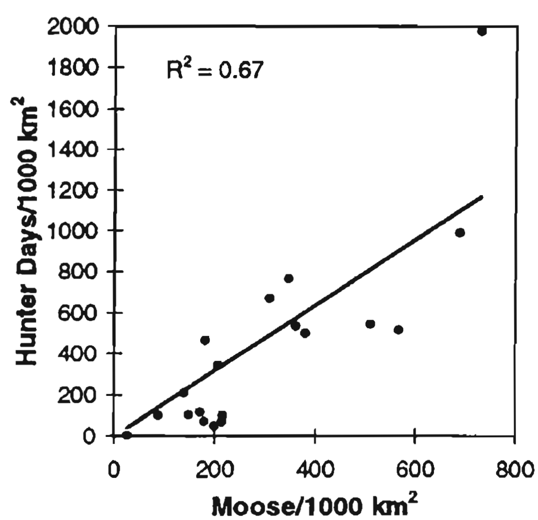

Fig. 2. Relationship between hunting pressure and moose density in central and northern BC.

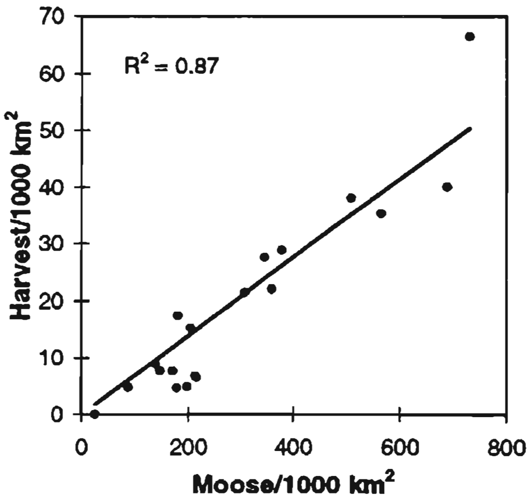

Fig. 3. Relationship between harvest density and moose density in central and northern BC.

respectively. Harvests dropped substantially with the implementation of the SOFT strategy in the Peace–Liard in 1996 (e.g., GMZ 7Pb; 38 kills/1,000 km^2 from 1993–95 vs. 27 kills/1,000 km^2 in 1996: GMZ 7Pc; 35 kills/1,000 km^2 from 1993–95 vs. 20 kills/ 1,000 km^2 in 1996).

Hunting effort. - Current management guidelines recommend maintaining between 25 and 35 days per harvested moose (Hatter, *unpubl. report*). The Cariboo (GMZ's 5ab, 5c, and 5d) and Omineca (GMZ's 7Oa, 7Ob, 7Oc, and 7Od) met the proposed management guidelines, while Skeena provided less than 25 days/kill in all GMZ's (Table 2). Prior to implementing the SOFT strategy, the Peace–Liard Sub-region also provided less than 25 days/kill in all GMZ's. However, after implementing the strategy in 1996, DPK rose substantially in 7Pa (52 days/kill) and 7Pd (49 days/kill). Increases were also observed in 7Pb (23 days/kill), 7Pc (31 days/kill), and 7Pe (32 days/kill).

Adult sex ratios. - BC's provincial Wildlife Harvest Strategy recommends maintaining at least 30 bulls/100 cows post-season (MELP 1996). Post-season bull/ cow ratios were below 30 bulls/100 cows within GMZ's 5ab, 7Pa, and 7Pc (Table 2). Adult sex ratios exceeded 50 bulls/100 cows within GMZ's 5e, 6e, and 6f (Table 2).

Harvest rate. - The highest harvest rates (~8.5%) were observed in the Omineca (GMZ 7Ob and 7Od), while the lowest rates ($\leq$ 3.0%) occurred in the northern GMZ's. These harvest rates, while comparable to rates in the Yukon and Alaska, were substantially less than those reported for other North American jurisdictions (Crête 1987). Not all of the harvest rates were sustainable. GMZ's 6b, 6e, 7Oe, and 7Pc had λ < 0.97 and their harvests were not considered sustainable.

Overall, the harvest strategy employed in the Omineca, particularly within GMZ's 7Ob and 7Oc, sustained the highest hunting pressure, harvest density, and harvest rates, while meeting the provincial guidelines for hunter kills/day and post-season adult sex ratios. Harvest strategies employed in other administrative regions generally had lower bull/cow ratios and required more frequent changes to moose hunting regulations as populations declined. With only 2 years of information available, it was not possible to determine the long-term effectiveness of the SOFT strategy in the Peace–Liard. However, implementation of a similar strategy on the Kenai Peninsula improved bull/ cow ratios and is now supporting almost as many hunters as prior to implementation of the strategy (Schwartz *et al.* 1992, T. H. Spraker, Alaska Dept. Fish and Game, Soldotna, *pers. comm.*). In that study the harvest dropped by 48% following the first year of the new regulation, but increased thereafter. In the Peace-Liard, the harvest dropped by 45%, but increased by 5% during the second year.

MANAGEMENT IMPLICATIONS

Yield-density curves. - Yield-density curves for moose vary greatly between predator-free areas and areas where predator populations are present (Crête 1987, Gasaway *et al.* 1992). The carrying capacity (K) for moose in multi-ungulate systems in western North America, where predators are absent, is believed to be $\geq$ 1,500 moose/1,000 km² (Bergerud 1992); whereas in multi-ungulate systems with predators (i.e., wolves and bears), K likely ranges between 150 moose/1,000 km² (Gasaway *et al.* 1992) to 300 moose/1,000 km² (Bergerud 1992). The maximum rate of increase for moose observed in northern boreal ecosystems was approximately 15%/year (Van Ballenberghe and Dart 1982, Boertje *et al.* 1996) and the maximum sustained yield level for moose appears to occur at 60% of K (Crête *et al.* 1981). These parameters suggest a MSY of 95 moose/1,000 km² could be achieved from a post-season population size of 800 moose/1,000 km² in predator-free areas (Mh = 11%, Fig. 4). Conversely, in areas with lightly hunted predator populations, a MSY of 14 moose/1,000 km² should occur at a post-season population of 120 moose/1,000 km² (Mh = 10%, Fig. 4). Observed average harvests of moose within 14 GMZ's, where moose numbers were relatively stable ($0.97 \leq \lambda \leq 1.03$), were substantially less than those predicted by the theoretical "predator-free" yield curve. While the yield-density curve for moose with lightly exploited predator populations did provide a reasonable fit to harvest densities from northern BC (GMZ's 6d, 6f, 7Pd, and 7Pe), they were inadequate to verify the MSY. Gasaway *et al.* (1992: 44) suggests that the maximum harvest rate for moose in these systems is approximately 5%.

A sustained yield curve for moose was empirically derived for the 10 GMZ's where moose densities were relatively stable and predator populations were presumed to be more highly exploited (R^2=0.89, F=71.4; 1,9 df; P<0.001, Fig. 4). This yield curve indicated that harvests increased with density, and was similar to the yield-density curve

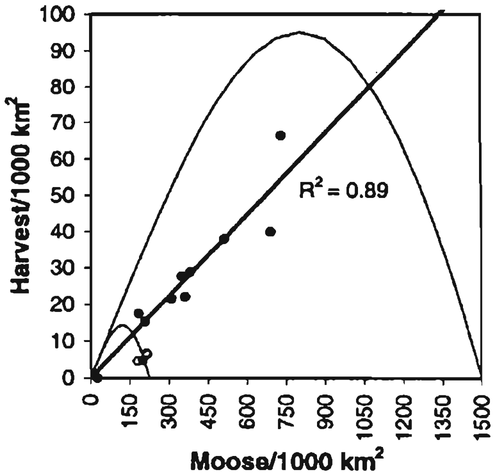

Fig. 4. Preliminary yield-density curves proposed for moose in central and northern BC. The large dome-shaped curve is the theoretical yield curve for moose in the absence of predators. The small dome-shaped curve is the theoretical yield curve for moose where predators are lightly exploited. Four Game Management Zones (GMZ's) appear to fit this curve (open circles). The intermediate yield-density curve was fitted to 10 GMZ's (solid circles) where predator populations were more heavily exploited. Only those GMZ's with stable populations were included

for moose with harvested-limited predator populations in Alaska and the Yukon (Gasaway *et al.* 1992:44). Sustainable harvests of moose ranged from 22 kills/1,000 km² at a post-season density of 300 moose/1,000 km² (Mh = 6.8%) to 53 kills/1,000 km² at 700 moose/1,000 km² (Mh = 7.0%). Actual harvest densities would be higher as the harvest estimates only included resident and non-resident hunting, and excluded harvests by First Nations and other non-reported mortalities (e.g., poaching) that were likely substantial in most GMZ's. This yield-density curve suggests that increasing moose densities may be more effective for increasing yields than restructuring the sex and age composition of the harvest.

Co-ordination of moose hunting regulations. - BC has evolved a relatively complex set of moose harvest regulations, involving numerous passive and active controls (Table 2). Consequently, co-ordination of moose hunting regulations has and continues to be an on-going management issue. While a single provincial strategy may not adequately address all conservation needs and meet the various demands and expectations from hunters, it should be possible to reduce the variety of active and passive controls currently employed in BC. The "Omineca" strategy could probably be successfully implemented in other GMZ's. However, variations in habitat quality, predator densities, and winter severity would necessitate adjusting the proportion of bulls, cows, and calves harvested. In low density populations with low recruitment, such as GMZ 7Pd and 7Pe, there would probably be little benefit to harvesting any antlerless moose. This is supported by modelling and empirical studies of similar systems in Yukon and Alaska which suggest bull-only hunting can provide near equivalent yields as either-sex hunting (Van Ballenberghe and Dart 1982, Gasaway *et al.* 1992, Boertje *et al.* 1996). The SOFT strategy employed in the Peace–Liard may provide another alternative to the "Omineca" bull moose strategy, by offering unlimited hunter participation for legal mature bulls.

Establishing management objectives. - Previous moose policy statements for British Columbia and other jurisdictions have developed management objectives pertaining to moose population size, harvest, hunter numbers, and hunter days (Munro and Petticrew 1979, Timmermann and Buss 1998). However, experience in BC has shown that without effective predator and habitat management, it generally has not been possible to meet the population and harvest objectives (Hatter, *unpubl. report*). Insufficient survey data, lack of reliable non-hunting mortality estimates, and inadequate information on unregulated harvests also make it difficult to determine if these objectives are being met. In addition, hunter numbers and days in BC appear to be declining from numerous causes (MELP 1996), and are no longer simply related to hunting opportunities. Finally, most wildlife management agencies are now adopting an ecosystem management approach, where moose are viewed as a component of ecosystems (Hatter, *unpubl. report*). Management objectives to enhance moose for greater yields may be inappropriate if higher moose densities have a detrimental impact on other species. For example, objectives to increase moose populations in southern BC may have contributed to declines in sympatric mountain caribou populations by sustaining greater numbers of wolves that preferentially prey on caribou during the summer months (Seip 1992).

It is recommended that BC establish new objectives for moose which are both achievable and measurable under current fiscal constraints; and which place wildlife conservation and ecosystem management as the highest priority. Management objectives should focus on maintaining appropriate adult sex ratios, providing a diversity of hunting opportunities and optimizing recreational days per moose harvested, as opposed to traditional measures associated with population size, harvest, hunter numbers, and hunter days.

ACKNOWLEDGEMENTS

I thank J. Youds, R. Marshall, S. Sharpe, D. Heard, and J. Elliott for providing moose management data and for technical review of an earlier management report, upon which this paper is based. Special thanks to K. Child, T. Timmermann, and V. Crichton who also conducted a technical review of a revised management report released for stakeholder discussion.

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