GROWTH PATTERNS OF NEW ENGLAND MOOSE: YEARLINGS AS INDICATORS OF POPULATION STATUS

Kip P. Adams and Peter J. Pekins

Wildlife Program, Department of Natural Resources, University of New Hampshire, Durham, NH 03824

ABSTRACT: Relationships among antler characteristics, body weight, age, and reproductive potential of moose (*Alces alces*) were analyzed from check station data from New Hampshire, Maine, and Vermont to determine if significant relationships existed between physical parameters, age, and reproductive potential of moose in New England. Sixty-three percent of yearling female moose in NH were sexually mature based upon corpora lutea (CL) counts. Reproductive potential among females was classified into four weight categories: <200 kg females typically were not reproductive, 200-250 kg females typically had 1 CL, those 251-275 kg averaged 1.5 CL, and those >275 kg 2 CL. Body weight of males was best predicted by multiple regression analysis with the variables age, antler spread, and antler beam diameter; weight of 93% of VT males was predicted accurately. The significant growth rate of body weight and antler characteristics, predictive relationships of such, inititation of reproductive potential, and ease of aging associated with the yearling age class suggests its potential as an indicator of the nutritional status of a population. Because moose populations continue to expand in each state, a wider range of habitat quality is needed to further test and validate the usefulness of the predictive relationships.

ALCES VOL. 31 (1995) pp.53-59

Physical parameters are used to assess the relative nutritional and reproductive status of individuals and populations of some cervids. For example, antler beam diameter and body weight of white-tailed deer (*Odocoileus virginianus*) are correlated with the nutritional level (Severinghaus and Moen 1983) and reproductive rates (Sauer and Severinghaus 1977) of a population. Similarly, antler beam diameter is correlated with the capacity of a given range to produce forage for existing deer populations (Severinghaus *et al.* 1950). Because of the close relationship between antler size and the nutritional status of populations, many researchers and state agencies use antler measurements to evaluate performance of deer populations (McCullough 1982). Several authors attempted to predict moose age, live and field dressed weights, and body condition from a variety of physical parameters. Parameters studied included heart girth (Karns 1976); hind foot length, total length, shoulder height, and ear length (Blood *et al.* 1967, Franzmann *et al.* 1978); head length, cranial breadth, and heart and kidney weight (Messier and Crête 1984); and antler spread, number of antler points, antler beam diameter, and palm width and length (Cringan 1955, Timmermann 1971). These studies yielded mixed results however. Body condition and growth rates were predicted from skeletal, organ, and total length measurements (Franzmann *et al.* 1978, Messier and Crête 1984), but not from antler characteristics (Timmermann 1971).

Significant correlations between body weight and reproductive characteristics have been established for moose. Calf production was related to body weight of primiparous females at time of breeding, but not for pluriparous females in Alaska (Schwartz and Hundertmark 1993). The onset of ovulation was closely related to body weight in Norway (Saether and Heim 1993), and the proportion of yearlings that ovulated increased with increasing body weight; a pronounced increase occurred at a carcass weight of 145 kg (Saether and Haagenrud 1983).

Body weight and reproductive capacity of female moose are influenced directly by their nutritional state, which is a function of habitat quality. If health and production of moose populations were predictable from easily measured physical parameters (e.g., antler characteristics), biologists could more easily relate check station data to population-habitat relationships. Use of the relationship between antler size and nutritional status is widespread in white-tailed deer management. The existence of similar relationships for moose could prove useful in management also. The objective of this study was to determine if significant relationships existed among physical parameters, age, and reproductive potential of moose in New Hampshire.

METHODS

Study Area

Harvest data of moose were collected from New Hampshire (NH; 1988-1994), Maine (ME; 1980, 1982-1993), and Vermont (VT; 1993-1994). Moose populations continue to expand in these New England states. Moose hunting is relatively new to New England; NH reopened a moose season in 1988, ME in 1980, and VT in 1993. Annual harvest quotas within each state are stable or increase conservatively. Mean annual harvest in 1993 and 1994 was approximately 325, 1000, and 30, respectively; hunter success exceeds 75% in all states.

The NH data were classified by four zones to provide regional comparison of physical parameters (Fig. 1). The north region (NR) was approximately 382,976 ha (83% forest) of about an equal softwood-hardwood mix. Softwoods were dominated by red spruce (*Picea rubens*) and balsam fir (*Abies balsamea*), hardwoods were dominated by sugar maple (*Acer saccharum*), yellow birch

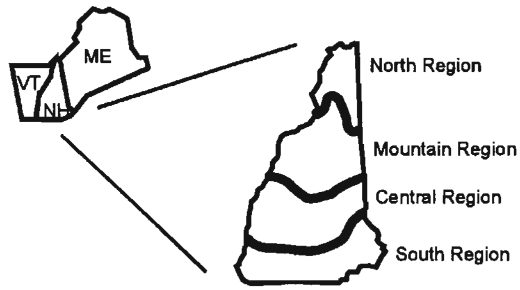

Fig. 1. New Hampshire's four moose management regions. Prevalent habitat types are spruce-fir lowlands in NR, hemlock-northern hardwood mountains in MR, hardwood uplands in CR, and white pine lowlands in SR.

(*Betula alleghaniensis*), and paper birch (*Betula papyifera*) (Frieswyk and Malley 1985). The mountain region (MR) was approximately 482,048 ha (83% forest) of about a 60:40 hardwood-softwood mix. Red spruce, white pine (*Pinus strobus*), and eastern hemlock (*Tsuga canadensis*) dominated softwood stands, sugar maple, red maple (*Acer rubrum*), and American beech (*Fagus grandifolia*) dominated hardwood stands (Frieswyk and Malley 1985). The central region (CR) was approximately 890,624 ha (85% forest) of about an equal softwood-hardwood mix. White pine, eastern hemlock, red maple, paper birch, and red oak (*Quercus rubra*) were the dominant species (Frieswyk and Malley 1985). The southern region (SR) was approximately 604,160 ha (86% forest) of about a 70:30 softwood-hardwood mix. White pine was the most prominent species, followed by red maple, red oak, and eastern hemlock (Frieswyk and Malley 1985).

Analysis

Hunters were required to bring their moose to a biological check station in each state. Measurements recorded for males include field dressed (minus heart and liver) body weight (BW), antler beam diameter (BD), antler spread (AS), and number of points (AP); for females, BW (minus reproductive tract) and number of corpora lutea

(CL; females ≥1.5 yr) were recorded. Age was estimated initially by tooth wear and later by counts of cementum annuli from a lower incisor (Sergeant and Pimlott 1959). Body weight was measured to the nearest kg by hanging scales suspended from a truck crane. Antler beam diameter was measured twice on one antler at perpendicular sites 2.54 cm above the pedicle with a micrometer; the average BD was recorded. Antler spread was measured as the maximum distance between any two AP. The total number of AP 2.54 cm in length was recorded. Ovaries were sectioned and the number of CL were counted by visual inspection. Data from NH (n=681 males, 291 females) were used to develop predictive relationships; data from ME (n=5065 males) were used to compare with NH data; data from VT (n=27 males, 7 females) were used to validate the predictive relationships.

Oneway analysis of variance was used to test for differences in physical parameters by age class; age classes were 0.5, 1.5, 2.5, 3.5, 4.5, 5.5, and ≥ 6.5 yr. Linear and multiple regression analyses were performed after log transformation of age class (Zar 1984) to develop predictive equations for BW. We used a Scheffe's test to make pairwise comparisons of means (Zar 1984). Female BW and CL counts were analyzed by analysis of variance to determine threshold weights for the onset of initial breeding and potential twinning. Comparisons were made between female BW and reproductive success, and male BW and antler parameters for each age class.

RESULTS

Females

Females exhibited large BW ranges per age class. Body weight increased significantly (>100 kg) only from 0.5 to 1.5 yr ($P<0.01$), although BW increased until 4.5 yr (Table 1). The number of CL increased from 1.5 to 2.5 yr ($P=0.016$), but did not change significantly thereafter (Table 1). The majority (63%) of yearling female moose harvested in NH were sexually mature. Age and BW influenced whether a female had 0 or 1 CL ($P<0.01$), but only BW influenced whether a female had 1 or 2 CL ($P<0.01$). New Hampshire females weighing <200 kg averaged 0.1±0.3 CL, females weighing 200-250 kg averaged 1.0±0.5 CL, females weighing 251-275 kg averaged 1.5±0.5 CL, and females weighing >275 kg averaged 1.9±0.5 CL. Females of these same weight classes in Vermont averaged 0.67, 1.5, and 2 CL, respectively.

Linear regression analysis revealed poor predictive relationships between BW and age ($r^2=0.55$; $P<0.01$). Two regional differences were found; 2.5 yr females from the

Table 1. Mean and standard deviations of body weight and number of corpora lutea per age class for female moose harvested in New Hampshire 1988-1994. Numbers in parentheses are sample sizes.

AGE CLASS (yr)	BODY WEIGHT[a] (kg)		CORPORA LUTEA	
0.5	108±23.4	(23)	-------	----
1.5	216±32.0	(65)	0.69±0.61	(68)
2.5	246±37.9	(59)	1.27±0.65	(63)
3.5	262±33.3	(46)	1.40±0.53	(53)
4.5	280±38.4	(18)	1.68±0.67	(19)
5.5	257±30.9	(15)	1.53±0.51	(17)
≥6.5	256±37.1	(43)	1.39±0.73	(49)

[a]Field dressed weight.

NR had significantly greater BW (271 kg) than 2.5 yr females from the MR (229 kg), CR (221 kg), and SR (237 kg; P=0.0001), and the average age of females in the NR with 1 CL (2.9 yr) was significantly less than those with 2 CL (3.9 yr) in that region (P<0.01).

Males

Body weight increased significantly from 0.5 to 1.5 yr (>100 kg) and 1.5 to 2.5 yr (>50 kg) (P<0.01; Table 2). Beam diameter, AS, and AP increased significantly from 1.5 to 2.5 yr (P<0.01; Table 2). Body weight, BD, AS, and AP increased annually to 5.5 yr (Table 2). No statistical difference in physical parameters among regions existed for yearlings (Table 3) or older age classes. However, AS, BD, BW, and AP within age classes >1.5 yr increased progressively from southern to northern regions. Body weight and BD of ME and NH bulls were not significantly different for any age class (Table 4).

The best combination of variables for predicting BW, based on stepwise multiple regression, was AS, age, and BD as described by the following equation:

$$BW = 8.38(AS) + 68.15(AG) + 1.97(BD) + 189.89, \quad (r^2=0.83; P<0.01; n=439) \qquad (1)$$

where:
AS = antler spread (cm)
AG = log animal age (yr)
BD = beam diameter (mm).

Body weight was predicted nearly as accurately with AS and BD:

$$BW = 9.25(AS) + 2.01(BD) + 186.97, \quad (r^2=0.81; P<0.01; n=515) \qquad (2)$$

Simple linear regression showed that BW was best predicted by AS:

$$BW = 10.84(AS) + 220.48, \quad (r^2=0.80; P<0.01; n=517) \qquad (3)$$

The relationship of Equation (3) was strongest for the yearling (r^2=0.70; P<0.01; n=109) and 2.5 yr age classes (r^2=0.64; P<0.01; n=97).

Body weight of VT males was predicted accurately (95% C.I.) 93% of the time when using Equation (1). Actual BW was higher (23.5±3.0 kg) than predicted 81% of the time, and lower (20.7±6.8 kg) 18% of the time. Body weight of VT males was also predicted accurately (95% C.I.) 93% of the time when using Equation (2). Actual BW was higher (22.5±3.0 kg) than predicted 81% of the time, and lower (20.2±7.2 kg) 18% of the time. Conversely, BW of VT males was predicted accurately (95% C.I.) only 37% of

Table 2. Mean and standard deviations of body weight, antler beam diameter, antler spread, and number of points per age class for male moose harvested in New Hampshire 1988-1994. Numbers in parentheses are sample sizes.

AGE CLASS (yr)	BODY WEIGHT (kg)[a]	BEAM DIAMETER(mm)	ANTLER SPREAD(cm)	ANTLER POINTS
0.5	112±18.7 (23)	------- ----	------- ----	------ ----
1.5	199±40.7 (139)	36.0±9.2 (153)	66.3±19.3 (125)	5.4±3.0 (152)
2.5	277±42.6 (114)	45.6±8.3 (127)	92.9±19.9 (111)	9.6±4.1 (127)
3.5	307±42.6 (111)	49.7±7.9 (117)	106.5±18.8 (106)	11.9±4.2 (118)
4.5	342±43.9 (70)	55.6±7.9 (79)	124.2±17.5 (66)	15.0±4.3 (77)
5.5	360±38.0 (48)	59.0±7.0 (51)	131.3±13.4 (42)	17.1±4.4 (51)
6.5	337±54.6 (133)	55.2±9.8 (148)	120.3±26.1 (132)	14.2±5.8 (149)

[a] Field dressed weight.

Table 3. Mean age and physical characteristics of yearling male moose harvested in New Hampshire, 1988-1994. No differences existed between regions.

REGION	BODY MASS (kg)		BEAM DIAMETER (mm)		ANTLER SPREAD (cm)		ANTLER POINTS	
North	224±36.6	(57)	36.0±9.9	(64)	63.0±18.8	(54)	5.3±2.5	(64)
Mountain	226±42.7	(60)	36.4±8.3	(63)	70.4±20.1	(49)	5.6±3.4	(63)
Central	221±46.0	(22)	35.1±10.0	(24)	66.8±18.8	(20)	5.0±3.3	(23)
South	----------	(0)	36.0±1.1	(2)	58.7±6.9	(2)	6.0±0.0	(2)

Table 4. Mean body weight and antler beam diameter of harvested male moose per age class in Maine, 1980, 1982-1993. Numbers in parentheses are sample sizes.

AGE (yr)	BODY WEIGHT (kg)		BEAM DIAMETER (mm)	
0.5	-----------		-----------	
1.5	212±26.4	(450)	33.9±6.0	(747)
2.5	266±33.1	(557)	41.7±5.7	(549)
3.5	297±39.1	(525)	46.7±5.5	(413)
4.5	332±41.1	(396)	51.5±5.6	(308)
5.5	352±46.0	(325)	55.7±5.9	(196)
>5.5	361±44.2	(718)	58.8±6.2	(496)

the time when using Equation (3). Actual BW was higher (26.0±3.2 kg) than predicted 77% of the time, and lower (19.0±7.1 kg) 23% of the time.

DISCUSSION

Continuous growth by NH female moose to 4.5 yr was consistent with growth patterns of female moose from Michigan (Karns 1976) and Norway (Solberg and Saether 1994); female moose from Alaska (Franzmann *et al.* 1978), Alberta (Blood *et al.* 1967), and Quebec (Messier and Crête 1984) increased body mass until at least 3.5 yr. Most females (78%) reached 200 kg as yearlings, and nearly 1 in 4 were 275 kg at 2.5 yr in the NR, presumably New Hampshire's best moose habitat. Similar consistency existed between BW of NH males (maximum at 5.5 yr) and other moose populations in Alberta (Blood *et al.* 1967), Maine (Table 4), Michigan (Karns 1976), Norway (Solberg and Saether 1994), and Quebec (Messier and Crête 1984).

Continuous increase in the number of CL to 4.5 yr, and correlation with weight class by NH female moose, was consistent with patterns described for female moose in Ontario (Simkin 1974) and Norway (Saether and Haagenrud 1983). The relationship identified between ranges in BW and the number of CL provides biologists with a quick technique to estimate the reproductive potential from BW, thereby reducing the need to collect reproductive tracts for CL counts. Further, the strong relationship between BW and the number of CL, the high proportion of yearlings that ovulated (63%), and the significant increase in BW from 0.5 to 1.5 yr indicates the potential for using the 1.5 yr female age class as an indicator of nutritional status. Importantly, yearlings demonstrated measurable and expected differences in BW and number of CL relative to other age classes, and these parameters are a function of nutritional status and habitat quality. Quick and precise identification of the yearling age class is possible from tooth wear and replacement (Peterson 1955).

The continuous growth in antlers (AP, AS, BD) of NH males until 5.5 yr was consistent with antler growth patterns in Maine (BD; Table 4), Ontario (AS; Cringan 1955), and Norway (AP; Solberg and Saether 1994). Although BW of NH males was best predicted by AS, BD, and age, use of AS and BD was reasonably accurate in comparison, particularly with 1.5 and 2.5 yr males. The accurate prediction of BW from antler characteristics could eliminate the time-consuming process of weighing carcasses at check stations, and reduce the necessity for hunters to provide whole carcasses. However, in New England hunter interest of carcass weight may influence an agency to continue such practice. More significant, however, is the potential use of AS and BD to assess growth rate (relative nutritional status) of 1.5 and 2.5 year old males, age classes reasonably identified by visual inspection of antlers and tooth wear and replacement (Peterson 1955). A greater range and sample size of antler characteristics and body mass particular to these age classes is needed to further assess the validity of these relationships.

The fact that few differences existed in physical parameters of moose from different regions in NH suggests that either differences in habitat quality do not exist, or that these differences are not yet reflected by the regional population densities relative to habitat quality. However, trends were apparent as 2.5 yr females were heavier, and mean BW, BD, AS, and AP per male age class >1.5 yr were highest in the NR, presumably New Hampshire's best moose habitat. It is probable that the quality of regional habitats are different, but population density in southern regions is too low to reflect such differences; moose populations continue to increase in these zones.

This analysis identified harvest check station data (e.g., antler characteristics of males and BW of females) that show potential use to predict the nutritional and reproductive status of moose populations. The yearling age class holds particular promise relative to predictive relationships because significant growth in weight and antler characteristics, and the onset of ovulation occurred in this age class. Use of the yearling age class as a population indicator would be ideal because of its ease of identification and availability relative to other age classes. The usefulness of any physical characteristic is dependent upon a range of growth response within or among age classes. Such response should reflect change in nutritional status, thus, it is questionable whether these data provide a sufficient range of response because moose populations are still expanding in New England. Therefore, even though the specific relationships identified for yearling males and females in this study may aid moose management efforts, analysis of these parameters from a range of population-habitat conditions is required to fully assess and validate their utility.

ACKNOWLEDGEMENTS

We are grateful to K. Bontaites of the New Hampshire Fish and Game Department, K. Morris of the Maine Department of Inland Fisheries and Wildlife, and C. Alexander of the Vermont Department of Fish and Wildlife for providing data for this study. K. Gustafson of the New Hampshire Fish and Game Department, and C. Neefus and W. Mautz, University of New Hampshire, provided statistical and/or editorial comments. Financial support was provided by the New Hampshire Fish and Game Department Federal Aid Project W-84-R. This is Scientific Contribution No. 1917 from the University of New Hampshire Agricultural Experiment Station.

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