ANALYSIS OF AGE, BODY WEIGHT AND ANTLER SPREAD OF BULL MOOSE HARVESTED IN MAINE, 1980-2009

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ABSTRACT: Age, field-dressed body weight, and antler spread data collected from 11,566 harvested moose (*Alces alces*) were analyzed to assess whether temporal change has occurred in the physical characteristics of bull moose from 1980–2009 in Maine. The annual proportion and antler spread of trophy bulls (spread ≥ 137 cm; n = 851) were also analyzed. There was no evidence of a measurable decline in the body weight or antler spread of adult bull moose (≥1.5 years old), similar to findings in Vermont and New Hampshire in a recent >20 year temporal analysis. There was a slight increase in physical characteristics of yearlings that contrasted with the trend in New Hampshire and Vermont where it is speculated that parasitism by winter ticks (*Dermacentor albipictus*) reduces growth rate and recruitment by yearlings. The proportion of trophy bulls in the harvest declined proportionally ~26% (9.3 to 6.9%) as harvest increased >2x from 1980–1987 to 2005–2009; however, the mean spread of trophy bulls declined by only 2% (P = 0.002). Additionally, there were no differences ($P > 0.05$) in the proportion of harvested bulls within each age class between 1980–1987 and 2005–2009, and the relatively stable proportion of mature bulls (>5 years old) in the harvest across time periods (30–44%) does not suggest selective harvest of older, trophy bulls. In the face of the declining regional population, continued monitoring of harvested moose is warranted to best manage the largest and longest harvested population in the northeastern United States.

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Measurement of physical characteristics of harvested moose (*Alces alces*) provides an opportunity to assess temporal trends and relative condition of a moose population. It is usually assumed that a direct relationship exists between habitat quality and physical condition. Age-specific body weight of male and female moose should reflect health and production (Schwartz and Hundertmark 1993). Antler measurements are used similarly because of the correlation between antler size and nutritional condition (Bubenik 1997). Adams and Pekins (1995) concluded that yearling moose are useful to estimate overall herd health because their potential growth rate reflects variance in body weight and onset of ovulation.

Antler morphology in cervids is determined by nutrition and genetics, and antler growth and size are strongly influenced by forage availability, quantity, and quality (Schmidt et al. 2007). Age also influences the size and formation of antlers as larger, older males invest less in body growth and allocate more resources toward antler growth, symmetry, and size (Stewart et al. 2000, Bowyer et al. 2001). As body size and age are strongly correlated with antler size and mating success (Clutton-Brock 1982), dominant males have the ability to limit the

mating opportunities of younger males (Van Ballenberghe and Miquelle 1996).

Hunting may influence ungulate populations by altering age and social structure, sex-ratio, and population dynamics (Milner et al. 2006). Mortality patterns in harvested populations commonly deviate from those in non-harvested populations, often with an increase in the mortality of prime-aged males (Ginsberg and Milner-Gulland 1994, Milner et al. 2006). Selective harvest is often applied as a management technique throughout North America to protect adult cow moose and maximize productivity (Timmermann 1987), often causing higher harvest of adult bulls. High harvest of older bull moose has the potential to impact normal age structure, and reduce average body size and antler spread in a population over time (Solberg et al. 2000); younger, smaller males are eventually predominant in the harvest (Schmidt et al. 2007).

Although hunting for older, large antlered moose can be a local economic stimulant and management tool (Monteith et al. 2013), an increasing focus on and popularity of trophy hunting further concentrates harvest on prime bulls (McCullough 1982, Timmermann and Buss 1997). Possible effects of trophy hunting include genetic selection for smaller antlers as well as negative demographic consequences due to other fitness-related genetic traits of trophy males; however, few studies have explored such implications (Festa-Bianchet and Lee 2009).

Since the initiation of modern moose hunting in 1980, the Maine Legislature set the moose hunting seasons and harvest levels. The overall goals, developed during the 1985 planning process, were to maintain the moose population at the 1985 level, increase harvest, and maintain viewing opportunities; permits were either sex prior to 1999. Since 2001, the Maine Department of Inland Fisheries and Wildlife (MDIFW) has set the moose hunting seasons and harvest levels under a Moose Management System that describes the decision process and actions necessary to meet population goals and objectives set by a public working group (Morris 2002). Desired levels of hunting opportunity, viewing opportunity, and road safety are assessed to categorize each Wildlife Management District (WMD) into either a Recreation, Road Safety, or Compromise Management Area. Addressing population goals in a WMD includes determining age structure of harvested animals, age and sex composition from sightings by deer and moose hunters and more recently from helicopter surveys (Kantar and Cumberland 2013). Among other measures, both the proportion of bulls and the percentage of mature bulls ($\geq$5 years old) in each WMD are examined annually and harvest quotas are adjusted to achieve desired levels, a marked shift in management strategy because bull composition was not a prior criteria.

A recent >20 year analysis (1988–2009) of physical parameters of harvested moose in New England indicated that body weight and ovulation rate of yearling cows in New Hampshire and Vermont have decreased; conversely, body weight of yearling cows increased in Maine. Further, body weight and most antler measurements of harvested bulls in New Hampshire and Vermont have also declined (Bergeron et al. 2013). Given this temporal decline in physical characteristics of bulls, there is reason to investigate baseline and trend data in bull moose harvested in Maine given the >30 year history of modern moose hunting in Maine where harvest has increased from 636 in 1980 to 2,582 in 2011, with higher permit allocations likely to continue (MDIFW 2011). Importantly, age, antler spread, and body weight of harvested bulls have been measured since 1980.

This study provides a temporal assessment of these physical characteristics to identify trends in the relative growth and

condition of bulls harvested in Maine from 1980–2009. The objectives were to assess trends in body weight and antler spread within age classes, the relative proportion of age classes, and the proportion and physical characteristics of trophy bulls in the harvest.

STUDY AREA

Northern Maine is located at the extreme northeast corner of the United States, above 44° 38' N. It is bordered by Quebec and New Brunswick to the north, New Hampshire to the west, and the Atlantic Ocean to the south and east. Maine is 90% forested and commercial timber harvesting is common throughout the northern portion of the state (Hoving et al. 2004). The sub-boreal Acadian forest has a mixture of spruce (*Picea* spp.) and balsam fir (*Abies balsamea*) stands and northern hardwood forests; common species include beech (*Fagus grandifolia*), maple (*Acer* spp.), hemlock (*Tsuga canadensis*), birch (*Betula* spp.), spruce, and balsam fir (Hoving et al. 2004).

Harvest data were analyzed for 12 Wildlife Management Districts (WMD; 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, and 19) in a 45,793 km^2 area, roughly the northern half of Maine (Fig. 1). This area contains a high proportion of suitable moose habitat in the form of active commercial forestlands, has had relatively consistent harvest over the study period (1980–2009; L. Kantar, pers. comm.), and these WMDs represent the core of Maine's moose population (MDIFW 2013).

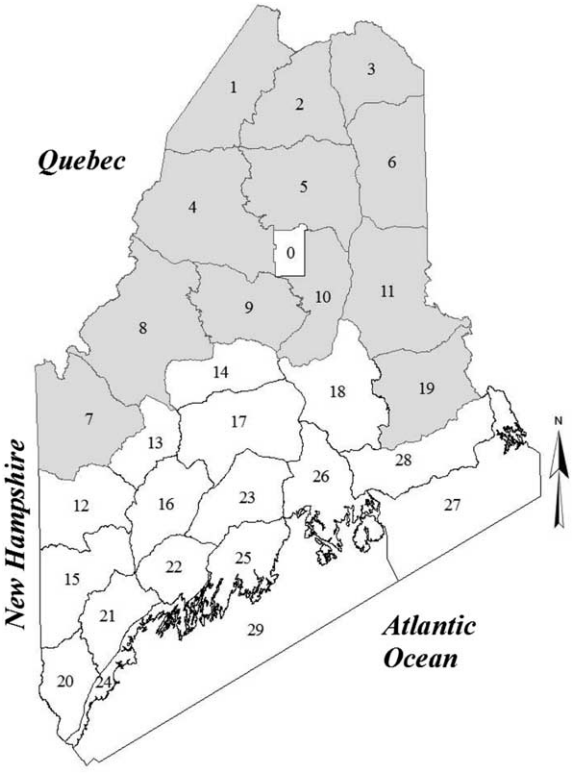

Fig. 1. Locations of Maine Wildlife Management Districts (shaded) from which data from harvested bull moose were used to assess temporal trends in physical characteristics, 1980–2009.

METHODS

Biological data collected at moose check stations in 1980–2009 were used to assess temporal trends in the physical characteristics of bull moose. Specific measurements were field-dressed body weight, antler spread, and age. Field-dressed body weight was defined as the entire carcass weight minus the heart, liver, lungs, and rumen-reticulum and was measured on certified scales at registration stations. Antler spread was equal to the greatest width (cm) on a plane perpendicular to the skull (L. Kantar, pers. comm.). Age was determined from cementum annuli counts on cross-sectioned canines (Sergeant and Pimlott 1959) performed by MDIFW biologists. Trophy bulls were defined as those with spreads ≥137 cm (54 in) which is similar to the minimum entry for Canada moose in the Boone and Crockett Club trophy record-book (Boddington 2011). Incomplete records of physical characteristics were excluded in order to allow for analysis of the proportional relationships between physical parameters.

Data were broken into 4 time periods (1980–1987, 1988–1998, 1999–2004, and 2005–2009) to maintain similarity with recent assessments of regional harvest data (Adams and Pekins 1995, Musante et al. 2010, Bergeron et al. 2013). Data were also analyzed by individual year for some tests; data were unavailable for 1981 (no harvest) and 1985 (data not age-specific).

Analysis of variance (ANOVA) was used to test for age-specific differences in physical parameters between years and time periods including body weight-age relationships, antler spread-age relationships, age class distribution, and relative condition of the population over time. Age classes were 1.5, 2.5, 3.5, 4.5, 5.5, and ≥6.5 years. Tukey's test was used to make pairwise comparisons; significance for all tests was assigned *a priori* at $\alpha = 0.05$.

RESULTS

A total of 11,566 harvested moose were included in the data analysis. The number of records per age class ranged from 1169 (5.5 years) to 2860 (≥6.5 years), with sample size increasing in subsequent time periods: 1619 and 1625 in 1980–1987 and 1988–1998, and 3789 and 4533 in 1999–2004 and 2005–2009, respectively.

Overall, there was an upward trend in mean body weight of harvested bulls over the 30-year period. Between 1980–1987 and 2005–2009, a 4–10% increase in mean body weight occurred in the youngest 4 age classes (1.5–4.5 years old, $P \leq 0.024$); minimal change (1–2%, $P > 0.05$) occurred in the older classes in the same periods (Table 1). The current (2005–2009) mean body weight was higher than the 30 year mean in all age classes, with the exception of the 5.5 year age class (Table 1). There was no significant difference ($P > 0.05$) in mean body weight among any time periods in the ≥6.5 year age class. The maximum mean weights occurred in the 1999–2004 time period for the 2.5–5.5 year age classes, and were significantly higher than in other time periods for 2.5 ($P \leq 0.002$) and 3.5 year old bulls ($P \leq 0.005$) (Table 1). Maximum mean weight of yearlings (225 kg) occurred in the 2005–2009 time period ($P \leq 0.02$).

The 1.5–4.5 year old classes had an overall significant increase (4.0–8.3%, $P \leq 0.014$) in mean antler spread between 1980–1987 and 2005–2009, with some variation in the intermediary periods; bulls ≥5.5 years had minimal change (<3.6%, $P > 0.05$) (Table 1). Yearlings were the only age class in which the current (2005–2009) mean spread (60 ± 15.9 cm) exceeded the 30 year mean (58 ± 13.6 cm); this age class had the most substantial increase between 1980–1987 and 2005–2009 (8.3%, $P = 0.013$). Though no significant difference ($P > 0.05$) existed between 1980–1987 and 2005–2009 in the ≥6.5 year age class, spread significantly

Table 1. Mean (± SD) field-dressed body weight (kg) and antler spread (cm) of bull moose harvested in select Wildlife Management Districts in Maine by time period and age class, 1980–2009. Mean body weight and antler spread of harvested trophy bulls are also presented by time period. Sample sizes are in parentheses. Within age classes, time periods with a letter in common were not significantly different.

Age	1980–1987		1988–1998		1999–2004		2005–2009		30 year mean
	Body weight (kg)								
1.5	217 ± 29 ^{b}	(196)	214 ± 26 ^{b}	(410)	218 ± 29 ^{b}	(573)	225 ± 36 ^{a}	(420)	219 ± 30
2.5	253 ± 44 ^{d}	(269)	268 ± 38 ^{c}	(264)	285 ± 35 ^{a}	(1035)	279 ± 35 ^{b}	(896)	278 ± 38
3.5	302 ± 45 ^{c}	(219)	298 ± 41 ^{c}	(245)	323 ± 37 ^{a}	(657)	316 ± 37 ^{b}	(805)	314 ± 40
4.5	329 ± 48 ^{c}	(226)	339 ± 44 ^{bc}	(193)	351 ± 43 ^{a}	(433)	346 ± 40 ^{ab}	(696)	344 ± 43
5.5	353 ± 50 ^{b}	(174)	360 ± 41 ^{ab}	(152)	366 ± 42 ^{a}	(337)	360 ± 40 ^{ab}	(506)	361 ± 43
≥6.5	374 ± 50 ^{a}	(535)	372 ± 46 ^{a}	(361)	374 ± 45 ^{a}	(754)	374 ± 41 ^{a}	(1210)	373 ± 44
Trophy	397 ± 47 ^{a}	(151)	392 ± 39 ^{a}	(145)	396 ± 41^{a}	(238)	396 ± 40 ^{a}	(317)	395 ± 41
	Antler spread (cm)								
1.5	56 ± 13 ^{bc}	(196)	55 ± 12 ^{c}	(410)	59 ± 13 ^{ab}	(573)	60 ± 16 ^{a}	(420)	58 ± 14
2.5	73 ± 17 ^{c}	(269)	79 ± 15 ^{b}	(264)	82 ± 14 ^{a}	(1035)	79 ± 13 ^{b}	(896)	80 ± 14
3.5	89 ± 18 ^{c}	(219)	92 ± 17 ^{bc}	(245)	97 ± 15 ^{a}	(657)	92 ± 15 ^{b}	(805)	94 ± 16
4.5	99 ± 21 ^{c}	(226)	107 ± 19 ^{ab}	(193)	109 ± 19 ^{a}	(433)	104 ± 16 ^{b}	(696)	105 ± 18
5.5	109 ± 22 ^{b}	(174)	118 ± 17 ^{a}	(152)	120 ± 17 ^{a}	(337)	113 ± 17 ^{b}	(506)	115 ± 18
≥6.5	123 ± 19 ^{bc}	(535)	128 ± 20 ^{a}	(361)	125 ± 19 ^{b}	(754)	122 ± 19 ^{c}	(1210)	124 ± 19
Trophy	146 ± 7 ^{ab}	(151)	146 ± 7 ^{a}	(145)	144 ± 7 ^{bc}	(238)	143 ± 7 ^{c}	(317)	145 ± 7

declined 5% ($P < 0.000$) between 1988–1998 and 2005–2009. The maximum spread occurred in 1999–2004 for 2.5–5.5 year olds and the mean spread was significantly higher than in other time periods for 2.5 ($P \leq 0.003$) and 3.5 year olds ($P < 0.000$) (Table 1).

There were no significant differences ($P > 0.05$) in the proportion of harvested bulls within each age class between 1980–1987 and 2005–2009; some variation occurred within the intermediary periods for each age class (Fig. 2). The proportion of yearlings in the harvest declined significantly (64%, $P = 0.0003$) between 1988–1998 and 2005–2009; conversely, an increase occurred in the 4.5 year age class (28.5%, $P = 0.027$).

A total of 851 harvested trophy bulls (spread ≥ 137 cm) were included in the analysis. The sample size for time periods varied but increased overall, with 151 and 145 in 1980–1987 and 1988–1998, and 238 and 317 in 1999–2004 and 2005–2009, respectively.

The mean antler spread of trophy bulls declined 2% ($P = 0.002$) from 145.7 ± 6.9 cm to 143.3 ± 6.6 cm between 1980–1987 and 2005–2009. There were no significant differences ($P > 0.05$) in the mean body weight of harvested trophy bulls between 1980–1987 and 2005–2009. The current (2005–2009) mean body weight was higher than the 30 year mean for trophy bulls (395 ± 40.6 kg; Table 1).

The proportion of trophy bulls declined (~26%, P = 0.128) from 9.3% in 1980–1987 to 6.9% in 2005–2009 as the absolute number increased (~2x) from 151 to 317 animals from 1980–1987 to 2005–2009 (Fig. 3, Table 1). There was a significant negative relationship between the annual proportion of trophy bulls and year ($r^2 = 0.14$, n = 28, $P = 0.03$). The mean age of trophy bulls was between 7 and 8.5 years in all time periods with 85–93% ≥5 years old. Across all time periods, 5.5–12.5 year olds accounted for 86–92% of all trophy animals (Fig. 4).

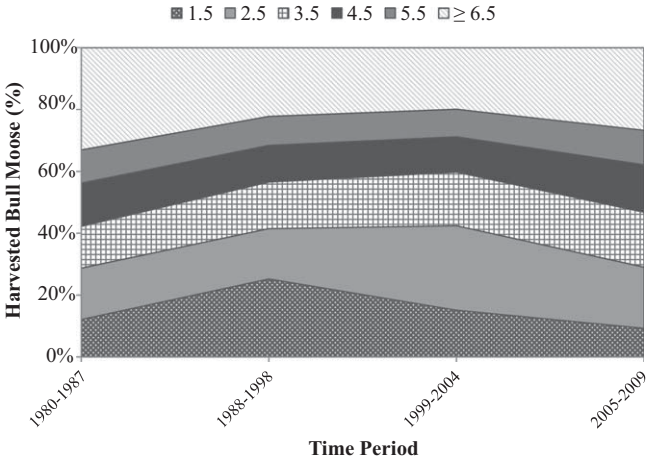

Fig. 2. Proportional age structure of bull moose harvested in Maine (WMDs 1–11 and 19) by time periods, 1980–2009.

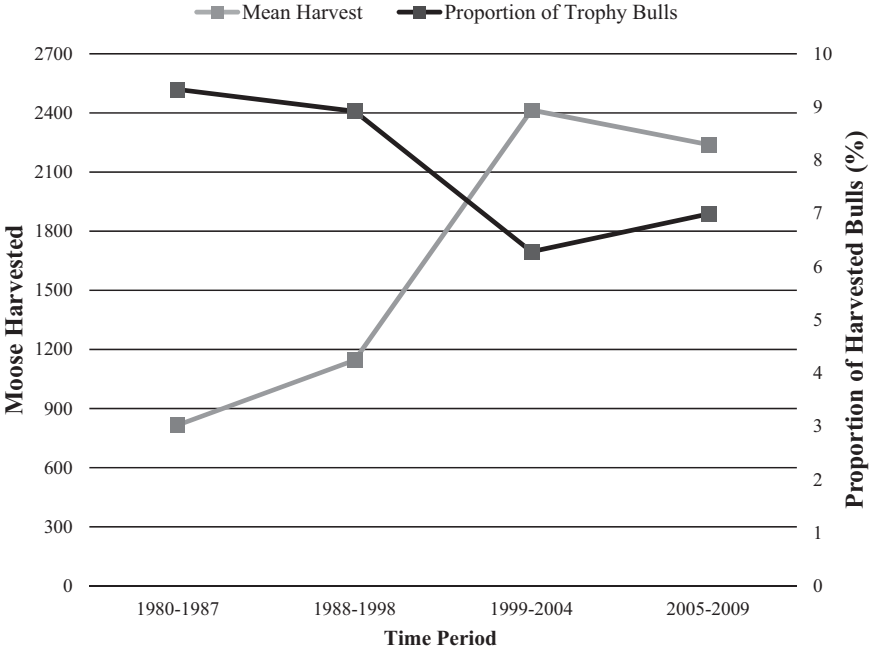

Fig. 3. Average annual moose harvest (MDIFW 2011) and proportion (%) of harvested bull moose considered trophy bulls (spread ≥137 cm) by time period in Maine, 1980–2009.

DISCUSSION

There was no statistical evidence of a measurable change in the physical parameters of bull moose harvested in northern Maine from 1980–2009. A minimal upward trend occurred in mean body weight during the 30-year time period as the 2005–2009 mean body weight exceeded the 30-year mean in all age classes (Table 1). Similarly, a slight overall increase occurred in the

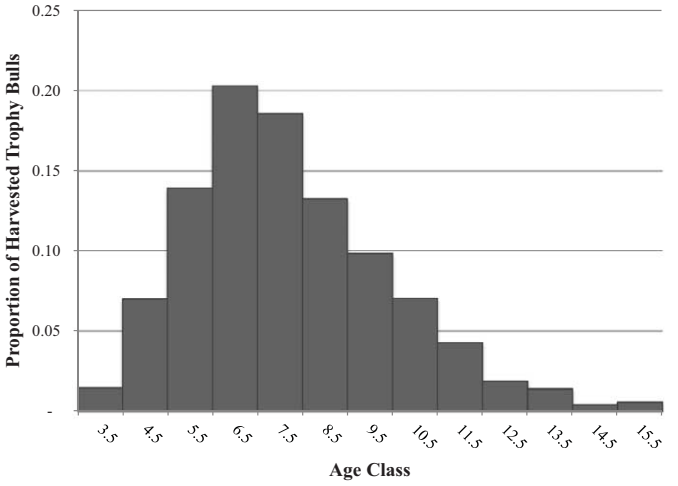

Fig. 4. Proportion (%) of harvested trophy bulls (spread ≥137cm) within each age class in Maine (WMDs 1–11 and 19), 1980–2009.

mean spread of the 4 youngest age classes across the 30-year time period, with some variability but no clear trend in bulls ≥5.5 years old. The lack of declining trends in adult physical characteristics is similar to that measured in nearby Vermont and New Hampshire and presumably indicates adequate habitat quality (Bergeron et al. 2013). However, unlike in Vermont and New Hampshire, where declines occurred in both body weight and productivity measures in the yearling age class, the physical characteristics of Maine yearlings increased slightly indicating variability within the northeastern United States.

The downward trend in the proportional harvest within the yearling age class between 1988–1998 and 2005–2009 could indicate a reduction in the proportion of yearlings in the population possibly due to lower recruitment (Fig. 2). However, this decline was not coupled with reduced physical parameters that are indicative of a decline in relative health and nutritional status; both body weight and spread increased in yearlings during the 30-year period.

Numerous factors can influence physical parameters of moose including habitat quality, weather, and disease and parasites. In nearby New Hampshire, parasitism by winter ticks (*Dermacentor albipictus*) is considered a primary negative influence on survival and growth of calves and subsequent productivity of yearlings (Musante et al. 2010, Bergeron and Pekins 2014). Declining trends in yearling body weight and antler spread in New Hampshire and Vermont bulls from 1988–2009 (Fig. 5) are suggestive of such impact (Bergeron et al. 2013). Importantly, the core moose habitat in New Hampshire and Vermont is not considered poor or inadequate based on forest regeneration surveys in both (Bergeron et al. 2011, Andreozzi et al. 2014), and that commercial forests dominate both areas as in Maine. The lack of measurable decline in physical characteristics of adult bulls and slight increase in physical characteristics of yearling bulls in Maine from 1980–2009 suggests that parasitism by winter ticks could be less problematic in Maine. The majority of the Maine study area lies above

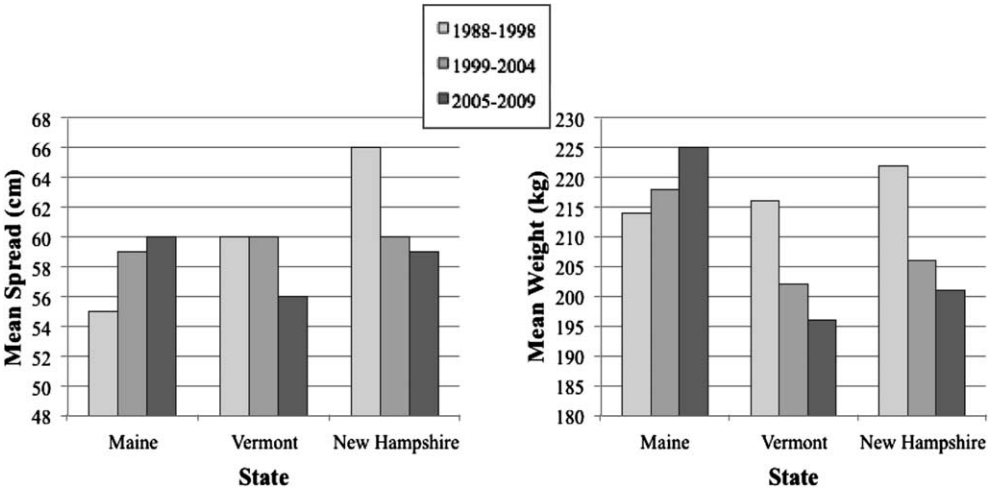

Fig. 5. Mean field-dressed body weight (kg) and mean antler spread (cm) of harvested yearling bull moose in Maine (WMDs 1–11 and 19), Vermont, and New Hampshire (1988–2009; Bergeron et al. 2013).

44° 38' N extending as far north as 47° 28' N, an area further north than the entirety of New Hampshire and Vermont, both below 45° 18' N. Because abundance of winter ticks and their annual impact are largely determined by length of winter and snow cover (Samuel and Welch 1991), the core of Maine's moose population may be less influenced by this parasite.

The 2% decline in antler spread of trophy bulls is probably not biologically significant, and unlikely to be harvest related as small variation in antler size is often explained by annual weather influences, or variation in population density and uneven sex ratios (Solberg and Saether 1994). Additionally, the relatively stable proportion (30–44%) of bulls >5 years old in the harvest across time periods does not indicate excessive selective harvest pressure towards older, trophy bulls (Fig. 2). The majority of trophy bulls (86–92%) are between 5.5 and 12.5 years old in all time periods, with an average age between 7 and 8.5 years (Fig. 4). In Alaska, spread was maximum in prime age bulls (7–11 years) and declined with senescence at ~12 years (Bowyer et al. 2001). The high proportion of trophy bulls >5 years old and the declining proportion at age 12 in Maine suggests that the proportion of trophy bulls in each age class is likely not influenced by harvest pressure, but reflects normal antler growth and maturation, and senescence.

Most studies with empirical evidence of the effects of trophy hunting on growth of horn-like structures occurs outside of the moose literature; for example, targeted hunting on bighorn trophy rams (*Ovis canadensis*) over a 30-year period resulted in smaller-horned and lighter rams, and fewer trophy animals (Coltman et al. 2003). Hundertmark et al. (1998) simulated selective harvest for bull moose based on antler size (>127 cm spread) and showed a significant decrease in the frequency of favorable antler alleles; however, empirical evidence of the genetic impact of trophy hunting is rare and such changes are assumed to be undetectable for many generations (Harris et al. 2002).

Age distribution can shift toward younger age classes as harvest intensity increases (Jenks et al. 2002). Therefore, selective harvest that targets older, larger males can result

in increased breeding by younger bulls and alter age structure of the population by reducing mean bull age and size over time (McCullough 1982). MDIFW determines bull composition by analyzing the age of harvested animals, sightings by deer and moose hunters, and more recently aerial surveys (Kantar and Cumberland 2013). Harvest levels and permit types (i.e., sex-specific) are adjusted annually to maintain desired bull composition levels and limit over-harvest of prime age and mature bulls. For example, in WMDs 1–10 and 19, the goal is to maintain 17% mature (≥5 years old) bulls, whereas in WMD 11 it is to maintain a ratio of 60 bulls:100 cows (Morris 2002). Despite fourfold higher harvest after 30 years of moose hunting in Maine (MDIFW 2011; Fig. 3), the study population has maintained consistent age structure. Specifically, there has been no measurable decline in the proportion of harvested bulls ≥6.5 years that would indicate an overall younger age structure due to selective harvest of larger, trophy males (Fig. 2).

Maine's current moose population estimate is >70,000 moose, and mean annual harvest has increased from 816 in 1980–1987 to 2239 in 2005–2009 (MDIFW 2011, 2012, Fig. 3). Current harvest is only about 3% of the current population estimate, but will probably increase as hunting interest and moose conflicts increase. While this study indicates that physical characteristics of bull moose in Maine have not changed appreciably after 30 years of harvest, understanding the potential and realized influences of harvest on age structure and physical parameters of moose populations is fundamental to proper management. Similar harvest analyses have indicated recent declines in body weight, antler measurements, and reproductive rate in moose in nearby Vermont and New Hampshire (Bergeron et al. 2013). These productivity measurements have been collected in Maine since 2010 in combination with Potvin double-count aerial surveys and age-sex composition flights. Integration of these techniques with harvest data will provide the essential data necessary for managing moose under the 3 primary management goals in Maine. Continued monitoring of physical parameters of harvested moose is warranted to monitor the relative condition and best manage the largest and longest harvested moose population in the northeastern United States.

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