STATUS AND MANAGEMENT OF MOOSE IN THE PARKLAND AND GRASSLAND NATURAL REGIONS OF ALBERTA

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ABSTRACT: Moose (*Alces alces*) naturally colonized the Parkland Natural Region of Alberta during the 1980s and early 1990s, and later colonized the Grassland Natural Region by the early 2000s. We summarize population data during 1996–2016 for these regions, examining density, population trends, productivity, distribution, management, and moose-human conflicts to determine population status and sustainability. Within the Parkland, aerial surveys from one frequently monitored Wildlife Management Unit (WMU) indicated a significant increase ($R^2 = 0.7476$, $P < 0.001$) in density, representing an annual rate of change of 1.07. Pooled data from an additional 21 Parkland WMUs indicated a mean annual rate of change of 1.11. Mean density for the 22 Parkland WMUs over the study period was 0.19 ± 0.06 moose/km^2, and aerial surveys indicated a mean of 74.4 ± 3.6 calves/100 cows and 51.9 ± 2.9 bulls/100 cows. Within the Grassland, winter aerial survey data from 4 WMUs indicated a mean density of 0.05 ± 0.01 moose/km^2, and 72.5 ± 6.75 calves/100 cows and 108.8 ± 34.4 bulls/100 cows. Hunting in these regions has been managed with a limited entry hunt. Resident rifle hunting opportunity for moose in the Parkland and Grassland increased 4.2-fold between 1996 and 2015. Opportunity in this region also represented an increasing proportion of that available province-wide, from 3.4% in 1996 to 19.8% in 2015.

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Moose (*Alces alces*) have a circumpolar distribution and are typically associated with forested boreal ecosystems (Peterson 1974, Reeves and McCabe 2007). They are renowned as a reliable source of food and recreation and for their cultural and economic significance (Franzmann 1978). Recent population declines in some regions of Canada and the United States are causing growing concerns among wildlife managers and the public (Murray et al. 2006, Lenarz et al. 2009, Crichton et al. 2015). In contrast, this paper documents the success of a population of moose during a 20-year period (1996–2016) following establishment at low density in the agriculturally-dominated Parkland and Grassland Natural Regions (hereafter Parkland and Grassland) of Alberta (Bjorge 1996).

The Parkland and Grassland has extensive agricultural and human development, making these regions appear unlikely to support growing moose populations. In the Parkland, about 90% of the natural vegetation has been removed and in the Grassland, excluding riparian areas, there is limited woody vegetation. In forested ecosystems moose select habitats that provide forage, cover, and security from predators (Telfer 1984). Although agricultural areas with limited woody cover may provide moose with adequate forage resources (Laforge et al. 2016), these habitats may be associated with increased risk of heat stress (Dussault et al. 2004) due to lack of cover. In addition, infrastructure including roads, highways, farms, towns, cities, and energy development is abundant and, along with associated human activity, may pose additional challenges for moose. Since the time of European settlement, moose were not commonly observed here by residents (Dwier 1969, Stelfox and Stelfox 1993) nor were they often observed during aerial inventory of the Parkland prior to the early 1980s or in the Grassland prior to 2000.

Here we document density, population trends, productivity, harvest management, and public complaints of a moose population in the Parkland and Grassland of Alberta from 1996–2016. We also discuss biological and social factors contributing to utilization of this agricultural and human-dominated landscape, and future concerns regarding population dynamics and management.

STUDY AREA

The study area included the Parkland (primarily Alberta 200 series Wildlife Management Units [WMUs], plus WMUs 728, 730, and 936) and Grassland WMUs (primarily Alberta 100 series WMUs) in southeastern Alberta (Dowling and Pettapiece 2006; Fig. 1). WMU 224 was excluded from analysis because of the high proportion that fell within the Boreal Natural Region. WMU 166 was treated as a Parkland WMU because of the high proportion of the area that fell within the Parkland. WMUs 728 and 730 (Canadian Division Support Base, Edmonton Detachment, Wainwright) were treated as a single WMU because they abutted each other and were managed as one unit.

The Parkland is a broad transitional zone between the warmer, drier grass-dominated Grassland to the south and the more heavily treed Boreal Natural Region to the north and west (Strong and Leggat 1992). In Alberta, the Central and Foothills Parkland cover almost 9% (57,627 km^2) of Alberta and extend into Saskatchewan and Manitoba (Riley et al. 2007); the outlying Peace Parkland in northwest Alberta was not part of this study. The dominant tree species in the Parkland was trembling aspen (*Populus tremuloides*), although they were less common prior to European settlement when wildfires were more frequent (Strong and Leggat 1992). Scattered pockets of white spruce (*Picea glauca*) and balsam poplar (*Populus balsamifera*) also occur. Common shrubs included willow (*Salix spp*.), chokecherry (*Prunus virginiana*), Saskatoon berry (*Amelanchier alnifolia*), red osier dogwood (*Cornus stolonifera*), and Canada buffaloberry (*Shepherdia canadensis*). The dominant natural grass in the area was rough fescue (*Festuca scabrella*). Common large mammal species included white-tailed deer (*Odocoileus virginianus)*, mule deer (*O. hemionus*), and coyote (*Canis latrans*), all of which are found in the Grassland. About 4% of the land area was covered by water (Dowling and Pettapiece 2006) including thousands of small wetlands. Major rivers with valleys and tributaries included the North Saskatchewan, Red Deer, and Battle. Average total annual precipitation was ~400 mm (Strong and Leggat 1992). More than 90% of the Parkland was privately owned (Bjorge et al. 2004) and it includes the major urban centers of Edmonton, Calgary, Red Deer, Wetaskiwin, Camrose, and Lloydminster.

The Grassland is the warmest and driest Natural Region in Alberta. Water comprises 1–2% of the land base (Dowling and Pettapiece 2006), consisting primarily of major rivers (Red Deer, South Saskatchewan, Oldman, Bow), and shallow lakes and wetlands. Native grass species included needle and thread grass (*Hesperostipa comate*), wheat grass (*Agropyron* spp.), and rough fescue. Narrow leaf cottonwood

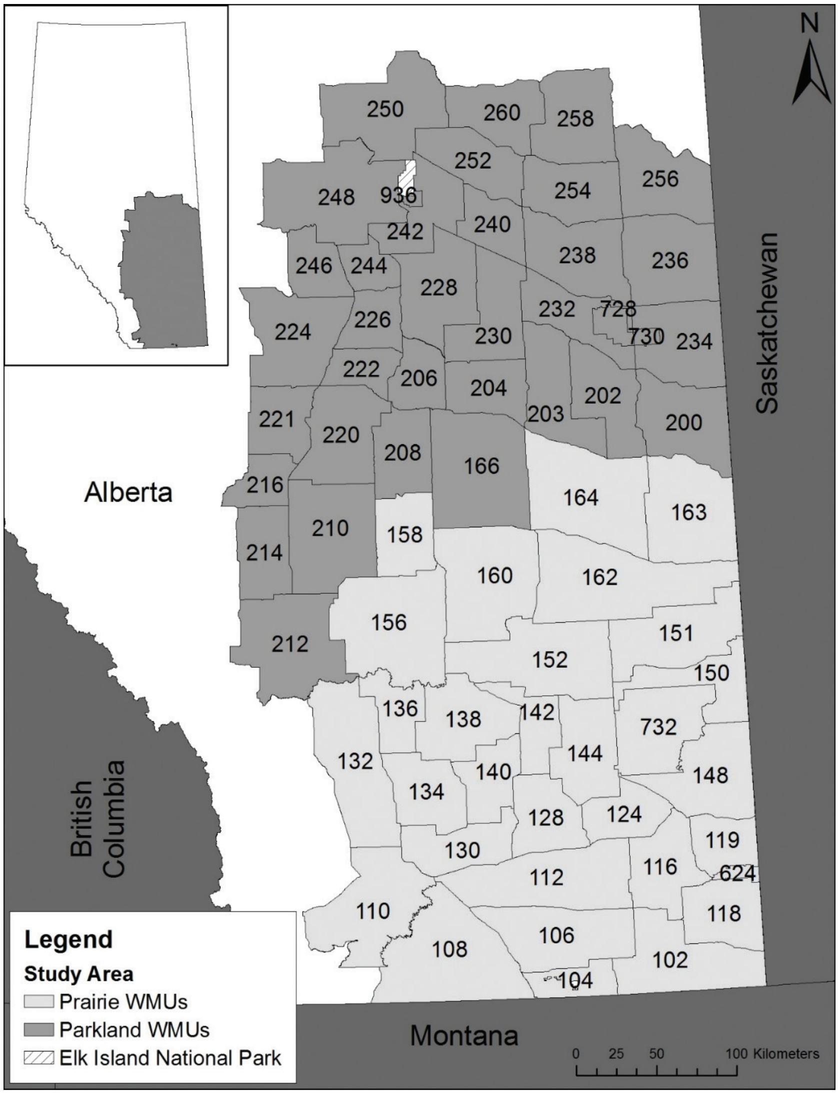

Fig. 1. Wildlife Management Units (WMUs) in the Parkland and Grassland (Prairie), Alberta, Canada.

(*Populus angustifolia*), western plains cottonwood (*P. deltoids*), and balsam poplar were the dominant trees and found primarily in riparian areas. Shrubs included willow, buck brush (*Ceanothus cuneatus*), silverberry (*Elaeagnus commutate*), silver sage (*Artemisa cana*), and Saskatoon berry. Private ownership was estimated at 70% (Prairie Conservation Forum 2016) and major urban centers included Calgary, Lethbridge, and Medicine Hat.

Land in both Natural Regions has been heavily modified for agriculture, industrial development (primarily oil and gas and renewable energy), infrastructure, and urban development. Bjorge et al. (2004) estimated ~10% of the Central Parkland remained as native vegetation, mostly as woody vegetation. Remaining native vegetation in the Grassland was ~40% (ABMI 2015) with native grass dominant. The current human population in the combined area was estimated at >3 million (Statistics Canada 2017).

METHODS

We examined data collected during aerial surveys conducted for ungulate management in the Parkland and Grassland during 1996–2016. Prioritization of WMUs for aerial surveys was based on the following criteria: 1) time interval since most recent survey, 2) local budgets, 3) density of target species in the WMU, 4) prevalence of chronic wasting disease, and 5) stakeholder interests including hunter concerns and public complaints. Surveys of individual WMUs were intended to occur once every 3–6 years; however, this was often not achieved due to budgetary and/or weather constraints. The notable exception to this was WMU 728/730 where the objective was to fly the unit a minimum of once every 2 years. Surveys occurred during prime snow conditions, generally in December, January, and early February.

Two types of aerial survey methods were utilized during the study period: 1) stratified random block surveys (1996–2010) and 2) strip-transect surveys (all surveys in WMU 728/730 and other WMUs in 2011–2016). The change to strip-transect surveys was to implement a more efficient methodology by eliminating pre-flight stratification surveys and minimizing time travelling between study blocks. Comparison of the 2 survey methods produced similar results on the same areas (J. Allen, Alberta Environment and Parks, pers. commun.). Therefore, we assumed that the 2 survey methods provided data suitable for direct comparison between years in the same WMU.

Stratified random block surveys followed Gasaway et al. (1986) and were modified according to Lynch and Schumaker (1995). The survey area was broken into degree blocks, (such as 3 min latitude by 5 min longitude) and stratified into 3 or 4 strata (high, medium, low, very low) based on pre-flights for the target species or interpretation of aerial photos. Survey blocks within each strata were randomly selected for inventory (Hofman and Grue 2012). Surveys were conducted from Bell 206 helicopters on flight lines spaced 15 sec apart, with the objective of complete coverage of each block. Flight crews consisted of a pilot, a navigator/recorder seated beside the pilot, and observers seated behind the pilot and the navigator/recorder. Survey speed was 80–120 km/h and height was 80–120 m agl. All observed ungulates were counted and classified to age and sex when possible. Female moose were identified by their white vulva patch visible from the air and calves by their small size (Timmermann 1993). Population estimation spreadsheets (i.e., Quad6.xls files, Microsoft Excel, Redmond, Washington) adapted from Gasaway (1986) were used to calculate population size, confidence limits, density, and sex/age classifications.

Strip-transect surveys (Jolly 1969, Alberta Environment and Sustainable Resource Development 2014) were conducted by flying transect lines at 1.6 km intervals with 25% coverage (400 m-wide survey strip); some variability in transect spacing occurred depending on tree cover, size of the WMU, and study objectives. In Parkland WMU 728/730, the most frequently surveyed WMU, transects were flown at 800-m intervals, with moose observed within 400 m on either side of the flight line. Surveys were conducted from a Bell 206 helicopter with flight speed, altitude, and survey crew as described for the stratified random block surveys (see above). Because transects varied in length (Jolly 1969, Alberta Environment and Sustainable Resource Development 2014), beginning in 2011, the average density (R; moose/km^2)

was calculated by summing the total animals counted per transect (∑x), and dividing by the total area searched (length of transects multiplied by width of survey strip [∑z]). We calculated population estimates (unequal sized units, sampling without replacement) by multiplying the average density (R) by the overall area of the WMU (Z). We estimated 90% confidence intervals by multiplying the *t* statistic for the left-tailed inverse of the Student's *t*-distribution, ($t_{0.05,df=n-1}$) by standard error (SE; without replacement) of the abundance estimate, where SE = square root of variance, and variance=$N*(N-n)/(n*(n-1))*(\sum x^2+R^2*\sum z^2-2*R*\sum xz)$ with N as the total number of possible transects given 100% coverage, and n as the number of transects sampled. We estimated the mean overall density of moose in the Parkland over the study period by establishing the mean density in each WMU and then calculating the overall mean for the 22 WMUs. Where appropriate, means were presented as ± standard error of the mean (SE).

We used population estimates to estimate population growth rates and trend during the study period. In WMU 728/730, where 12 population estimates were available for the study period, we used log-linear regression (Harris 1986) of moose/km^2 against year to test for evidence of a significant population trend. In the other 21 WMUs (166, 200, 202, 203, 204, 206, 208, 220, 228, 230, 232, 234, 236, 240, 242, 246, 248, 250, 258, 260, 963) where fewer inventories were conducted, as well as WMU 728/730, we calculated annual population growth rates (λ) after Hatter (1999, 2001). Growth rates were estimated as $\lambda = (N_t/N_0)^{1/t}$, where N_t is the number of moose/km^2 in year t, and N_0 is the number moose/km^2 in the initial survey year. We then estimated the mean population growth rate as the average of λ estimates per WMU, recognizing that specific study periods varied by WMU.

Harvest data were also available from compulsory reporting at a WMU check station in WMU 728/730. In all other WMUs, harvest statistics were estimated from data collected by an annual telephone questionnaire (Lynch and Birkholz 2000); beginning in 2011, an online questionnaire was distributed to all licenced hunters. Hunter success was calculated based on the success of respondents that held licences and hunted. We used log-linear regression to test for a significant trend in the harvest of moose in WMUs 728/730 over the study period. Harvest rates (%; harvest/preseason population estimate) were estimated for WMU 728/730 for the 12 years that winter population estimates were available. Preseason estimates were calculated by applying an annual winter mortality rate of 5% (an estimate) to the winter population estimate and adding calf production as indicated from aerial surveys the previous winter. Management history was derived from a review of annual Alberta Guide to Hunting Regulations, Alberta Hunting Draw annual publications, other provincial summaries, and from personal communication with provincial wildlife management staff.

Data summarizing public complaints (concerns expressed by the public and recorded by District Fish and Wildlife officers) about moose were summarized for Parkland WMUs and were available for 1999–2015. Categories of complaint included vehicle collision/unspecified injury (including injury of all types, many of which were from moose-vehicular collisions), human conflict (specific concerns such as human safety and nuisance that did not fit into other categories), sighting (usually close to human activity and of concern to humans), agricultural conflict (garden damage, tree damage, crop damage, stack damage, damage to game farms and harassment of livestock, plus other unspecified damage), disease, orphaned moose, and harassment of wildlife. All categories of public complaint were summarized, except for those subject to enforcement actions which were unavailable due to privacy concerns. We treated sightings as legitimate complaints within these summaries because they demonstrated marked concerns from the public about the presence of moose. WMUs 212, 220, and 248 were classified as urban WMUs because they included Alberta's 3 largest cities and associated urban sprawl.

RESULTS

The mean density of moose in the 22 Parkland WMUs was 0.19 ± 0.06/km² (range = 0.05 – 1.28/km²). The most consistent population data were available from WMU 728/730, a military base inventoried with strip-transect surveys 12 times between 1998 and 2015. Moose were first observed in WMU 728/730 during aerial surveys in 1983 when the density was estimated at 0.02/km² (Bjorge 1996). From 1998–2015, the population growth rate was λ = 1.07 and significantly increasing ($R^2 = 0.74$, $F = 28.8$, $P < 0.001$; Fig. 2). Compulsory registration of all hunting indicated substantial and increasing harvest ($R^2 = 0.81$, $F = 79.1$, $P < 0.001$; Fig. 3); the mean harvest rate was 17.9% (range = 13.3–22.4%) for the 12 years following the winter population estimates. The mean rate of population increase for 21 additional Parkland WMUs was λ = 1.11 (range = 0.94–1.41); only 2 WMUs (220 and 250) had declining populations. Sex and age classifications were available from 60 aerial surveys from Parkland WMUs in winters 1996–2016. The mean number of calves/100 cows was 74.4 ± 3.5 (range = 27–150). The mean number of bulls/100 cows was 51.9 ± 2.90 (range = 5–97).

Parkland moose populations began expanding into Grassland WMUs during their growth phase in the mid- to late 1990s. Multiple aerial surveys conducted in 4 Grassland WMUs (151, 152, 162, 163 - fully within the Grassland area) indicated the pattern of population establishment and growth (Table 1). In these WMUs, no moose were observed in aerial inventories during the 1990s, very low numbers were observed in the early 2000s, but by 2014–2016, populations were well established at low density, ranging from 0.02 to 0.07 moose/km². Populations were large enough to warrant establishment of hunting seasons in 5 Grassland WMUs adjacent to Parkland WMUs (156, 158, 160, 163,164) by 1999, and by 2015, hunting seasons were established in 16 of 26 Grassland WMUs. Productivity was

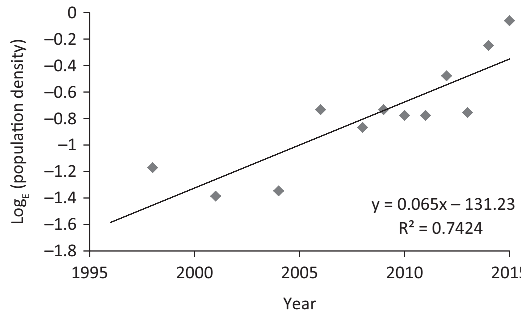

Fig. 2. The increase in moose population density estimates derived from natural log-linear regression analysis of aerial survey data in WMU 728/730, 1998-2015, Alberta, Canada. Zero values indicate years when surveys were not conducted.

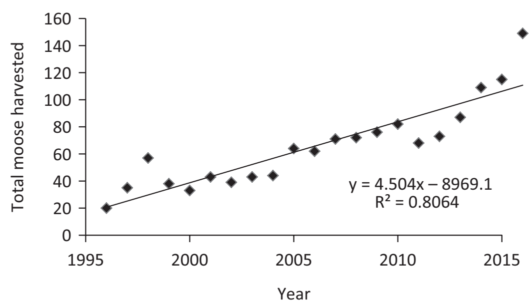

Fig. 3. The increase in moose harvest (linear regression) in WMU 728/730 from 1996 to 2016, Alberta, Canada.

Table 1. Number of moose counted per survey during aerial surveys in 4 WMUs in the Grassland Natural Region of Alberta (1990s-2016), including population estimates (± SE) and moose density during the most recent period, 2011–2016. NA = no survey conducted.

WMU	1990s	2000–2005	2006–2010	2011–2016	Population Estimate	Density (moose/km^2)
151	0	3	NA	50	98 ± 22	0.07
152	0	5	49	79	154 ± 46	0.04
162	0	10	NA	32	64 ± 17	0.02
163	0	5	NA	72	186 ± 29	0.05

Table 2. Moose hunting opportunity (# and %) for residents of Alberta in the Parkland and Grassland Natural Regions (PGNR) compared to Province-wide totals, 1996 and 2015. Special licences were managed through a draw system where the number of licences available for a given group (e.g., antlered) was limited. By 2015, general licences which had previously been issued with no restriction in number were no longer available, and special calf licences were considered as special antlerless licences.

Licence	Province 1996	PGNR 1996	Province 2015	PGNR 2015
Special Antlered	11,800	378 (3%)	12,114	1515 (12%)
Special Antlerless	1435	439 (31%)	4603	2040 (44%)
Special Calf	562	35 (6%)	1155	0
General	11,549	0	0	0
Total	25,346	852 (3%)	17,872	3555 (20%)

72.5 ± 6.7 calves/100 cows, with an adult sex ratio of 109 ± 34 bulls/100 cows during recent winter surveys in 4 WMUs (151, 152, 162, 163).

Since inception, hunting in the Parkland and Grassland was through limited entry antlered and antlerless special licences using a draw process. In WMU 728/730, special licences for calves were available until 2013 when they were amalgamated with antlerless licences. The exception was for archery hunts in WMUs 212 and 248 that surround the cities of Edmonton and Calgary, in which there was no restriction on licences issued for archery hunting. There was a substantial increase in moose hunting opportunity in the Parkland and Grassland during the study period as 3,555 Special Licences were granted in the Parkland and Grassland in 2015 compared to 852 in 1996. Specifically, there was a 4.1-fold increase in antlered special licences and a 4.3-fold increase in antlerless and calf special licences combined (Table 2). The proportion of provincial rifle hunting opportunities for residents also increased in the Parkland and Grassland from 3.4% of the provincial total in 1996 to 19.9% in 2015. This pattern was driven by increasing opportunity in the Parkland and Grassland as provincial opportunity declined when all moose hunting in Alberta was placed on limited entry hunting during this period. Resident hunter success rates in the Parkland and Grassland (excluding Archery-only hunts) were estimated at 74.5 ± 7.3% in the Grassland and 79.3 ± 3.1% in the Parkland in 2015, compared to 48.0 ± 2.5% for Alberta as a whole. A similar pattern was observed 20 years earlier in 1996 when hunter success rates were 76.5 ± 2.5% in the Parkland and 36.7% for Alberta, which still had general resident moose seasons over much of the province.

A total of 5,653 public complaints about moose were registered at provincial Fish and Wildlife Enforcement Branch offices and recorded into provincial enforcement databases during 1999–2015 for the Parkland (Fig. 4, Table 3). Complaints more than doubled from a low of 219 in 1999 to a high of 482 in 2015, but varied substantially over the study period. Overall, the most common complaints were vehicle collisions/injury (42%), human conflict (27%), and sightings (19%). Agricultural damage (6%), disease (3%), orphaned moose (3%), and harassment of wildlife (<1%) were minor complaints. Only 14 of 330 (4%) agricultural complaints were attributed to crop damage. Damage to trees, livestock including harassment, feed stacks, gardens, game farms, and unspecified damages (125 complaints) comprised the other agricultural complaints; some of the unspecified damage could have been crop-related. The majority of complaints (60%) were from WMUs 212, 220, and 248 (Fig. 1 and 4, Table 3) which include Alberta's 3 largest cities—Calgary, Edmonton, and Red Deer. Here the majority of complaints related to human conflict (34%), vehicle collision/injury (31%), and sightings (28%). These WMUs were estimated to hold < 20% of the Parkland moose population, but supported an estimated 2.8 million people (Statistics Canada 2017). Among rural WMUs, the most common complaints were vehicle collisions/injury (56%), human nuisance conflict (16%), and agricultural damage (10%).

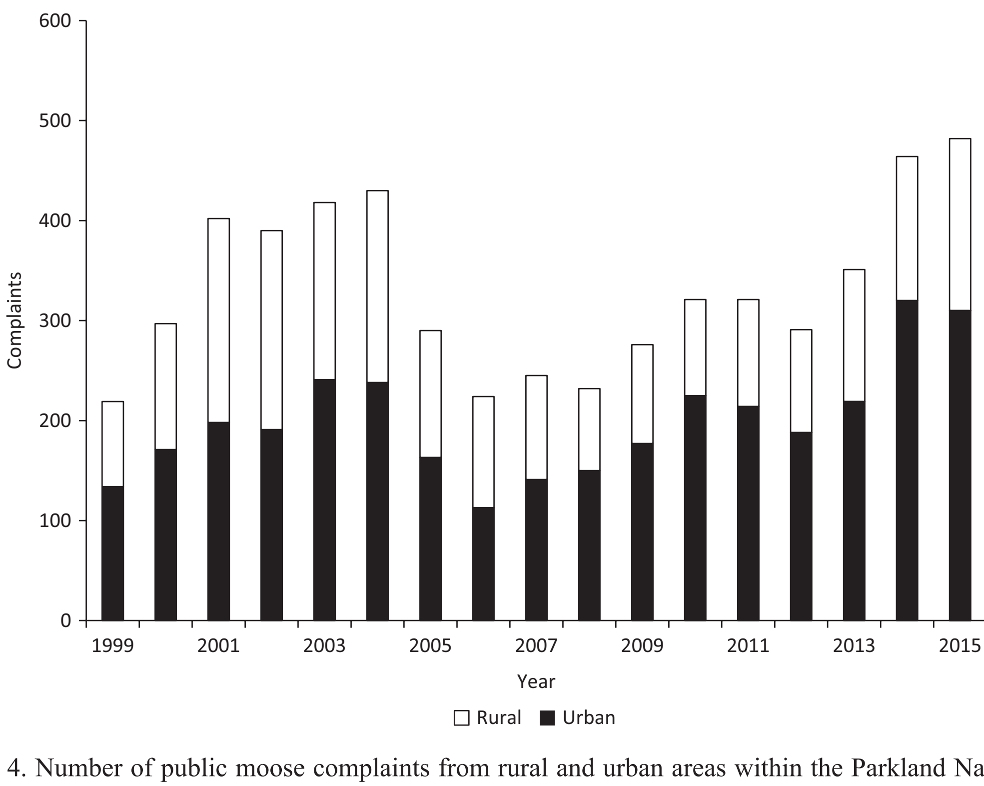

Fig. 4. Number of public moose complaints from rural and urban areas within the Parkland Natural Region as registered by the Alberta Fish and Wildlife Enforcement Branch, 1999-2015, Alberta, Canada.

Table 3. Summary of wildlife complaints (#) regarding moose in the Parkland Natural Region of Alberta between 1999 and 2015 in urban (n = 3) and rural (n = 31) Wildlife Management Units.

Complaint Type	Urban	Rural	Total
Road kill/injury	1058	1330	2388
Human conflict	1131	369	1500
Sighting	942	148	1090
Agricultural damage	104	226	313
Disease	63	104	167
Orphan	74	76	150
Wildlife harassment	10	18	28
Total	3382	2271	5653

DISCUSSION

Moose populations that established in the Alberta Parkland during the 1980s and mid-1990s (Bjorge1996) have continued to grow and expand over the last 20 years. In the early 2000s moose expanded into Grassland WMUs and established at low density, eventually providing an increasing proportion of moose hunting opportunity in Alberta. Overall, production and survival have been greater than the combined influences of natural and human-induced mortality, resulting in substantial population growth. The success of this population has occurred at a time when moose populations are declining in several boreal WMUs within Alberta (J. Castle, C. Found, L. Vander Vennen, Alberta Environment and Parks, unpublished data), and in several other North American jurisdictions (Murray et al. 2006, Crichton et al. 2015, Kuzyk 2016). This agriculturally-dominated study area with limited natural habitat and extensive fragmentation would seem unlikely habitat for expansion of a moose population. However, these 2 Natural Regions have the basic ecological and social conditions necessary for population growth, as observed in similar habitats in Saskatchewan (LaForge et al. 2016), Manitoba (Crichton et al. 2015), and North Dakota (J. Smith, North Dakota Game and Fish, pers. commun.). Between 2001 and 2014, the provincial moose population increased ~25% from 92,000 to 115,000 (Timmermann and Rodgers 2017). The estimated population increased 3-fold between 2000 and 2014 in Parkland WMU 728/730, indicating much higher local growth.

Calf production and survival was high in the study area at >70 calves/100 cows based on winter surveys, similar to that observed earlier by Bjorge (1996), and much higher than the 46 calves/100 cows estimated in Boreal WMUs in northwestern Alberta (D. Moyles, Alberta Environment and Parks, unpublished data). The high survival of calves is presumed to reflect the paucity of moose predators throughout the study area. Major predators (Ballard and VanBallenberghe 2007) such as wolves (*Canis lupus*), black bears (*Ursus americanus*), and grizzly bears (*U. arctos*) were essentially absent from all but the extreme western and northern perimeter of the study area. Cougars (*Felix concolor*) were also at very low density, although coyotes, which have potential to prey on moose calves (Benson and Patterson 2013), were considered abundant. High calf:cow ratios are not uncommon among moose populations with limited predators (Rolley and Keith 1980, J. Smith, North Dakota Game and Fish, pers. commun.).

Although browse production and availability was not assessed in our study area, we suggest that the abundance and diversity of shrubs and vegetation in riparian habitats, and the remaining patches of forest and associated edge (Schneider and Wasal 2000), provide adequate browse and forage for population growth (Gasaway and Coady 1974). The Parkland, and to a lesser extend the Grassland, has an abundance of small wetlands and several major river valleys and tributaries which likely contribute measurably to available moose habitat. Moose are subject to heat stress (Dussault et al. 2004) during summer, and wetlands and other riparian areas presumably play a role in thermoregulation (Renecker and Hudson 1986, Renecker and Schwartz 2007). Laforge et al. (2016) documented strong selection for wetlands and forest cover in farmland in southcentral Saskatchewan, indicating the proportional importance of these habitats. Moose also consume agricultural crops such as canola, cereals, and legumes such as alfalfa which are likely important food sources (Sorenson et al. 2015), although their consumption level and nutritional quality are unknown.

Human-associated mortality including licenced hunting, poaching, aboriginal harvest, vehicular collisions, and infrastructure-associated injuries, in combination with natural mortality, did not prohibit population growth in the study area. Harvest rates were often conservative, estimated at 13–22% of the moose population. Given our observations of >70 calves/100 cows during winter and the absence of significant predators, these harvest rates would allow population growth. Crichton et al. (2015) noted the expansion of moose into Parkland and Grassland habitats of Manitoba, Saskatchewan, and Alberta occurred during a period of human depopulation of these areas as farms became larger, which may have reduced undocumented illegal harvest. Bjorge (1996) indicated that establishment of moose populations in the Parkland may have been associated with a possible change in attitude of rural residents resulting in less poaching of moose dispersing from adjacent boreal habitats.

One consequence of population growth in our study area was the increasing occurrence of moose in urban environments and areas of concentrated rural residences that pose unique management issues. Urban environments appear to provide several advantages to moose including unutilized browse and forage, limited or no hunting, and very few predators, albeit, high potential for moose-human conflicts. In Norway, Lykkja et al. (2009) observed that moose moved away from inhabited houses during periods of high human activity, suggesting they are somewhat responsive to such activity. In our experience, moose complaints in 3 urban WMUs exceeded complaints in 31 rural Parkland WMUs combined, suggesting that urban residents have high interest and interactions in moose. Although the time, labor, and costs associated with responding to urban complaints have not been quantified, it is reasonable to conclude that it is substantial. Further, it requires specialized training and equipment to immobilize and transport or euthanize moose in areas with high visibility and human population. Managers need to consider impacts and issues associated with urban moose populations when establishing harvest goals and management strategies in adjacent rural areas, and be prepared to address moose-human conflicts in urban environments.

We were surprised that only 6% of all public complaints were related to agricultural damage, given that moose in the Parkland and Grassland were living in an agriculturally-dominated landscape. Further, only 4% of these complaints were attributed specifically to crop damage. We believe that this low rate likely reflects the low density of often solitary moose spread over an extensive agricultural land base, making widespread damage attributable to moose less evident. Laforge et al. (2016) indicated that moose in southcentral Saskatchewan did not exhibit strong selection for crop types with the possible exception of oilseeds in summer; conversely, Maskey (2008) found selection for local crops in North Dakota. We also expected more complaints related to disease (3% of complaints), especially parasitism by winter tick (*Dermacentor albipictus*) because associated hair loss (Samuel et al. 2000, Samuel 2007) was common in the study area.

Although the moose population in the Parkland and Grassland continuously increased during the study period, several factors could deter future population growth. For example, decline in wetlands and woody cover would negatively impact moose habitat and carrying capacity. The associated vegetative and cover resources are especially important in consideration of climate change (Parmesan 2006, McGraw et al. 2012), and that only about 10% of the Parkland remains as native woody cover (Bjorge et al. 2004), with even less in the Grassland. Further, increased impact of winter tick parasitism or disease could negatively impact moose populations. Higher poaching or legal First Nations and Métis harvest might also reduce local populations (Carmichael 2015). Regadless of environmental changes, the moose population will eventually exceed its carrying capacity or some other density-dependent mechanism will curb population growth. A paradigm in the management of large herbivores is that following introduction to a new range or cessation of harvest, the population may increase to peak abundance and then crash and re-establish at a lower level (Caughley 1970, Forsyth and Caley 2006). We suggest it is important that Parkland and Grassland moose populations be managed to avoid major declines due to exceeding the carrying capacity or other factors related to population density.

Multiple and often unique conditions influence the moose populations in the agricultural landscape of the Parkland and Grassland. Clearly, adequate population monitoring and assessing both social and ecological carrying capacity of these populations are necessary management objectives in this human-dominated ecosystem. Effective management will involve measuring these carrying capacities, stakeholder priorities, and risks to safety and property. Means to determine stakeholder values and ongoing measures of public safety and property damage are required to assess social tolerance - both education and preventative management must be emphasized. Appropriate training and equipment to respond professionally to urban moose issues, monitoring disease and conflicts, and continued enforcement oversight are critically important for an adaptive and effective management program.

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