THE STATUS AND MANAGEMENT OF MOOSE IN NORTH AMERICA – CIRCA 2015

H. R. Timmermann[1] and Arthur R. Rodgers[2]

[1]RR #2 Nolalu, Ontario, Canada POT 2K0; [2]Ontario Ministry of Natural Resources and Forestry, Centre for Northern Ecosystem Research, 103–421 James Street South, Thunder Bay, Onatario, Canada P7E 2V6

ABSTRACT: Both declining and increasing moose (*Alces alces*) populations have been reported across North America over the last decade. We surveyed all jurisdictions with extant moose populations to determine the extent of these population trends. In 2014–2015, the North American moose population was estimated at ~1,000,000 animals distributed in 30 jurisdictions, which is unchanged since the turn of the century. Populations occurred in 12 Canadian provinces or territories, and in at least 18 states. In the past 5 years, moose density is believed to be increasing in 9, relatively stable in 8, and declining in 11 jurisdictions; estimates of change were unavailable in 2 jurisdictions. In 2014–2015, an estimated 425,537 licensed moose hunters harvested 82,096 moose in 23 jurisdictions. Hunter numbers increased by 39,118, whereas total harvest remained virtually unchanged from a decade earlier. Harvests by Indigenous and subsistence users, although largely unquantified, are believed substantial and important to quantify in certain jurisdictions. A variety of active and passive harvest strategies used to manage moose are discussed.

ALCES VOL. 53: 1–22 (2017)

Key words: *Alces alces*, distribution, harvest, hunter numbers, Indigenous hunters, licensed qualifications, moose population status, National Parks, seasons, subsistence

Over the last decade there have been several reports of declining moose (*Alces alces*) populations across North America (Lenarz et al. 2010, Smith et al. 2011, DeCesare et al. 2014), but there have also been accounts of increasing numbers in other areas (Wattles and DeStefano 2011, Harris et al. 2015, LaForge et al. 2016, Tape et al. 2016). In this paper, we update the status and management of North American moose circa 2014–2015 from that reported in 2000–2001 (Timmermann 2003) to determine the extent of these population trends across the continent. A comprehensive 9-page questionnaire (located at http://alcesjournal.org/index.php/alces) similar to that employed previously (Timmermann 1987, Timmermann and Buss 1995, Timmermann 2003), and a literature review were used to update the status, population estimates, and harvest and non-harvest management strategies used in 23 jurisdictions with an annual licensed moose harvest. An additional 7 jurisdictions where hunting is currently prohibited were contacted to determine population status. Tabulated data were returned for final perusal, edits, or corrections solicited. This paper reports on current (year 2014–2015) population status and strategies used to manage hunting harvest and non-harvest management of moose across North America. Affiliations of those providing information through personal communication (pers. comm.) are provided in Acknowledgements.

HISTORICAL DISTRIBUTION AND CURRENT STATUS

The distribution of moose in North America during the 20th century has been described by several authors including Peterson (1955), Telfer (1984), Kelsall (1987), Karns (1998), Franzmann (2000), and Rodgers (2001); 4 subspecies are recognized, namely *A. a. gigas*, *andersoni*, *americana*, and *shirasi* (Peterson 1955). In the past 40+ years many have detailed expanding distributions of moose in both western and eastern states, provinces, and territories (Kelsall and Telfer 1974, Compton and Oldenberg 1994, Karns 1998, Peek and Morris 1998, Brimeyer and Thomas 2004, Toweill and Vecellio 2004, Base et al. 2006, Thomas 2008, Wolfe et al. 2010, Matthews 2012, Labonte et al. 2013, Wattles and DeStefano 2011, 2013, DeCesare et al. 2014).

Periodic winter aerial surveys based on the Gasaway method are used by most agencies to estimate moose populations and trends (Gasaway et al. 1986, Peterson and Page 1993, Timmermann 1993, Smits et al. 1994, Lynch and Shumaker 1995, Bisset 1996, Lenarz 1998, Timmermann and Buss 1998, Bisset and McLaren 1999, Bontaities et al. 2000, Ward et al. 2000, Gosse et al. 2002, Heard et al. 2008, Larter 2009, Moen et al. 2011a, Cumberland 2012, Fieberg and Lenarz 2012, DelGiudice 2013, Kantar and Cumberland 2013, Millette et al. 2014, Seaton 2014, Harris et al. 2015). Moose are considered among the more difficult ungulates to survey (Harris et al. 2015) and estimating either abundance or population trends from raw counts obtained by aerial survey can be challenging. Most agencies estimate total jurisdictional populations based on the cumulative total of specific management areas sampled every 3 or more years. Such jurisdictional estimates are often considered relatively crude and are primarily used to assess population trends, recruitment, and distribution over time. Real changes in population estimates are indicated by changes of ~20% or more between surveys (Gasaway and Dubois 1987). New Hampshire, Maine, and Vermont rely heavily on surveys of moose observations by deer (*Odocoileus virginianus*) hunters and vehicle collision rates to estimate population trends. New Hampshire and Vermont use these annual deer hunter surveys in a related regression formula developed from concurrent infrared aerial surveys in a 3-year New Hampshire study (Bontaites et al. 2000, Millette et al. 2014). Jurisdictions not employing formal methods of population assessment base their estimates on professional opinion. Consequently, population estimates are not necessarily comparable across jurisdictions or years because of the high variation in methodology and quality of data. As with all survey data, absolute counts are not achievable and the data herein should be treated as providing an indication of trends rather than absolute population estimates; the direction of population change (decreasing, increasing, or stable) is more important than the magnitude of change since the last jurisdictional survey (Timmermann 2003).

Eastern North America

Currently, moose (*A. a. americana*) appear to be still expanding and/or occupying former range in the states of Maine, Massachusetts, New York, and Connecticut (Kilpatrick et al. 2003, Hickey 2008, Labonte et al. 2013, Wattles and DeStefano 2011, 2013, S. Heerkens, L. Kantar, A. LaBonte, and D. Scarpitti, pers. comm. 2015; Fig. 1, Table 1). Moose in Vermont and New Hampshire have reoccupied all suitable habitat and are currently considered to be in slow decline (Musante et al. 2010, C. Alexander and K. Rines, pers. comm. 2015; Fig. 1, Table 1). Factors believed responsible for lower densities in Vermont include purposeful harvest to reduce specific regional populations (Andreozzi et al. 2014). In New Hampshire, high abundance of winter ticks *(Dermacentor albipictus)* due to shorter winters and possible increased

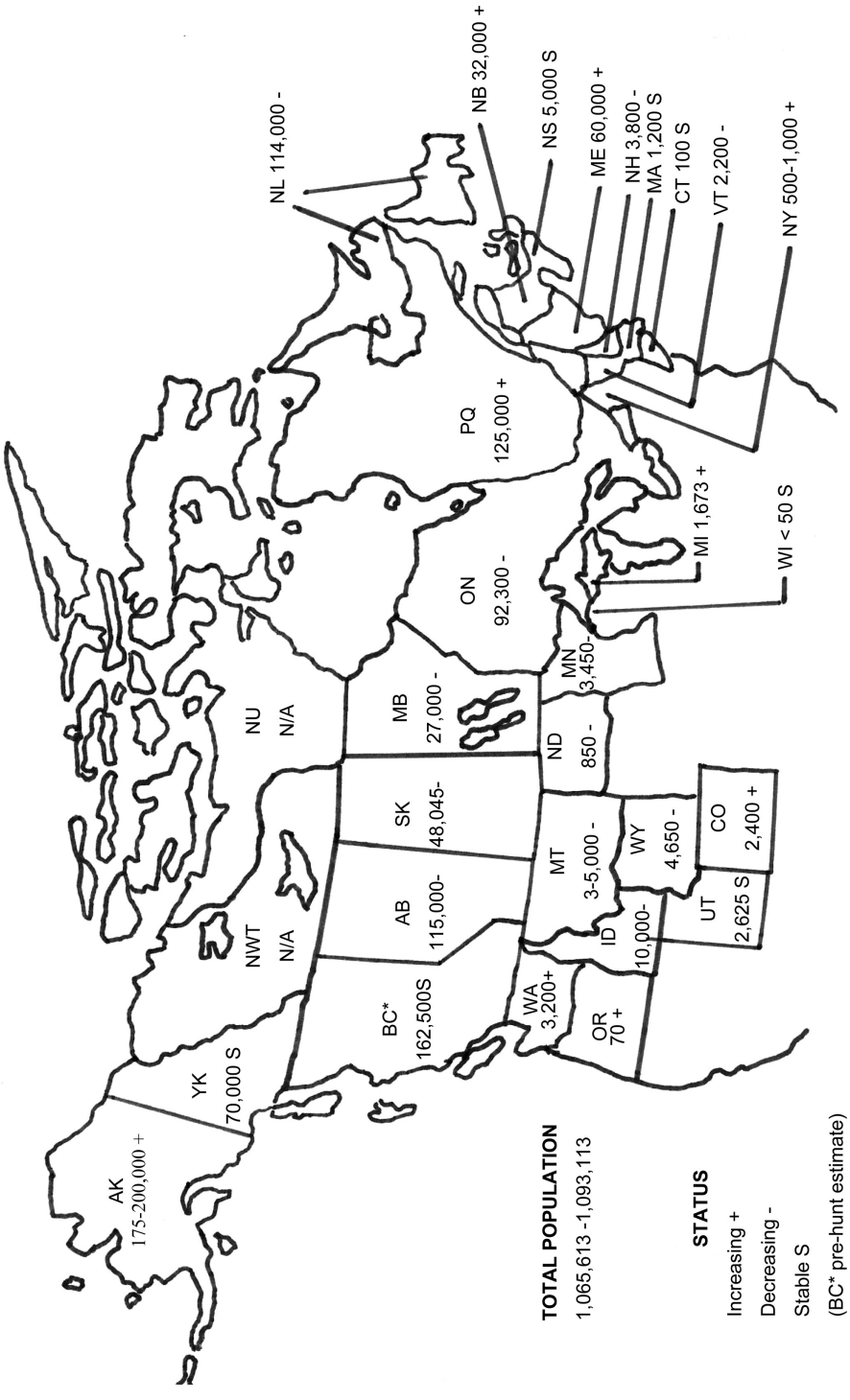

Fig. 1. Estimates of 2014-2015 post-hunt moose populations in 30 North American jurisdictions.

Table 1. Numbers of sport hunters, harvest, and post-hunt population estimates for 24 North American jurisdictions surveyed in 2000–01 (2001) and 2013–14 (2014). Symbols are as follows: population trend: +, −, S indicate increasing, decreasing, or stable, respectively; — indicates no non-resident season and N/A indicates not available.

	Total hunters		Non-resident hunters		Total estimated harvest		Estimated moose population	
Agency	2001	2014	2001	2014	2001	2014	2001	2014
Yukon Territory[1]	2,440	2,793	389	501	716	617	70,000+	70,000 S
Northwest Territories[2]	1,300	1,125	65	123	1,400	244	20,000+	N/A
Nunavut[3]		N/A		N/A		N/A		N/A
British Columbia	31,500	31,188	2,250	1,232	9,200	6,890	130–200 K	162,500 S
Alberta	20,249	21,560	1,139	1,040	7,971	7,748	92,000 S	115,000 −
Saskatchewan	10,000	12,931	254	114	4,151	5,543	46,000 S	48,045 −
Manitoba[4]	5,409	3,252	100	143	1,000	600[2]	35,000 +	27,000 −
Ontario	100,000	106,752	3,000	1,743	11,000	5,071	100–110 K S	92,300 −
Quebec	130,000	176,710	2,000	2,706	14,000	21,105	95–105 K +	125,000 +
New Brunswick	4,174	4,626	97	97	2,537	3,683	25,000 +	32,000 +
Nova Scotia	200	346	—	—	186	240	6,000 +	5,000 S
Newfoundland	40,449	26,770	3,044	3,930	19,322	18,226	115–140K S	114,000 −
Alaska	30,000	31,607	3,200	1,967	5,509	7,942	120,000 −	175–200 K +
Washington	69	134	—	2	64	118	1,000 +	3,200 +
Idaho	1,011	863	101	86	774	662	15,000 +	10,000 −
Utah	182	137	7	10	175	128	3,400 +	2,625 S
Wyoming	1,379	461	199	90	1,215	415	13,865 +	4,650 −
Montana	609	357	16	11	596	278	4,000 S	3-5,000 −
North Dakota	132	106	—	—	117	93	700 +	850 −
Colorado	74	255	—	25	64	209	1,070 +	2,400 +
Minnesota[5]	442	—	—	—	125	—	5,100 −	3,450 −
Maine	6,000	3,095	300	310	2,550	2,022	29,000 +	60,000 +

Table 1 continued . . . .

Table 1 continued

Agency	Total hunters		Non-resident hunters		Total estimated harvest		Estimated moose population	
	2001	2014	2001	2014	2001	2014	2001	2014
Vermont	215	342	22	34	155	171	3,500 +	2,200 –
New Hampshire	585	127	76	19	419	91	5,000 +	3,800 –
TOTAL	386,419	425,537	16,158	14,183	83,246	82,096	935,635–1,050,635	1,082,020–1,089,020

[1] YK Indigenous harvest is not included.
[2] NWT Indigenous harvest is not included.
[3] NU established 1999, formerly part of NWT, population 32,000 (2011), 9,984,670 km^2.
[4] MB 2014 harvest estimate pending survey completion.
[5] MN closed moose season beginning 2013.

incidence of brainworm (*Parelaphostrongylus tenuis*) due to higher deer densities are of concern. Current moose populations in Maine, however, appear to have more than doubled since 2001 (Timmermann 2003, Wattles and DeStefano 2011) and are second to only Alaska in the United States (Lichtenwalner et al. 2014). Populations in the Canadian Provinces of New Brunswick and Quebec have increased, while those on Cape Breton, Nova Scotia are believed relatively stable or in slight decline since 2001 (Beazley et al. 2008, Smith et al. 2010, S. Lefort, P. MacDonald, and D. Sabine, pers. comm. 2016; Fig. 1, Table 1). On mainland Nova Scotia, the current population estimated at 500 is likely still in decline, and is designated "Endangered" under the Nova Scotia Endangered Species Act (P. MacDonald, pers. comm. 2016). Moose numbers on the island of Newfoundland have been decreasing since 2001, whereas moose in the Labrador portion of the Province appear to be increasing in recent years (J. Neville, pers. comm. 2015). Overabundant moose populations on the island of Newfoundland, where densities remained higher than elsewhere in North America at the turn of the century, have led to habitat deterioration and localized population decline (McLaren et al. 2004). Consequently, harvest quotas were adjusted to modify population size in an effort to reduce and sustain specific populations (McLaren and Mercer 2005), and more recently to help address moose-human conflicts in select management units (J. Neville, pers. comm. 2016).

Western North America

Moose populations (*Alces a. shirasi*) are believed to have doubled in Washington State since 2000–2001 (R. Harris, pers. comm. 2015) and have dispersed into Oregon (P. Matthews, pers. comm. 2015; Fig. 1, Table 1). Density has declined in Idaho and Wyoming, but is stable in Utah (D. Brimeyer, K. Hersey,

and S. Nadeau, pers. comm. 2015). Wyoming populations declined from an estimated 13,865 in 2001 to 7,700 in 2008, and to 4,650 currently (Timmermann 2003, Brimeyer and Thomas 2004, Smith et al. 2011, D. Brimeyer, pers. comm. 2015). Populations have grown in Colorado and remain relatively stable compared to a declining trend in Montana (Tyers 2006, DeCesare et al. 2014, N. DeCesare and A. Holland, pers. comm. 2015). Periodic dispersal into the central United States, primarily from North Dakota and Minnesota, is reported as far south as Kansas and Missouri (Hoffman et al. 2006). Moose (*Alces a. andersoni*) populations in central British Columbia have declined, but overall, the Provincial population has remained relatively stable since 2000–2001 (Kuzyk and Heard 2014, Kuzyk 2016). Moose (*Alces a. gigas*) in Alaska have increased and those in the Yukon Territories have remained stable (B. Dale, R. Florkiewicz, and K. Titus, pers. comm. 2015; Fig. 1, Table 1).

Moose on the Arctic coastal plain in Alaska have expanded and contracted their numbers and range twice in the past 25 years (B. Dale and K. Titus, pers. comm. 2015). Recent research has linked range expansion in Arctic Alaska to warming and the associated increase in shrub habitat (Tape et al. 2016). Moose have also expanded their range in northern Southeast Alaska where first observed in Haines in 1924, and now inhabit the Gustavus Forelands (1966; Glacier Bay National Park). Populations of moose now occur on all the major islands of the central Southeast Panhandle of Alaska (B. Dale and K. Titus, pers. comm. 2015).

Central North America

Moose have expanded northward in Nunavut and Labrador, and are found as far north as 67˚ 31″ near Kugluktuk in Nunavut and Richards Island in the Northwest Territories Mackenzie Delta (V. Crichton, pers. comm. 2015). Population estimates for vast portions of the Northwest Territories and Nunavut (formerly part of the NWT) are not currently available (M. Dumond and A. Smith, pers. comm. 2015; Fig. 1, Table 1).

A further 6 of 8 jurisdictions in the mid-continent report recent, declining trends in moose populations (*Alces a. andersoni/americana*) including the adjacent provinces of Alberta, Saskatchewan, Manitoba, and Ontario, as well as the neighboring states of North Dakota and Minnesota (Lenarz et al. 2010, R. Corrigan, G. DelGiudice, H. Hristienko, G. Lucking, L. McInenly, J. Smith, R. Tether, pers. comm. 2015; Fig. 1, Table 1). LaForge et al. (2016) report increasing moose populations in the farmlands of southern Saskatchewan. Similarly, Manitoba populations have increased in the last 20 years in the southwest farmlands of the province where access is controlled and few predators exist (H. Hristienko and K. Rebizant, pers. comm.). These expansions appear linked to the reduction of small, privately owned farms being replaced by larger corporate farms, and a corresponding decline in undocumented harvest. However, the adjacent jurisdictions of Ontario, Manitoba, and Minnesota give lower overall estimates than in 2001 (Table 1).

Minnesota closed their harvest in the northwestern region in 1997 due to dramatic population decline from unknown causes (M. Schrage, pers. comm. 2001, Wünschmann et al. 2015). The estimated decline was from 4,264 in 1983 to 1,486 in 1995, to ~900 animals in 2001; essential collapse of this population occurred by the early 2000s. Murray et al. (2006) concluded that the giant liver fluke (*Fascioloides magna*) was largely responsible for this decline. A concurrent decline in adjacent northeastern North Dakota was investigated by Maskey (2011) who suggested other factors such as brainworm play a larger role in moose mortalities. Minnesota closed its moose hunting season in

northeastern Minnesota in 2013 after numbers dropped from ~8,500 in 2006 to 3,500 in 2014 (G. DelGiudice and L. McInenly, pers. comm. 2015). Manitoba's moose population is believed to have dropped from a historical high of 45,000 several decades ago to 27,000 in 2015 (H. Hristienko, pers. comm. 2015). Disease, over-harvest, and human development of landscapes are the primary factors thought responsible for the decline (Crichton et al. 2004). Recent surveys in northwestern Ontario indicate a corresponding decline in certain moose populations (OMNRF 2015, Table 1).

Current populations are increasing in Michigan, largely due to higher density estimates on Isle Royale (Vucetich and Peterson 2015). Abundance in 2015 was estimated as 323 in the reintroduced population in the western Upper Peninsula, but low productivity and calf:cow ratios suggest population decline (Dodge et al. 2004, D. Beyer, pers. comm. 2015). Populations in neighboring Wisconsin, where moose regularly move in and out of northern Michigan and Minnesota, are currently estimated at <50 (K. Wallenfang, pers. comm. 2015; Fig. 1). The United States Fish and Wildlife Service (USFWS) is considering a listing under the Endangered Species Act of the northwestern subspecies of moose (*Alces a. andersoni*) that is purported inhabiting upper Michigan, Isle Royale, Minnesota, North Dakota, and Wisconsin (https://www.fws.gov/midwest/es/soc/pdf/FRBatch90DayFndngs03June2016PIversion.pdf). In response, Michigan and Wisconsin submitted letters to the USFWS indicating that moose in their jurisdictions originated from eastern moose populations (*Alces a. americana*) (K. Wallenfang, pers. comm. 2016).

To summarize in 30 jurisdictions, current moose density is believed stable in 8, increasing in 9, decreasing in 11, with data unavailable in 2 (Fig.1, Table 1). In 22 jurisdictions (circa 2014–2015) for which population estimates are available, and in which an annual licensed harvest occurred in 2014, the total population estimate is 1,082,020 to 1,089,020 animals which is collectively similar to that reported in 2001 (Table 1). Remarkably little overall change has occurred despite the majority of jurisdictions reporting either increasing or decreasing populations. Population estimates in 12 Canadian jurisdictions totaled 790,845 in 2014 compared to a range of 734,000 to 849,000 in 11 jurisdictions in 2001 (Table 1, Fig.1, Timmermann 2003). The total population increased in 17 states from 204,150–205,130 in 2001, to 274,768–302,268 in 18 states in 2014 (Table 1, Fig.1, Timmermann 2003). Of the 7 states where hunting is prohibited, 3 report expanding populations (Oregon, Michigan, New York), stable populations exist in Wisconsin, Massachusetts, and Connecticut, whereas Minnesota closed their season in 2013 due to significant population decline (Moen et al. 2011b; Fig. 1).

Factors affecting decreasing densities

A host of factors are believed responsible for moose population declines including climate change, illegal harvest, habitat loss or degradation, parasites and disease, disturbance, moose-vehicular collisions, predators, and unregulated recreational and Indigenous and subsistence harvests (West 2009). In the 11 of 30 (37%) jurisdictions that indicated a declining population trend, the "most important factors" were: Parasites and Disease (8 jurisdictions), Predators (7), Natural Habitat Loss (5), Unregulated Harvest (3), Warmer Summers/Winters (2), Increased Access and Vehicle Technology (1), Higher Deer Densities (1), Over harvests by Licensed Hunters (1), Increased Hunting Pressure (1), and Variable Factors (1). Minnesota initiated a $1.2 M moose mortality study in 2013 to help determine factors responsible for the recent dramatic population decline. Preliminary results provide evidence of the

importance of parasites and disease and predators as mortality factors (Wünschmann et al. 2015). In Maine and New Hampshire, similar research initiated in 2014 indicates that winter ticks remain a primary influence on calf mortality and adult cow productivity (L. Kantar and K. Rines, pers. comm. 2016).

HARVEST MANAGEMENT

Economic impact

Moose, a symbol of wilderness, are much valued by Indigenous hunters, Metis People, recreational hunters, and a host of non-consumptive users (Timmermann and Rodgers 2005). Licensed recreational hunting promotes substantial benefits to local economies valued in the $100s of millions annually. In the early 1990s, for example, Legg (1995) estimated CAN $134.7 M in Ontario for all hunter-related activities in 1993. More recently, Maine estimated the economic impact of 3,095 resident and 310 non-resident hunters to represent US $11.9 M and $3.9 M in 2014 (L. Kantar, pers. comm. 2015), and Alaska valued its non-resident hunt at $11M in 2014 (B. Dale, pers. comm. 2015). Similarly, Quebec estimated 176,710 residents and 2,707 non-residents generated CAN $204 M and $8.0 M in 2014 (S. Lefort, pers. comm. 2015).

Harvest control objectives

Three territories and 9 provinces in Canada, and 11 states in the United States administered a moose hunt in 2014 (Table 1). Collectively, 425,537 licensed hunters harvested an estimated 82,096 moose in 2014–2015; a decade earlier, the harvest was 83,246 moose by 386,419 licensed hunters (Table 1). Hunting regulations continue to become more restrictive and complex as the demand on moose populations and corresponding harvest success rates increase, due in part, to increased road access and use of mechanized equipment (Timmermann and Buss 1998). Specific and strategic management of hunting is required to affect the desired allocation of moose harvest among licensed hunters, secure the sustainability of moose populations, and achieve other specified management objectives for a particular area. Specific moose management plans, guidelines, or statements existed in 13 jurisdictions in 2000–2001 (Maine, Vermont, New Hampshire, Utah, Colorado, Wyoming, Idaho, Yukon Territory, British Columbia, Alberta, Saskatchewan, Ontario and Quebec; Timmerman 2003). Specific harvest policy is currently guided by an approved or draft management policy including goals and objectives in 13 jurisdictions; 3 employ unwritten or a generalized wildlife policy. For example, Alaska's constitution, statutes, and regulations direct management activities and objectives through a public process (B. Dale, pers. comm. 2015), Minnesota's policy is guided by a research and management plan (McGraw et al. 2010, Minnesota DNRC 2011, Moen et al. 2011b), and Colorado uses a specific management plan for each of 10 herds (A. Holland, pers. comm. 2015).

British Columbia has recently developed a provincial guidance and direction framework for sustainable moose management (British Columbia Fish &Wildlife Branch 2015). Beginning in 2007, Ontario conducted a 2-year broad review and wide consultation of their moose management program that produced a new set of policies and guidelines with objectives and strategies to address the declining population and harvest (OMNRF 2008). Two options to control calf harvests included a shorter calf season within the regular season and a draw for calf tags (Bottan et al. 2002, Timmermann et al. 2002, OMNRF 2009a, b). A moose management plan has been developed in Newfoundland and Labrador that will help address human-wildlife conflicts (J. Neville, pers. comm. 2015), and Quebec currently employs a fourth iteration of a management plan spanning the period 2012–2019

(S. Lefort, pers. comm. 2015). Saskatchewan and Manitoba are developing specific management plans (H. Hristienko and R. Tether, pers. comm. 2015).

Allocation of Hunting Opportunities

Moose are publicly owned and held in trust by provincial, territorial, and state wildlife agencies. The first priority of most agencies is to ensure the long-term conservation of moose populations and their habitats. Harvest allocation is given prime consideration to subsistence use by Indigenous people under Treaty or other legal agreements in at least 20 of 23 jurisdictions that currently manage a harvest. Resident hunters in 20 of 23 jurisdictions are typically favored over non-residents and non-resident foreigners (10 of 23) in allocating harvest opportunities. In 2014–2015, non-residents were eligible to hunt in 20 of 23 jurisdictions (Table 1). Additional controls such as increased license fees, resident-only seasons, guide requirements, and limited permits are commonly placed on non-resident hunters giving residents priority in allocation of hunting opportunities. A guide was required by 10 of 23 agencies, and at least 6 agencies required non-residents to register with a licensed tourist outfitter, and 8 required foreigners to do so to enhance safety and success, as well as provide local economic benefit.

Some agencies restrict or limit moose hunting opportunities including all states except Alaska. Washington and North Dakota offer a single moose hunt per lifetime, and Colorado, Utah, and Idaho limit hunters to one antlered animal per lifetime. Others require a waiting period between hunts: 2 years in Idaho, 3 years in New Hampshire, Maine, Saskatchewan, and Manitoba, 5 years in Wyoming, Vermont, and Nova Scotia, and 7 years in Montana (if successful). Hunters in Alaska and 8 Canadian jurisdictions may hunt annually within quotas regardless of previous harvest success. Minnesota closed the entire state to moose hunting in 2013 after the northeastern population declined by half since 2006. Manitoba legislated 3 Conservation Closure Game Hunting Areas and 1 partial closure in 2011, coupled with a wolf reduction initiative to promote moose recovery (H. Hristienko, pers. comm. 2015, V. Crichton, pers. comm. 2016). Ontario continues to offer moose hunting opportunities for physically-challenged hunters in one Wildlife Management Unit (Armstrong and Simons 1999).

Control Concepts

Agencies employ a variety of strategies to regulate harvests and distribute hunting pressure (Timmermann 1987, 2003). Passive strategies include season length and timing, access restrictions, weapon requirements, and license qualification prerequisites; active measures include limiting license sales or specifying the sex, age, or number of animals taken by specific area. Objectives often include the harvest of pre-determined numbers to sustain, increase, or reduce populations. In Alberta, Xu and Boyce (2010) developed an age-sex matrix model for harvest quota management of moose populations that allows easy application by managers responsible for setting harvest quotas. Antler-based hunting regulations in British Columbia may have resulted in disrupted reproductive patterns and a consequent over-harvest of large bulls (Child et al. 2010). In interior Alaska, harvest restrictions on bull moose based on antler architecture allowed the recovery of bull:cow ratios from 26:100 to 32:100 after only 2 years of use (Young and Boertje 2008). Conversely, liberal antlerless hunts in Alaska are considered vital to control moose populations from reaching unsustainable densities in specific management units - a general season harvest ticket is available to all residents/non-residents (Young and Boertje 2004, Young et al. 2006, Boertje et al. 2007, 2009, Young and Boertje 2011).

A specific controlled hunt to reduce a local moose population and impacts on cole crops was implemented in Maine in 2009 (Kantar 2011). New Hampshire and Vermont have increased regional/local harvest rates with higher antlerless quotas to alleviate browsing impacts on regenerating forests and vehicular collisions (C. Alexander, pers. comm. 2002, Andreozzi et al. 2014). In 2014–2015, 9 agencies offered unlimited selective or non-selective harvest opportunities, and all 23 jurisdictions restricted or limited harvests on a selective or non-selective basis in certain management areas (Fig. 2). In addition, closed seasons were employed to prevent licensed harvest in specific areas, including certain provinces, territories, states, National Parks, and Wildlife Refuges.

License qualifications and fees

In 2014, proof of hunting proficiency, either a previous license or completing a hunter safety education course, was required to obtain a moose hunting license in all jurisdictions. In 2015, Canadian resident license fees averaged CAN $52.57 (range $5.00 in the Yukon Territory to $81.30 in New Brunswick), and non-resident licenses averaged $374.45 (range $48.00 in Quebec to $619.24 in New Brunswick). Resident fees in the states averaged US $162.00, (range = $25.00 in Alaska to $ 413.00 in Utah), and non-resident fees averaged $1,168.03 (range = $350.00 in Vermont to $2,271.25 in Idaho). Some agencies, including Alaska and Maine, charged higher fees to non-resident foreigners. Export permits or trophy fees are required, in addition to the license fee, to transport an animal from the Yukon Territory, Northwest Territories, British Columbia, Alberta, and Ontario. Currently, only New Hampshire requires moose hunters to demonstrate shooting proficiency using conventional fire-arms prior to purchasing a hunting license, as described by Buss et al. (1989). Previously, New Brunswick and Newfoundland required hunters to pass a shooting and written test before qualifying for a big game hunting license (Timmermann and Buss 1995). Alaska requires all archery and black powder hunters to pass a proficiency test (W. Regelin, pers. comm. 2002).

Seasons

Season length and timing are used to manage the availability of hunting opportunity, hunter success relative to vulnerability based on moose behavior, and seasonal access. Seasons are generally specific to weapon type (e.g., conventional firearms, black powder, or archery), and seasons tend to be longer in more remote areas and shorter closer to population centers. The most liberal season length (365 days, 1 July-30 June) occurs in 3 Game Management Areas in Nunavut (Table 2). Season lengths for all hunts in parts of Alaska, Idaho, Wyoming, Montana, North Dakota, Yukon, Northwest Territories, British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, and Newfoundland equal or exceed 3 months; New Brunswick, Nova Scotia, Vermont, and New Hampshire restrict season length to 5–9 days. Early archery seasons are typically in addition to firearm seasons, and are offered in 17 jurisdictions (Table 2). Most firearm seasons begin during the latter portion of the rut period (Wilton 1995) and many extend into November or December. Split seasons (early vs. late fall) occur in at least 11 jurisdictions. Minnesota closed their northeast moose hunt in 2013 after a continuous 41-year period of offering a limited non-selective hunt requiring all eligible hunters to apply in groups of up to 4 individuals (Judd 1972).

Management areas and harvest strategies

All agencies have subdivided their moose range into various sized management areas (Wildlife, Game, or Moose Management Units) to facilitate specific harvest control

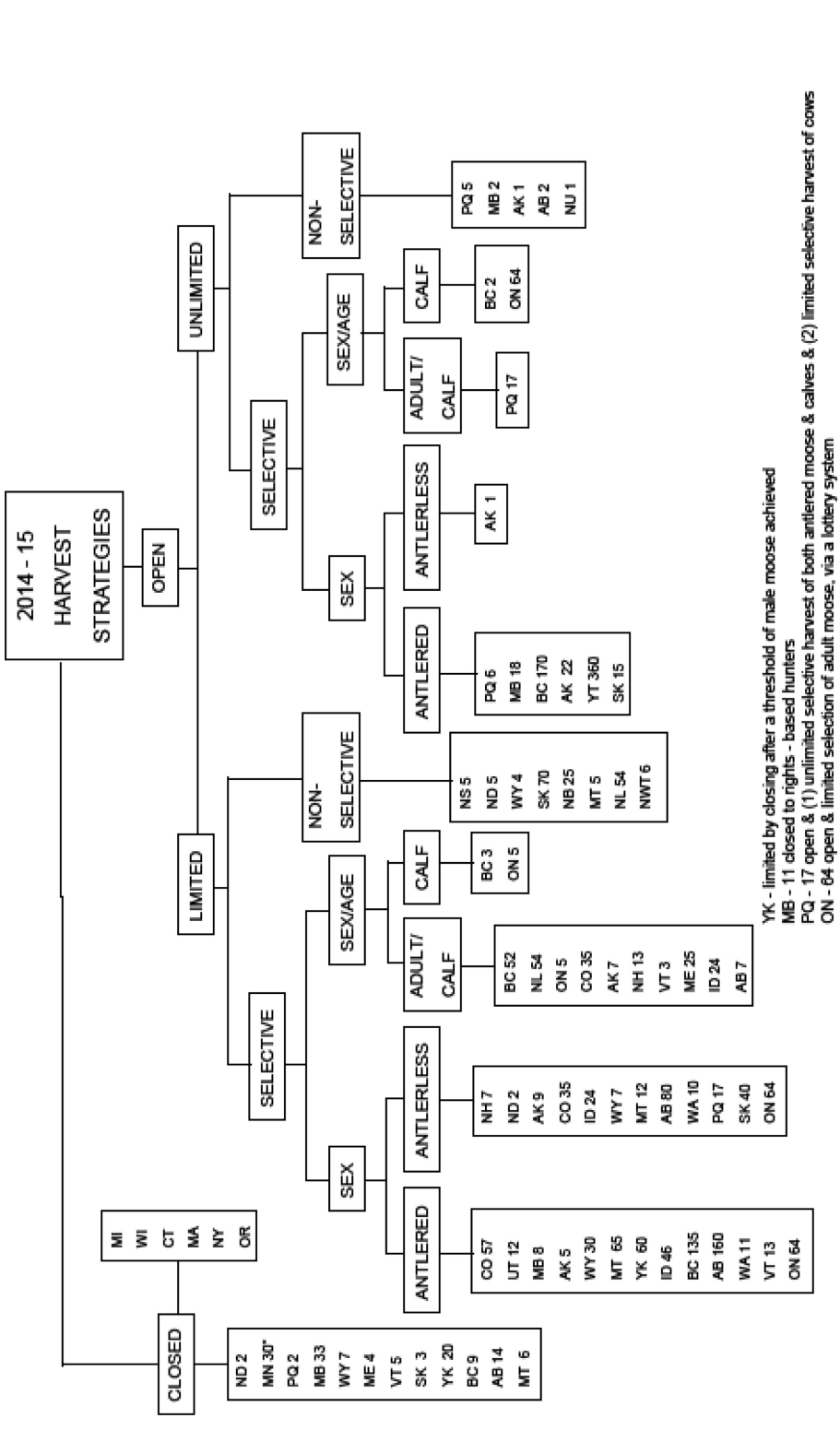

Fig. 2. Moose harvest strategies employed by 30 North American jurisdictions (circa 2014–2015). Numbers indicate management areas or subdivisions under each harvest strategy in each jurisdiction.

Table 2. Characteristics of moose hunting seasons in North America, 2014–2015.

	Number of management areas				Season length/timing		
		Size (km^2)					
Agency	With moose	Min.	Max.	With open Season	Max days	Earliest	Latest
Yukon Territory	443	64	2,919	360	92	Aug. 01	Oct. 31
Northwest Territories	6	56,270	278,183	6[1]	123	Sept. 01	Jan. 31
Nunavut	3	N/A	N/A	1	365	July 01	June 30
British Columbia	193	465	18,982	177[1]	107	Aug. 15	Nov. 30
Alberta	177	99	26,079	163[1]	91	Aug. 25	Nov. 30
Saskatchewan	82	232	82,443	80[1]	92	Sept. 01	Nov. 30
Manitoba	60	222	139,204	29[1]	117	Aug. 31	Jan. 24
Ontario	76	832	122,397	69[1]	93	Sept. 14	Dec. 15
Quebec	30	1,471	204,142	28[1]	92	Aug. 27	Dec. 01
New Brunswick	25	826	6,402	25	10	Sept. 20	Sept. 30
Nova Scotia	5	204	2,700	5[1]	6	Sept. 29	Dec. 11
Newfoundland	54	217	4,533	54[1]	121	Aug. 29	Jan. 24
Alaska	22	9,117	217,559	22[1]	243	July 01	April 15
Washington	11	747	2,857	11[1]	60	Oct. 01	Nov. 30
Idaho	70	220	7,843	46[1]	86	Aug. 30	Dec. 01
Utah	15	809	5,394	12	34	Sept. 12	Oct. 15
Wyoming	38	100	10,000	31[1]	81	Sept. 01	Nov. 20
Montana	88	95	60,926	82[1]	87	Sept. 15	Nov. 30
North Dakota	7	47	36,514	5[1]	101	Sept. 04	Dec. 13
Colorado	65	130	1,540	57[1]	25	Sept. 12	Oct. 14
Minnesota	30	200	875	—	season closed - 2013		
Maine	28	1,424	5,320	25	24	Sept. 28	Nov. 28
Vermont	21	639	2,036	16[1]	6	Oct. 1	Oct. 26
New Hampshire	22	391	1,365	20	9	Oct. 18	Oct. 26

[1] Offers early archery season.

strategies. The number of management areas ranges from 3 in Nunavut to 443 in the Yukon, and vary in size from 47 km^2 in North Dakota to 278,183 km^2 in the Northwest Territories (Table 2). All jurisdictions except Nunavut continue to employ either a selective or non-selective limited hunter participation strategy, or a combination of both (Fig. 2). Most favor some form of limited selective or limited non-selective strategy to control sex- and age-related harvests. Alaska alone continues to employ registration hunts which require mandatory kill registration and season termination once a prescribed harvest is achieved.

Several agencies have developed harvest strategies that maximize hunter participation. For example, sharing a moose between 2 or more hunters optimizes hunting opportunities and accommodates hunters who wish to hunt with friends. Perhaps the most liberal approach is in Ontario which previously allowed all eligible hunters to hunt calves in any of 64 Wildlife Management Units (Timmermann

2003, Fig. 2). In 2015 calf hunting was reduced to a 2-week period, and beginning in 2016, opening seasons will be delayed by 1 week (OMNRF 2016). In addition, Ontario hunters may apply in groups of up to 15 hunters for the chance of obtaining an adult tag that is area-specific, allowing a limited number of tags to be spread more evenly among hunter groups (OMNRF 2015, 2016). Sharing a moose is currently required in at least 2 jurisdictions including Quebec (minimum 2 hunters/moose) and Manitoba which provide an option of purchasing a conservation license (2 hunters using a single tag; S. Lefort and V. Crichton, pers. comm. 2015). Timmermann (2003) detailed additional moose-sharing mechanisms including a "Group Hunt" and a "Limited Entry Shared Hunt" in British Columbia, a "Special Antlered Moose Partner License" in Alberta, and a "Companion Moose Hunting Stamp" in Nova Scotia. Each successful permittee in Maine, New Hampshire, and Vermont may select a sub-permittee to hunt together and harvest a single moose. To help maximize hunter opportunity, Newfoundland gives preference to party applications (restricted to 2 individuals) over individuals, and to those unsuccessful in previous years (Timmermann 2003). Yukon has "Special Guide Licenses" that annually allow 100 Yukon residents to guide a non-resident hunter, in part to accommodate family members/friends from outside the Territory (S. Czetwertynski, pers. comm. 2016).

Harvest assessment

All sources of mortality must be assessed to monitor the effectiveness of various harvest strategies. Hunters, whether successful or not, are required to report their hunting activity in 11 of 23 jurisdictions, and harvest registration is compulsory in 13 (Table 3). Twelve jurisdictions apply a non-compliance penalty to hunters failing to report, although enforcement of these requirements varies among agencies. Timmermann (2003) provided a more detailed description of this subject, including the use of interactive voice response technology, use of a telephone questionnaire, and modeling to predict population changes resulting from various harvest strategies.

Moose hunter education and engagement

All first time hunters are required to successfully complete a hunter safety/education course in 23 jurisdictions that managed a moose hunt in 2014. Most (19 of 23) charged fees ranging in Canada from no fee in Yukon to CAN $160 in Ontario, and in the United States from no fee in Washington and Vermont, US $5 in New Hampshire, and $10 in Utah and Wyoming. Four states (Idaho, Utah, Vermont, and New Hampshire) incorporate a practical shooting test in their Hunter Safety/Education Course. All jurisdictions (22 of 23) except Nunavut provide moose hunters with information on their official websites, and 9 use social media. Printed hunting regulations were available in 22 of 23 jurisdictions, and 15 provided printed pamphlets, brochures, and/or fact sheets. Television and/or radio was used to provide information in 4 jurisdictions, 10 used newspapers and/or magazines, and 17 used email and/or traditional mail.

Harvest by native and subsistence users

Currently, most North American moose management agencies give primary consideration to subsistence use by Canadian Indigenous peoples and Native American peoples in recognition of obligations made under historical treaties signed by both federal governments (Crichton et al. 1998, Lynch 2006). Currently, nine 9 of 24 jurisdictions (Yukon, Northwest Territories, British Columbia, Manitoba, Ontario, Quebec, Nova Scotia, Idaho, Montana) report primary allocation of the moose resource to subsistence use by Indigenous People under Treaty or other legal agreements. In many areas unrestricted

Table 3. Moose harvest assessment strategies used in North America, 2014–2015.

	Hunt activity report		Kill registration		Non-compliance penalty
Agency	Compulsory	Voluntary	Compulsory	Voluntary	
Yukon Territory		X	X[1]		Fine - CDN$100.00
Northwest Territories		X		X[1]	none
Nunavut		X	X		Fine - CDN$200.00
British Columbia		X	X		Fine - CDN$230.00
Alberta		none		X	N/A
Saskatchewan		X		none	N/A
Manitoba		X		none	N/A
Ontario[2]	[2]	X	[2]	none[1]	N/A[2]
Quebec		none	X		Fine- CDN$250-750.00
New Brunswick	X		X		Fine- CDN $100-500.00
Nova Scotia	X		X		N/A
Newfoundland	X		X		none
Alaska	X		X		Loss of future eligibility
Washington	X			X	Fine - US$25.00
Idaho	X		X		Fine - US$25.00 - 1,000 & jail
Utah	X			none	Ineligible to apply next year
Wyoming		X		X	none
Montana		X		X	N/A
North Dakota	X		X		Ineligible to apply next year
Colorado	X			X	Loss of future eligibility
Minnesota	Season Closed 2013				
Maine	X		X		Fine - US$100-1,000 / Lic. loss
Vermont		X	X		Fine- US$262 + & Lic. loss
New Hampshire	X		X		Fine- US$248-1,000 & loss of future eligibility

[1] Export permit/trophy fee.
[2] Compulsory hunt activity/harvest report in 5 Wildlife Management Units; $150.00 fine for non-compliance and inability to receive a tag in subsequent year.

access to moose exists year-round, and current regulations are considered liberal given the widespread use of modern technology (Courtois and Beaumont 1999). Because conflicts often occur between licensed sport hunters and Indigenous People, moose managers must consider the annual harvest by both groups in formulating hunting regulations (Lynch 2006). The harvest by Indigenous hunters is difficult to quantify and unfortunately, little effort has been made to measure the magnitude of this harvest which some managers believe approaches or exceeds the licensed harvest in certain jurisdictions. Metis, who are considered people of mixed Indian and White ancestry (Swail 1996), are testing their perceived rights in court in Alberta, Manitoba, and Nova Scotia where they claim the right to hunt and fish on traditional territory both within and outside their current harvesting zone (V. Crichton, pers. comm. 2016). The Supreme Court of Canada

has refused to hear an appeal involving Metis hunting and fishing rights in Alberta following a Supreme Court ruling 10 years previous that granted hunting rights to Ontario Metis. However, in April 2016 the Supreme Court declared that the federal government has constitutional responsibility for Métis and non-status Indians, which could have important implications for their hunting and fishing rights. Timmermann (2003) provided estimates of the annual moose harvest by Indigenous and Metis peoples in British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia, Northwest Territories, and the Yukon Territory.

A moose monitoring program was established in the Northwest Territories between the Dehcho First Nations and government biologists that yielded valuable biological information to identify changes in moose populations (Larter 2009). In a similar effort to involve Indigenous people in northwestern Ontario, LeBlanc et al. (2011) suggested that provincial calculations may underestimate total harvests by up to 40%, and concluded that developing a working relationship with Indigenous communities is necessary to effectively manage moose in Ontario. A moose management plan was drafted by the Nova Scotia Mi'Kmaq in 2005 to aid in tripartite negotiations between the band and the provincial and federal governments (Bridgland et al. 2007). The Nova Scotia DNR is currently working with the Nova Scotia Mi'Kmaq to develop a collaborative management plan for Cape Breton moose (P. MacDonald, pers. comm. 2016). It is hoped such collaborative management will sustain moose populations long-term on Cape Breton Island. Cooperative management of moose between state and 3 tribal bands in northeastern Minnesota has led to increased levels of trust since 1988 (Edwards et al. 2004). In Colorado, moose harvested by Native and subsistence hunters is monitored by the Brunot Agreement with the Southern Ute and Ute Mountain Tribes (A. Holland, pers. comm. 2015). Future sustainable harvests and population goals will largely remain elusive until the total harvest, including harvests by Indigenous and Metis peoples and subsistence users, are both agreed to and verifiable.

Under federal regulations in Alaska, all rural residents are subsistence users which allows certain communities or households to harvest moose. In addition, special regulations allow moose harvesting outside of normal hunting seasons by Alaskan natives for ceremonial and cultural purposes. All agencies suggested such harvests were "substantial" in specific local areas during the period 2000–2001. Oregon has 2 native tribes which hunt ungulates in areas where moose occur; one tribe hunts moose and the other is considering a moose season (P. Matthews, pers. comm., 2016).

Illegal hunting losses appear to be significant in some jurisdictions including Colorado, Utah, and Ontario (Timmermann 2003). Most agencies encourage all hunters to report illegal infractions using a toll-free telephone number. Ontario introduced a "Moose Watch" Program in 2001 to help reduce poaching (Todesco 2004). Conservation Officers in Ontario's Northeast Region found 1,741 illegally killed moose from 1997–2014 (Todesco 2004, C. Todesco, pers. comm. 2016). During this period, >238,000 hunters were contacted, 7,328 warnings issued, and 5,514 charges were laid while conducting moose hunt enforcement duties.

MANAGING UNHUNTED POPULATIONS

Parks, refuges, and special areas

Most North American jurisdictions where moose occur provide for areas where hunting is not a primary management objective. Currently, 7 states have no open moose hunting season and 11 of 23 jurisdictions provide closed seasons in 2–33 management

areas (Fig. 2). The assumed common objective of closed areas that include game or wildlife reserves, national, provincial, territorial, and state parks, and nature reserves is the preservation of moose in representative natural habitats for education and recreational enjoyment. Further maintenance of biodiversity and ecosystem function is often a stated objective. A review of moose management objectives and programs in parks, refuges, and special areas was detailed by Timmermann and Buss (1995) and Timmermann (2003). Moose are native to at least 30 North American national parks in 18 jurisdictions with Isle Royale perhaps the most famous, boasting a 58-year continuous ecological study of wolves and moose beginning in 1959 (Vucetich and Peterson 2015). Timmermann (2003) detailed moose-related studies in several National Parks including Isle Royale in Michigan, Elk Island in Alberta, Voyageurs in Minnesota, and Gros Morne in Newfoundland. West (2009) reported approximately 39,000 moose inhabited 35 National Wildlife Refuges in the United States, with ~38,000 in Alaska alone; 9 refuges used management practices to specifically benefit moose (i.e., prescribed wildland fire).

DISCUSSION

Telfer (1984) found a close correspondence between the southern limit of moose distribution worldwide and the 20 °C July isotherm. Since then, several studies have suggested that moose numbers and the southern limit of their distribution may be affected by climate change (Thompson et al. 1998, Murray et al. 2006, Lenarz et al. 2010) but others have documented increasing numbers and expanding moose populations at the southern edges of their jurisdictional boundary (Wattles and DeStefano 2011, Harris et al. 2015, LaForge et al. 2016). Our survey across North America further indicated that 10 of 15 moose populations at the southern limit of their distribution are stable or increasing. Although we acknowledge that many of the reported population estimates and trends were based on professional opinion rather than systematic surveys, the weight of evidence suggests that moose are not immediately at risk of disappearing from southern regions of their distribution. The more interesting enquiry at this time would be to determine how and why moose continue to thrive and even expand their range southward in certain areas.

Moving forward in the face of climate change and ever-increasing human development, it will be vitally important to maintain systematic aerial surveys to monitor moose population trends, and to implement these wherever they are not in use. This will be a challenge not only because of the financial and human resources required, but also because climate change may hinder the collection of long-term data due to lack of snow required to efficiently conduct aerial surveys. Thus, further research into new technologies that are not hindered as much by environmental conditions will be highly beneficial, such as forward-looking infrared radiometer systems (FLIR; Millette et al. 2014) and sensor-equipped drones.

Our survey revealed variation in moose population trends across North America, and local variation expected within jurisdictions. As indicated by survey respondents, numerous factors can affect moose population trends both locally and regionally. Although research might be undertaken to identify the most important factors in a particular area, the responses of local moose managers are limited because many cannot be controlled directly (e.g., parasites and disease, weather). Instead, most moose managers can only use harvest and habitat management to mitigate declines in moose population numbers. These options will become ever more important as climate change and human development gradually increase their influence on moose numbers and distribution across North America.

ACKNOWLEDGEMENTS

Appreciation is extended to the following individuals in the United States who provided unpublished information in response to a 9-page questionnaire survey: Bruce Dale and Kim Titus, Alaska Department of Fish and Game, Juneau, Alaska; Rich Harris, Washington Department of Fish and Wildlife, Olympia, Washington; Pat Matthews, Oregon Department of Fish and Wildlife, Enterprise, Oregon; Steve Nadeau, Idaho Fish and Game, Boise, Idaho; Kent Hersey, Division of Wildlife Resources, Salt Lake City, Utah; Andy Holland, Colorado Parks and Wildlife, Fort Collins, Colorado; Doug Brimeyer, Wyoming Game and Fish Department, Jackson, Wyoming; Nick DeCesare, Montana Fish, Wildlife and Parks, Missoula, Montana; Jason Smith, North Dakota Game and Fish Department, Jamestown, North Dakota; Glenn DelGiudice and Leslie McInenly, Minnesota Department of Natural Resources, Forest Lake, Minnesota; Dan Storm and Kevin Wallenfang, Department of Natural Resources, Rhinelander, Wisconsin; Dean Beyer, Michigan Department of Natural Resources and Northern Michigan University, Marquette, Michigan; Lee Kantar, Maine Department of Inland Fisheries and Wildlife, Bangor, Maine; Kristine Rines, New Hampshire Fish and Game Department, New Hampton, New Hampshire; Cedric Alexander, Vermont Fish and Wildlife Department, St. Johnsbury, Vermont; Andrew LaBonte, Department of Energy and Environmental Protection, North Franklin, Connecticut; David Scarpitti, Massachusetts Division of Fisheries and Wildlife, West Boylston, Massachusetts; Steven Heerkens, Department of Environmental Conservation, Utica, New York.

Appreciation is extended to the following individuals in Canada who provided unpublished information in response to a 9-page questionnaire survey: Sophie Czetwertynski and Rob Florkiewicz, Environment Yukon, Whitehorse, Yukon; Angus Smith and Jan Adamczewski, Department of Environment and Natural Resources, Government of Northwest Territories, Yellowknife, Northwest Territories; Mathieu Dumond, Department of Environment, Arviat, Nunavut; Gerry Kuzyk, Ministry of Forests, Lands and Natural Resources Operations, Victoria, British Columbia; Rob Corrigan, , Environment and Parks, Edmonton, Alberta; Rob Tether and Mike Gollop, Saskatchewan Ministry of Environment, Saskatoon, Saskatchewan; Hank Hristienko and Ken Rebizant, Manitoba Conservation, Winnipeg, Manitoba; Vince Crichton, retired Manitoba Conservation, Winnipeg, Manitoba; Greg Lucking and Patrick Hubert, Ontario Ministry of Natural Resources and Forestry, Peterborough, Ontario; Charlie Todesco, Ontario Ministry of Natural Resources and Forestry, Wawa, Ontario; Sébastien Lefort, Quebec Ministère des Forêts, de la Faune et des Parks, Quebec City, Quebec; Dwayne Sabine, New Brunswick Department of Natural Resources, Fredericton, New Brunswick; Peter MacDonald, Nova Scotia Department of Natural Resources, Kentville, Nova Scotia; John Neville and Conor Edwards, Newfoundland and Labrador Department of Environment and Conservation, Corner Brook, Newfoundland.

REFERENCES

Andreozzi, H. A., P. J. Pekins, and M. Langlais. 2014. Impacts of moose browsing on forest regeneration in northeastern Vermont. Alces 50: 67–79.

Armstrong, E. R., and R. Simons. 1999. Moose hunting opportunities for physically - challenged hunters in Ontario: a plot study. Alces 35: 125–134.

Base, D. L., S. Zender, and D. Martorello. 2006. History, status, and hunter harvest of moose in Washington State. Alces 42: 111–114.

Beazley, K., H. Kwan, and T. Nette. 2008. An examination of the absence of established moose (*Alces alces*) populations

in southeastern Cape Breton Island and Nova Scotia, Canada. Alces 44: 81–100.

Bisset, R. A. 1996. Standards and Guidelines for Moose Population Inventory in Ontario. Ontario Ministry of Natural Resources, Fish and Wildlife Branch, Peterborough, Ontario, Canada.

———, and M. A. McLaren. 1999. Moose Population Aerial Inventory Plan for Ontario: 1999–2002. Ontario Ministry of Natural Resources, Northwest Science and Technology. Information Report IR-004. Thunder Bay, Ontario, Canada.

Boertje, R. D., K. A. Kellie, C. T. Seaton, M. A. Keech, D. D. Young, B. W. Dale, L. G. Adams, and A. R. Aderman. 2007. Ranking Alaska moose nutrition: signals to begin liberal antlerless harvests. Journal of Wildlife Management 71: 1494–1506.

———, M. A. Keech, D. D. Young, K. A. Kellie, and C. T. Seaton. 2009. Managing for elevated yield of moose in Interior Alaska. Journal of Wildlife Management 73: 314–327.

Bontaites, K. M., K. Gustafson and R. Makin. 2000. A Gasaway-type moose survey in New Hampshire using infrared thermal imagery: preliminary results. Alces 36: 69–75.

Bottan, B., D. Euler, and R. Rempel. 2002. Adaptive management of moose in Ontario. Alces 38: 1–10.

Bridgland, J., T. Nette, C. Dennis, and D. Quann. 2007. Moose on Cape Breton Island Nova Scotia: 20th century demographics and emerging issues in the 21st century. Alces 43: 111–121.

B.C. F&W (British Columbia Fish And Wildlife) Branch. 2015. Provincial framework for moose management in British Columbia. Ministry of Forests, Lands and Natural Resources Operations, Fish and Wildlife Branch, Victoria, British Columbia, Canada.

Brimeyer, D. G., and T. P. Thomas. 2004. History of moose management in Wyoming and recent trends in Jackson Hole. Alces 40: 133–143.

Buss, M., R. Gollat, and H. R. Timmermann. 1989. Moose hunter shooting proficiency in Ontario. Alces 25: 98–103.

Child, K. N., D. A. Aitken, R. V. Rea, and R. A. Demarchi. 2010. Potential vulnerability of bull moose in central British Columbia to three antler-based hunting regulations. Alces 46: 113–121.

Compton, B. B., and L. E. Oldenburg. 1994. The status and management of moose in Idaho. Alces 30: 57–62.

Courtois, R., and A. Beaumont. 1999. The influence of accessibility on moose hunting in northwestern Québec. Alces 35: 41–50.

Crichton, V. F. J., W. L. Regelin, A. W. Franzmann, and C. C. Schwartz. 1998. The future of moose management and research. Pages 655–663 *in* A. W. Franzmann and C. C. Schwartz, editors. Ecology and Management of the North American Moose. Smithsonian Institution Press, Washington, D. C., USA.

———, T. Barker, and D. Schindler. 2004. Response of a wintering moose population to access management and no hunting- a Manitoba experiment. Alces 40: 87–94.

Cumberland, R. E. 2012. Potvin double-count aerial surveys in New Brunswick: are results reliable for moose? Alces 48: 67–77.

DeCesare, N. J., T. D. Smucker, R. A. Garrott, and J. A. Guide. 2014. Moose status in Montana. Alces 50: 35–51.

DelGiudice, G. D. 2013. Minnesota Moose Aerial Survey. Minnesota Department of Natural Resources, St. Paul, Minnesota, USA.

Dodge, W. B. Jr., S. R. Winterstein, D. E. Beyer Jr., and H. Campa III. 2004. Survival, reproduction, and movements of moose in the western upper peninsula of Michigan. Alces 40: 71–85.

Edwards, A. J., M. Schrage, and M. Lenarz. 2004. Northeastern Minnesota moose management - a case study in cooperation. Alces 40: 23–31.

Fieberg, J. R., and M. S. Lenarz. 2012. Comparing stratification schemes for aerial moose surveys. Alces 48: 79–87.

Franzmann, A. W. 2000. Moose. Pages 578–600 *in* S. Demarais and P. R. Krausman, editors. Ecology and Management of Large Mammals in North America. Prentice Hall, Upper Saddle River, New Jersey, USA.

Gasway, W. C., S. D. Dubois, D.J. Reed, and S. J. Harbo. 1986. Estimating moose population parameters from aerial surveys. Biological Papers of the University of Alaska, Number 22. Fairbanks, Alaska, USA.

———, and S. D. Dubois. 1987. Estimating moose population parameters. Swedish Wildlife Research (Supplement) 1: 603–617.

Gosse, J., B. McLaren, and E. Eberhardt. 2002. Comparison of fixed- wing and helicopter searches for moose in a mid-winter habitat-based survey. Alces 38: 47–53.

Harris, R. B., M. Atamian, H. Ferguson, and I. Keren. 2015. Estimating moose abundance and trends in northeastern Washington State: index counts, sightability models, and reducing uncertainty. Alces 51: 57–69.

Heard, D. C., A. B. D. Walker, J. B. Ayotte, and G. S. Watts. 2008. Using GIS to modify a stratified random block design for moose. Alces 44: 111–116.

Hickey, L. 2008. Assessing re-colonization of moose in New York with HSI models. Alces 44: 117–126.

Hoffman, D., H. H. Genoways, and J. R. Choate. 2006. Long-distance dispersal and population trends of moose in the central United States. Alces 42: 115–131.

Judd, S. L. 1972. Minnesota's 1971 moose hunt. Proceedings of the North American Moose Conference and Workshop 8: 240–243.

Karns, P. D. 1998. Population distribution, density and trends. Pages 125–139 *in* A. W. Franzmann and C. C. Schwartz, editors. Ecology and Management of North American Moose. Smithsonian Institution Press, Washington, D. C., USA.

Kantar, L. E. 2011. Broccoli and moose, not always best served together: implementing a controlled moose hunt in Maine. Alces 47: 83–90.

———, and R. E. Cumberland. 2013. Using a double-count aerial survey to estimate moose abundance in Maine. Alces 49: 29–37.

Kelsall, J. P. 1987. The distribution and status of moose (Alces alces) in North America. Swedish Wildlife Research Supplement 1: 1–10.

———, and E. S. Telfer. 1974. Biogeography of moose with particular reference to western North America. Naturaliste Canadien 101: 117–130.

Kilpatrick, H. J., R. Riggs, A. Labonte, and D. Celotto. 2003. History and Status of Moose in Connecticut. Connecticut Department of Environmental Protection, Hartford, Connecticut, USA. http://www.ct.gov/deep/lib/deep/wildlife/pdf_files/game/moose02.pdf (accessed July 2016).

Kuzyk, G. 2016. Provincial population and harvest estimates of moose in British Columbia. Alces 52: 1–11.

———, and D. Heard. 2014. Research Design to Determine Factors Affecting Moose Population Change in British Columbia: Testing the Landscape Change Hypothesis. Wildlife Bulletin No. B-126. British Columbia Ministry of Forestry, Lands and Natural Resources Operations, Victoria, British Columbia, Canada. http://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/wildlife-wildlife-habitat/wildlife-health/wildlife-health-documents/2014_bc_moose_research_design.pdf (accessed July 2016).

Labonte, A. M., H. J. Kilpatrick, and J. S. Barclay. 2013. Opinions about moose and moose management at the southern extent of moose range in Connecticut. Alces 49: 83–98.

Laforge, M. P., N. L. Michel, A. L. Wheeler, and R. K. Brook. 2016. Habitat selection by female moose in the Canadian prairie ecozone. Journal of Wildlife Management 80: 1059–1068.

Larter, N. C. 2009. A program to monitor moose populations in the Dehcho region, Northwest Territories, Canada. Alces 45: 89–99.

LeBlanc. J. W., B. E. McLaren, C. Pereira, M. Bell, and S. Atlookan. 2011. First Nations moose hunt in Ontario: a community's perspectives and reflections. Alces 47: 163–174.

Legg, D. 1995. The Economic Impact of Moose Hunting in Ontario, 1993. Ontario Ministry of Natural Resources, Wildlife Branch, Toronto, Ontario, Canada.

Lenarz, M. S. 1998. Precision and bias of aerial moose surveys in northwestern Minnesota. Alces 34: 117–124.

———, J. Fieberg, M. W. Schrage, and A. J. Edwards. 2010. Living on the edge: viability of moose in northeastern Minnesota. Journal of Wildlife Management 74: 1013–1023.

Lichtenwalner, A., N. Adhikari, L. Kantar, E. Jenkins, and J. Schurer. 2014. *Echinococcus granulosus* genotype G8 in Maine moose (Alces alces). Alces 50: 27–33.

Lynch, G. M. 2006. Does First Nation's hunting impact moose productivity in Alberta? Alces 42: 25–31.

———, and G. E. Shumaker. 1995. GPS and GIS assisted moose surveys. Alces 36: 145–151.

Maskey, J. J. 2011. Giant liver fluke in North Dakota moose. Alces 47: 1–7.

Matthews, P. E. 2012. History and status of moose in Oregon. Alces 48: 63–66.

McGraw, A. M., R. Moen, G. Wilson, A. Edwards, R. Peterson, L. Cornicelli, M. Schrage, L. Frelich, M. Lenarz, and D. Becker. 2010. An advisory committee process to plan moose management in Minnesota. Alces 46: 189–200.

McLaren, B. E., B. A. Roberts, N. Djan-Chekar, and K. P. Lewis. 2004. Effects of overabundant moose on the Newfoundland landscape. Alces 40: 45–59.

———, and W. E. Mercer. 2005. How management unit license quotas relate to population size, density, and hunter access in Newfoundland. Alces 41: 75–84.

Millette, T. L., E. Marcano, and D. Laflower. 2014. Winter distribution of moose at landscape scale in northeastern Vermont: a GIS analysis. Alces 50: 17–26.

Minnesota DNRC (Department Of Natural Resources - Moose Advisory Committee). 2011. Minnesota Moose Research and Management Plan. Minnesota Department of Natural Resources, St. Paul, Minnesota, USA.

Moen, R., M. E. Nelson, and A. Edwards. 2011a. Using cover type composition of home ranges and VHF telemetry locations of moose to interpret aerial survey results in Minnesota. Alces 47: 101–112.

———, R. O. Peterson, S. K. Windels, L. Frelich, and M. Johnson. 2011b. Minnesota Moose Status: Progress on Moose Advisory Committee Recommendations. NRRI Technical Report No. NRRI/TR-2011–41. Minnesota Department of Natural Resources, St. Paul, Minnesota, USA.

Murray, D. L. E. W. Cox, W. B. Ballard, H. A. Whitlaw, M. S. Lenarz, T.W. Custer, T. Barnett, and T. D. Fuller. 2006. Pathogens, nutritional deficiency, and climate influences on a declining moose population. Wildlife Monographs 166: 1–30.

Musante, A. R., P. J. Pekins, and D. L. Scarpitti. 2010. Characteristics and dynamics of a regional moose *Alces alces* population in the northeastern United States. Wildlife Biology 16: 185–204.

(OMNRF) Ontario Ministry Of Natural Resources and Forestry. 2008. Ontario Moose Program Review 2008. Information Package. Queen's Printer, Toronto, Ontario, Canada.

———. 2009a. Moose Management Policy. June 2009. Queen's Printer, Toronto, Ontario, Canada.

———. 2009b. Moose. Population Objectives Setting Guidelines. June 2009. Queen's Printer, Toronto, Ontario, Canada.

———. 2015. Hunting Regulations 2015–2016. Ontario Ministry of Natural Resources and Forestry. Queen's Printer, Toronto, Ontario, Canada.

———. 2016. Hunting Regulations 2016–2017. Ontario Ministry of Natural Resources and Forestry. Queen's Printer, Toronto, Ontario, Canada.

Peek. J. M., and K. I. Morris. 1998. Status of moose in the contiguous United States. Alces 34: 423–434.

Peterson, R. L. 1955. North American Moose. University of Toronto Press, Toronto, Ontario, Canada.

Peterson, R. O, and R. E. Page. 1993. Detection of moose in midwinter from fixed-wing aircraft over dense forest cover. Wildlife Society Bulletin 21: 80–86.

Rodgers, A. 2001. Moose. World Life Library, Voyageurs Press, Stillwater, Minnesota, USA.

Seaton, K. A. K. 2014. Evaluating options for improving GSPE performance and developing a sightability correction factor. Alaska Department of Fish and Game, Division of Wildlife Conservation, Federal Aid Final Research Performance Report 1 July 2007–30 June 2014, Federal Aid in Wildlife Restoration Project 1.66, Juneau, Alaska, USA.

Smits, C. M., R. M. P. Ward, and D. G. Larsen. 1994. Helicopter or fixed-wing aircraft; a cost-benefit analysis for moose surveys in Yukon Territory. Alces 30: 45–50.

Smith, C., K. Beazley, P. Duinker, and K. A. Harper. 2010. The impact of moose (*Alces alces andersoni*) on forest regeneration following a severe spruce budworm outbreak in the Cape Breton highlands, Nova Scotia, Canada. Alces 45: 135–150.

Smith, M. A., S. Kilpatrick, B. Younkin, L. Work, and D. Wachob. 2011. Assessment of crucial moose winter habitat in Western Wyoming. Alces 47: 151–162.

Swail, P. J. 1996. Blais vs the Queen. A conviction under the Criminal Code of Canada on August 22, 1996, for hunting big game out of season contrary to Section 26 of the Manitoba Wildlife Act. http://www.canlii.org/ca/cas/scc/2003/2003Scc44.html. (accessed July 2016).

Tape, K. D., D. D. Gustine, R. W. Ruess, L. G. Adams, and J. A. Clark. 2016. Range expansion of moose in Arctic Alaska linked to warming and increased shrub habitat. Plos One | DOI: 10.1371/journal.pone.0152636.

Telfer, E. S. 1984. Circumpolar distribution and habitat requirements of moose (*Alces alces*). Pages 145–182 *in* R. Olson, R. Hastings, and F. Geddes, editors. Northern Ecology and Resource Management. University of Alberta Press, Edmonton, Alberta, Canada.

Thomas, T. P. 2008. Moose Population Management Recommendations. Wyoming Game and Fish Department, Cheyenne, Wyoming, USA. https://wgfd.wyo.gov/WGFD/media/content/PDF/Habitat/SWAP/Mammals/Moose.pdf (accessed July 2016).

Thompson, I. D., M. D. Flannigan, B. M. Wotton, and R. Suffling. 1998. The effects of climate change on landscape diversity: an example in Ontario forests. Environmental Monitoring and Assessment 49: 213–233.

Timmermann, H. R. 1987. Moose harvest strategies in North America. Swedish

Wildlife Research Supplement 1: 565–579.

———. 1993. Use of aerial surveys for estimating and monitoring moose populations-a review. Alces 29: 35–46.

———. 2003. The status and management of moose in North America – circa 2000–01. Alces 39: 131–151.

———, and M.E. Buss. 1995. The status and management of moose in North America-early 1990's. Alces 31: 1–14.

———, and ———. 1998. Population and harvest management. Pages 559–615 *in* A. W. Franzmann and C.C. Schwartz, editors. Ecology and Management of the North American Moose. Smithsonian Institution Press, Washington, D. C., USA.

———, R. Gollat, and H. A. Whitlaw. 2002. Reviewing Ontario's moose management policy - 1980–2000: targets achieved, lessons learned. Alces 38: 11–45.

———, and A. R. Rodgers. 2005. Moose: competing and complementary values. Alces 41: 85–120.

Todesco, C. 2004. Illegal moose kill in northeastern Ontario: 1997–2002. Alces 40: 145–159.

Toweill, D. E., and G. Vecellio. 2004. Shiras moose in Idaho: status and management. Alces 40: 33–43.

Tyers, D. B. 2006. Moose population history on the northern Yellowstone winter range. Alces 42: 133–149.

Vucetich, J. A., and R. O. Peterson. 2015. Ecological Studies of Wolves on Isle Royale. Annual Report, Michigan Technological University, Houghton, Michigan, USA.

Ward, M. P., W. C. Gasaway, and M. M. Dehn. 2000. Precision of moose density estimates derived from stratification survey data. Alces 36: 197–203.

Wattles, D. W., and S. Destefano. 2011. Status and management of moose in the northeastern United States. Alces 47: 53–68.

———, and ———. 2013. Space use and movements of moose in Massachusetts: implications for conservation of large mammals in a fragmented environment. Alces 49: 65–81.

West, R. L. 2009. Moose conservation in the National Wildlife Refuge system, USA. Alces 45: 59–65.

Wilton, M. L. 1995. The case against calling and hunting moose during the main rut period-a viewpoint. Alces 31: 173–180.

Wolfe, M. L., K. R. Hersey, and D. C. Stoner. 2010. A history of moose management in Utah. Alces 46: 37–52.

Wünschmann, A., A. G. Armien, E. Butler, M. Schrage, B. Stromberg, J. B. Bender, A. M. Firshman, and M. Carstensen. 2015. Necropsy findings in 62 opportunistically collected free-ranging moose (*Alces alces*) from Minnesota, USA (2003–2013). Journal of Wildlife Diseases 51: 157–165 doi: 10.7589/2014–02-037.

Young, D. D. Jr., and R. D. Boertje. 2004. Initial use of moose calf hunts to increase yield, Alaska. Alces 40: 1–6.

———, and ———. 2008. Recovery of low bull:cow ratios of moose in interior Alaska. Alces 44: 65–71.

———, and ———. 2011. Prudent and imprudent use of antlerless moose harvests in interior Alaska. Alces 47: 91–100.

———, ———, C. T. Seaton, and K. A. Kellie. 2006. Intensive management of moose at high-density: impediments, achievements, and recommendations. Alces 42: 41–48.

Xu, C., and M. S. Boyce. 2010. Optimal harvesting of moose in Alberta. Alces 46: 15–35.