ASSESSING MOOSE HUNTER DISTRIBUTION TO EXPLORE HUNTER COMPETITION

Tessa R. Hasbrouck[1], Todd J. Brinkman[2], Glenn Stout[3], and Knut Kielland[2]

[1]Alaska Department of Fish and Game, 2030 Sea Level Drive, Ketchikan, AK 99901, USA; [2]University of Alaska Fairbanks, 1731 South Chandalar Drive, Fairbanks, AK 99975, USA; [3]Alaska Department of Fish and Game, 1300 College Road, Fairbanks, AK 99701, USA

ABSTRACT: Traditional values, motivations, and expectations of seclusion by moose (*Alces alces*) hunters, more specifically their distributional overlap and encounters in the field, may exacerbate perceptions of competition among hunters. However, few studies have quantitatively addressed overlap in hunting activity where hunters express concern about competition. To assess spatial and temporal characteristics of competition, our objectives were to: 1) quantify temporal harvest patterns in regions with low (roadless rural) and high (roaded urban) accessibility, and 2) quantify overlap in harvest patterns of two hunter groups (local, non-local) in rural regions. We used moose harvest data (2000–2016) in Alaska to quantify and compare hunting patterns across time and space between the two hunter groups in different moose management areas. We created a relative hunter overlap index that accounted for the extent of overlap between local and non-local harvest. The timing of peak harvest was different ($P < 0.01$) in urban and rural regions, occurring in the beginning and middle of the hunting season, respectively. In the rural region, hunter overlap scores revealed a concentration in 20% of the area on 16–20 September, with 50% of local harvest on 33% of the area and 54% of non-local harvest on 18% of the area. We recommend specific management strategies, such as lifting the air transportation ban into inaccessible areas, to redistribute hunters and reduce overlap and concerns of competition in high-use areas. We also encourage dissemination of information about known hotspots of hunter overlap to modify hunter expectations and subsequent behavior. Our hunter overlap index should prove useful in regions where similar concerns about hunter competition, hunter satisfaction, and related management dilemmas occur.

ALCES VOL. 56: 79 – 95 (2020)

Key words: Alaska, *Alces alces*, competition, harvest patterns, hunting, moose, overlap index

Local concern over competition for game with non-local hunters has been an ongoing policy issue for wildlife managers in most places hunting occurs, including Alaska (ADF&G 2016a). We define local hunters as people who hunt in the same area they reside, whereas non-local hunters are those who travel away from their resident management area for hunting opportunities. These two groups typically have the same hunting regulations, although in some situations rural residents in Alaska have priority on federal lands. Competition may be linked to conflict which occurs when the physical presence of an individual directly interferes with the goals of another individual (Jacob and Schreyer 1980), or when individuals pursuing the same goal have different values (Saremba and Gill 1991) or norms (Ruddell and Gramann 1994). We define competition as the rivalry between user groups for game or hunting space, either of which may be limited or perceived to be limited, regardless of harvest success. For example, hunters may experience negative consequences from competition even when they successfully harvest game because the pursuit of seclusion or a certain traditional experience can be equally or more important than harvest success (Vaske et al. 1995, Brinkman 2014). Competition is exacerbated when different hunter types (local hunters or non-local hunters) overlap in the same area at the same time, creating a higher potential for direct encounters.

Proposed solutions to address competition concerns are often related to changes in the allocation of hunting opportunities. For example, 22 proposals were submitted to the Alaska Board of Game requesting changes in statewide or regional allocation of big game among hunter user groups between 2015 and 2018 (ADF&G 2016a). Many proposals (n = 12) focused specifically on moose (*Alces alces*) and described how local hunters are concerned that non-local hunters take too many moose and create excessive competition. Importantly, the extent of competition has not been objectively assessed in the areas where changes in allocation were requested. Information regarding the distribution and overlap of hunting activity by different stakeholder groups should provide insight about the extent of competition and inform potential solutions. Our research addresses this information gap by quantifying harvest patterns and overlap across space and time between two hunter types (local and non-local) in two hunting regions (accessible urban and inaccessible rural areas).

It is important to address concerns about moose hunter competition because of the direct relationship with hunt satisfaction and success (Heberlein and Kuentzel 2002, Fix and Harrington 2012). Managers regulate hunter activity and maintain wildlife populations to optimize hunting opportunities and maximize hunt satisfaction (Ericsson 2003), but satisfaction requires more than providing sufficient animal density (Hammitt et al. 1990, Brinkman et al. 2013). Hunters have expressed that the number of other hunters seen (i.e., perceived crowding) is an important factor of hunt satisfaction (Heberlein and Kuentzel 2002). Overall, these findings support multiple-satisfactions-approach-based management that recognizes multiple factors contribute to hunt satisfaction (Hendee 1974). Conflict can occur when spatial and temporal overlap among hunters surpasses expected hunter density (Shelby and Heberlein 1986, Brinkman 2018), and when hunters encounter other hunters who exhibit, or are perceived to exhibit, hunting values and motivations that do not align with local norms (Fix and Harrington 2012). This is relevant in rural communities that may perceive that non-locals do not understand or respect traditional local practices (Kluwe and Krumpe 2003). Altered behavior in response to competition may increase the time, effort, and cost (e.g., fuel) of hunters, which is particularly salient to rural communities with relatively weak cash economies (Brinkman et al. 2014). Assessing characteristics of competition may help better define the problem, enhance communication, and inform resolution of these issues (Decker and Chase 1997).

Moose are an ideal species to explore hunter competition because of their critical nutritional, cultural, and economic importance to Alaskan residents (Timmermann and Rodgers 2005, Northern Economics Inc. 2006). Hunter motivations may range from meat provision to trophy experiences, and from spending time with family to interacting with nature (Brinkman 2018). In 1987–2007 in Alaska, 29,000 hunters harvested 7260 moose annually (on average) (Titus et al. 2009) that were used by > 90% of rural Interior Alaska community households (Brown et al. 2010), representing > $78 million annually in the state economy (McDowell Group 2014).

With so much interest, importance, and investment in moose hunting, federal and state agencies create moose hunting regulations to sustain populations while optimizing diverse hunting opportunities. The Alaska Department of Fish and Game (ADF&G) has divided the state into 5 management regions with 26 Game Management Units (GMU). Some GMUs are subdivided into subunits allowing for more precise and localized management of wildlife populations. Management seeks to mitigate biological and sociopolitical issues (Bath 1995) with regulations that are often complex and differ in space and time. The Alaska Constitution ensures equal access to fish and wildlife for all Alaskans. However, the Alaska National Interest Lands Conservation Act of 1980 (ANILCA; P.L. [Public Law] 96-487) mandates that hunting and fishing priority be given to rural Alaskans on federal land. These contradictory pieces of literature have added complexity to hunting systems in Alaska.

Although hunting opportunities exist for diverse interests of many stakeholder types, conflict from perceived competition and differences in value systems among hunter types occurs. Typically, all Alaskan residents (i.e., local and non-local hunters) recreate under the same hunting regulations. Most hunting in Alaska occurs on public land, with many hunters using the same areas year-after-year including setting up hunting camps and informal territories on public land (Johnson et al. 2016, Brinkman 2018). Hunting motivations vary by individual, but local rural hunters place a high significance on meat provision, whereas non-resident and non-local hunters may be more motivated by novel experiences and trophy opportunities. It is common for people born in rural communities to move to urban areas for education or employment but return to rural communities to hunt (Kofinas et al. 2010).

In addition to comparing different hunter groups, it is also important to consider how hunting patterns may change in areas with different levels of accessibility (Brinkman et al. 2013). Access is a central logistical challenge to hunting in remote parts of Alaska and factors into the allocation of hunting permits. For example, easily accessible regions in Alaska are more likely to be managed using draw permits (limited) because of higher hunter demand and the potential for hunter pressure and competition (Woodford 2014). Similar to areas outside of Alaska, harvest generally increases with proximity to roads (Fuller 1990) or in areas with higher road density (Hayes et al. 2002). General harvest permits (unlimited) in Alaska are more common in remote and inaccessible areas where hunter activity is reduced and overharvest less likely.

The goal of our research was to explore hunter distribution in management areas with different accessibility and between hunter groups to assess competition concerns. Our objectives were to: 1) quantify harvest patterns over time in regions with low (roadless rural) and high (roaded urban) accessibility, and 2) quantify overlap in harvest patterns of 2 hunter groups (local, non-local) in rural regions where competition is more frequently expressed. By comparing local and non-local hunting patterns, our study addressed the spatial and temporal characteristics of user group issues that have not been studied extensively among moose hunters in Alaska.

STUDY AREA

We examined hunting patterns in GMUs 20, 21, and 24 in Interior Alaska (Fig. 1) where the main ecotype is the boreal forest comprised mostly of white spruce (*Picea glauca*), black spruce (*P. mariana*), birch (*Betula papyrifera*), aspen (*Populus* spp.), and willow (*Salix* spp.). The area contains low-lying wetlands mottled with lakes, low scrub bogs,

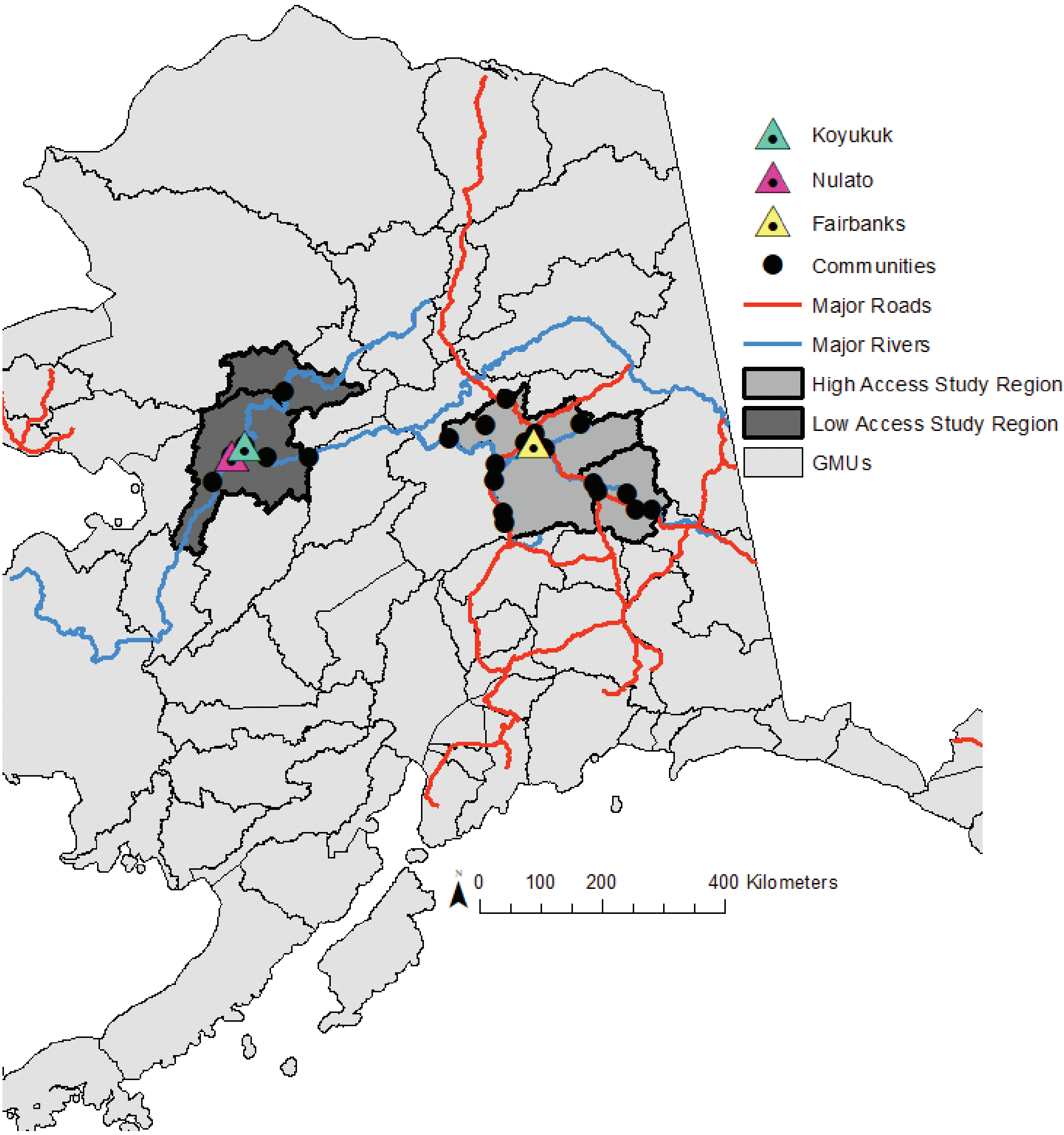

Fig. 1. Map of study area depicting the high-access urban and low-access rural regions used to evaluate hunter competition in Alaska, USA.

herbaceous meadows, and forb-herbaceous marshes. Intense winters and summers create annual temperatures ranging from -40 to 22°C (Brabets et al. 2000). Fire is the primary disturbance regime; however, fire suppression is concentrated on only 17% of the landscape, typically near roads and communities (DeWilde and Chapin 2007). Fire alters moose habitat quality and has shaped nearly all of Alaska's boreal forest, including the wildland-urban interface.

To examine differences between urban and rural hunting regions, we compared 3 GMU subunits with high accessibility near Fairbanks (GMU 20A, 20B, and 20D; 34,600 km^2) with 2 subunits (GMU 21D and 24D; 28,000 km^2) with low accessibility near Koyukuk, ~250 km west of Fairbanks.

Table 1. Difference in area, census, density, highway availability, and employment rate for the high access urban and low-access rural study regions, Alaska, USA. Census and employment rate was created by U.S. Census Bureau 2011.

	Urban Region	Rural Region
Area (km²)	34,600	28,000
Census (2000)	104,079	1,461
Density (# people/km²)	3.0	0.05
Highway length (km)	737	0
U.S. Census Bureau unemployment rate	7%	20%
# of moose hunting regulations (2017)	64	10

Although these two regions have relatively similar habitats, climate, and September moose hunting regulations, they have vastly different social systems, infrastructure, and defining characteristics (Table 1), as well as moose and predator population dynamics. Precise estimates of predator numbers are unknown, but wolf (*Canis lupus*) and bear (*Ursus* spp.) predation are significant causes of moose mortality in both regions. Although moose counts (density estimates) were done during our study period, they were not regularly completed across the entirety of the study area and we did not incorporate them for this reason. These subunits were selected because of the importance of moose hunting in each region despite their differences in social systems and infrastructure. In the study GMUs, hunters are typically allotted one moose during a September hunting season regardless of residency, ethnicity, or background; rural-priority hunts were not instituted during the study period. Although regulations around Fairbanks have been dynamic, harvest chronology has remained relatively constant over time in both study regions.

High-access urban region

The road-accessible urban region (GMU 20A/B/D) was situated around Fairbanks North Star Borough and was divided into 87 Uniform Coding Units (UCU) to provide finer spatial resolution to assess hunter harvest. Trail systems are used to access parts of this region and hunters use road vehicles, ATVs, watercraft (motorized or man-powered), and aircraft for access (Brinkman 2018). This GMU is subdivided into many smaller hunt areas with unique regulations that can change annually. For example, there were 64 different sets of regulations for moose harvest in 2017 (ADF&G 2016b) that included antlerless moose, any bull, and antler or brow-tine restriction hunts. Law enforcement is low in the region but "peer-policing" may help limit illegal hunting activity, although the regional poaching level is unknown. In 2016, 6,222 moose hunting permits were issued with 1,550 moose harvested (25% success rate; ADF&G 2020).

Low-access rural region

The rural region (GMUs 21D and 24D) was divided into 35 UCUs, not road-accessible, and situated along the Yukon and Koyukuk Rivers (Fig. 2); local hunters are predominantly Koyukuk Athabascan. The Koyukuk Controlled Use Area (KCUA; 12,408 km²) straddles the northern GMU 21D and the southern GMU 24D. Although moose hunting occurs across the entirety of this region, the majority (especially non-locals) occurs within the KCUA. In other communities on the Yukon River, all hunters

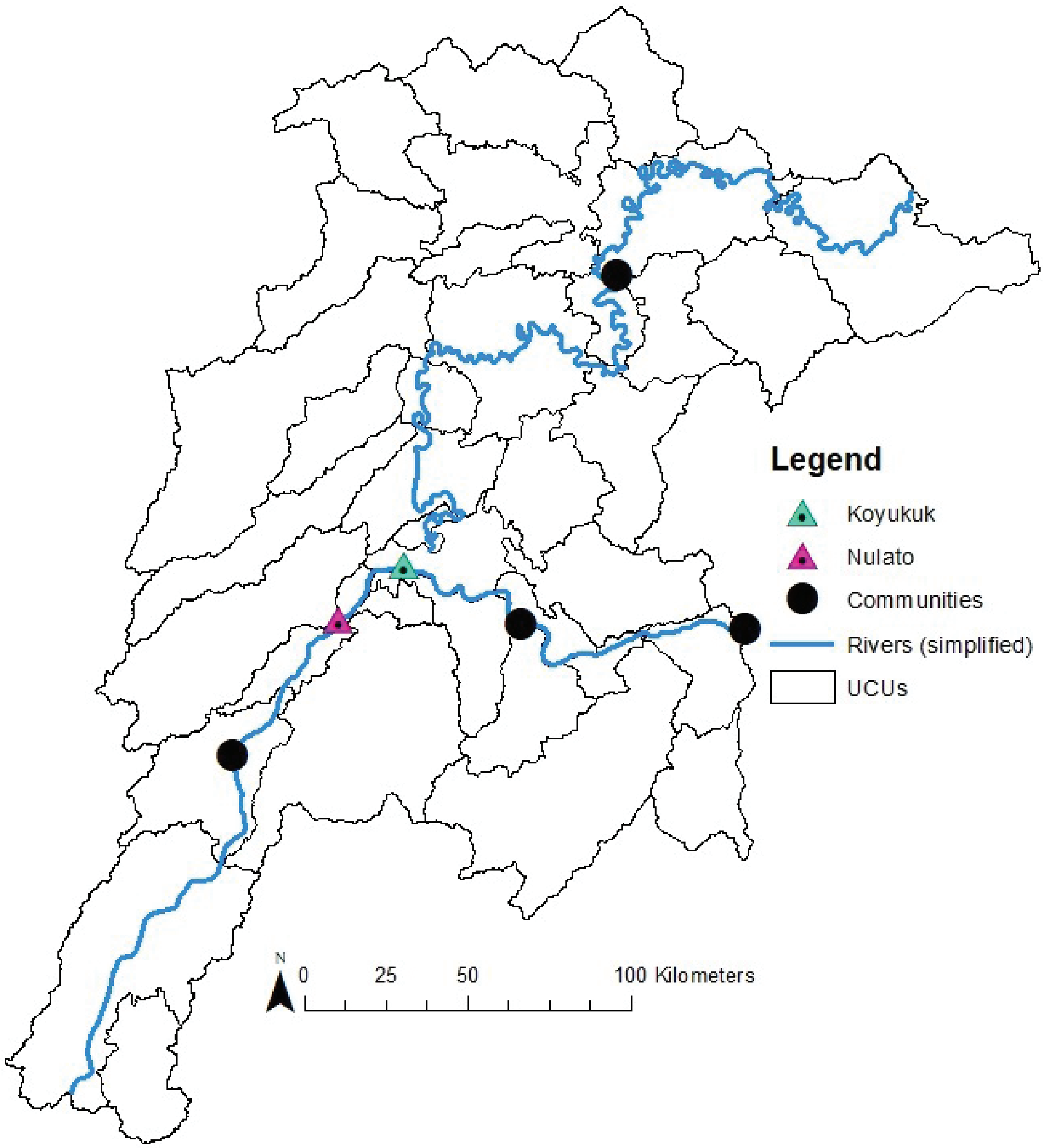

Fig. 2. Map of Uniform Coding Units (UCU) within Game Management Units 21D and 24D in the low-access rural study region used to evaluate hunter competition in Alaska, USA.

essentially travel and hunt by boat (Johnson et al. 2016). Although some trail systems exist, they are seldom used by moose hunters. The KCUA has a mandatory ADF&G check-in station on the Koyukuk River and the reporting rate is believed high compared to other rural areas. Because all hunters coming from the lower Koyukuk River are required to stop at the check-in station, a comprehensive 20-year dataset of hunter and harvest information was available for the KCUA. The check-in process helps ensure that hunters are harvesting legally, and although minor violations are common, it is believed that egregious activity is minimal during the hunting season; the level of poaching outside of the hunting season is unknown. Access to this region for non-local hunters requires considerable logistic effort and expense. For example, a Fairbanks resident would drive 220 km north on the Dalton Highway to the Yukon River bridge and then boat 483 km down the Yukon River to access Galena near the mouth of the Koyukuk River; however, many non-local hunters travel much further to access this hunting region.

This region had 10 different sets of moose harvest regulations in 2017 (Table 2; ADF&G 2016b). Under the registration hunt, Alaskan hunters (regardless of ethnicity or residency) can shoot any bull but are required to render the antlers unusable for trophy consideration by cutting one antler palm in half and forfeiting the cut portion to ADF&G. This "antler destruction" regulation was created to emphasize harvest for meat rather than trophy value (G. Stout, pers. commun.). Resident hunters can apply for a draw permit that allows them to harvest any size bull and to keep the antlers intact. Non-resident hunters can only participate if they receive a draw permit, and although they do not have to destroy an antler, they are mandated to harvest a bull with a minimum of 4 brow tines on at least one antler or with antler spread >127 cm. In 2016, 756 hunt permits were issued and 375 moose were harvested (50% success rate) (ADF&G 2020).

METHODS

Hunter database

The best available information on hunter patterns was accessible from ADF&G annual harvest data. Although mandatory harvest reporting exists statewide, harvest data is likely incomplete due to underreporting in remote areas (Schmidt et al. 2015), but is not considered an issue in our rural region where hunters accept and are compliant with the check-in station. We assumed that hunters who report harvest are representative of all successful hunters within the GMU with respect to location of harvest, hunt patterns, and effort. Because unsuccessful hunters do not report fine-resolution details such as

Table 2. Regulations in the low access rural hunting region in 2016 (ADF&G 2016b). Permit types are registration (RP) and drawing (DP), and residency types are residents (R) and non-residents (NR).

GMU	Permit Type	Residency	Special Instruction	Open Season
21D/24D, within KCUA	RP	R	Any bull, destroy antler	Sept 1–Sept 25
	DP	R	Any bull	Sept 5–Sept 25
	DP	NR	Antlers ≥127 cm, OR ≥4 browtines on one side	Sept 5–Sept 25
21D, outside KCUA	RP	R	Any bull, destroy antler	Aug 22–Aug 31, Sept 5–Sept 25
	DP	NR	Any bull	Sept 5–Sept 25
	DP	NR	Antlers ≥127 cm, OR ≥4 browtines on one side	Sept 5–Sept 25
21D, east of KCUA	DP	R	Any bull	Sept 5–Sept 25
	DP	NR	Antlers ≥127 cm, OR ≥4 browtines on one side	Sept 5–Sept 25
24D, remainder	RP	R	Any bull, destroy antler	Sept 5–Sept 25
	DP	R	Any bull	Sept 5–Sept 25
	DP	NR	Antlers ≥127 cm, OR ≥4 browtines on one side	Sept 5–Sept 25

temporal and spatial details of their hunt, our analysis was limited to hunters who harvested a moose. We acknowledge that unsuccessful hunters contribute to and are affected by hunter overlap and competition, but we assumed that successful hunters were a reasonable representation of all hunters because the hunter success rate was consistent over time, and many hunters use the same hunting area year-after-year, yet are unsuccessful 50% or more of the time.

We analyzed all harvest data during the September hunting season from 2000 to 2016. We included the following harvest data fields in our analysis: hunter residency, success (yes or no), date of kill, and hunt location (UCU). Although harvest data included number of hunting days, we deemed these data insufficient to assess hunter effort because of changes in reporting rates and possible issues with memory recall. We excluded data that were missing hunter residency or date of kill. Antlerless hunts and hunts that occurred outside the normal September hunting season were not included in the analysis because these hunts did not occur regularly during the study period and were not comparable between regions. Special hunts introduce circumstances that potentially influence harvest decisions that may introduce bias or inaccuracy in our results.

Analysis

ESRI ArcGIS was used to map and visualize harvest locations and the underlying landscape. We used a Mann-Whitney U test to compare the date of kills in the high-access urban and low-access rural regions (Objective 1). We calculated descriptive statistics on the proportion of successful local and non-local hunters in each UCU in the low-access rural region to measure spatial and temporal overlap between these 2 hunter groups (Objective 2). We compared the proportions using a Mann-Whitney U test to evaluate if local and non-local hunters used the same hunting space. We used a Kolmogorov-Smirnov test to compare the temporal overlap (i.e., distribution of date of kill) among hunters for the full study period. Further, we compared local harvest and non-local harvest over two even time periods: 2000–2008 and 2009–2016. This split allowed us to examine harvest locations over time for each hunter type while maintaining adequate sample sizes. Due to non-normal distribution, we used paired Wilcoxon signed ranks tests to assess changes in UCU use for each hunter type between the two study periods and used Mann-Whitney U tests to quantify the differences between local and non-local hunters use in each UCU for each time period.

Considering that spatial overlap was compared among UCUs, we created a relative overlap index (Eq. 1) that incorporated the non-local hunter density and the local hunter proportion in each UCU. Due to the low number of non-resident hunters and the similarity of patterns, we pooled non-residents and non-local resident hunters. We used river length (Hydrology 1:1000000) within each UCU to calculate non-local hunter density because nearly all hunters in the rural region access their moose hunting areas by watercraft (Johnson et al. 2016) and areas away from navigable waters are seldom used. Current regulations prohibit airplane transportation for hunters within the KCUA portion of 21D/24D. We ranked each UCU in order of highest relative overlap index. The relative overlap index was calculated for each UCU across the entire study period, and between the two time periods (2000–2008 and 2009–2016). We used a Wilcoxon signed-ranks test to compare overlap in distribution between the two time periods to capture any temporal change in overlap levels.

In our index, an increase in non-local hunter density within a specific UCU caused an increase in the relative overlap index score, but the increase was mediated by the level of importance of that UCU for local hunters. For example, a UCU with a high non-local hunter density that had high importance to local hunters had a higher score than a UCU with a high non-local hunter density that had low importance to local hunters. This approach was reasonable because this project was derived from and motivated by local hunter concerns in the rural region, and competition concerns between hunter types may be asymmetrical (i.e., locals are concerned about non-local presence, but not necessarily vice versa).

$$\left(\frac{\#\,\text{Non-Local Hunters}}{\text{Cumulative River Length(km)}}\right) \times \left(\frac{\#\,\text{Local Hunters}}{\text{Total Local Hunters}}\right) = \text{Relative Overlap Index} \quad \text{(Eq. 1)}$$

Finally, we split the hunting season into 5 equal time periods (1–5, 6–10, 11–15, 16–20, and 21–25 September) and generated a relative overlap index for each UCU for each time block across the full study period. This step allowed us to simultaneously evaluate the temporal and spatial overlap during the hunting season while maintaining adequate sample sizes.

RESULTS

A total of 25,113 harvest records from 2000 to 2016 were analyzed with 19,423 and 5692 moose in the urban and rural regions, respectively. The urban and rural regions exhibited different date-of-kill distributions ($P < 0.01$) based on the date of peak harvest (Fig. 3). Peak harvest occurred at the beginning of the season in the high-access urban region and in the middle of the season in the low-access rural region. Although local (n = 2286) and non-local hunters (n = 3156) in the rural region had different distributions in date of kill ($P < 0.01$), they had complete temporal overlap across the hunting season (Fig. 3).

In the rural region, 50% of the local harvest occurred on 33% of the hunting area (5 UCUs), whereas 54% of the non-local harvest occurred on 18% of the area (3 UCUs). Local and non-local hunters harvested fewer moose in the remaining UCUs (Fig. 4), revealing an uneven hunter distribution

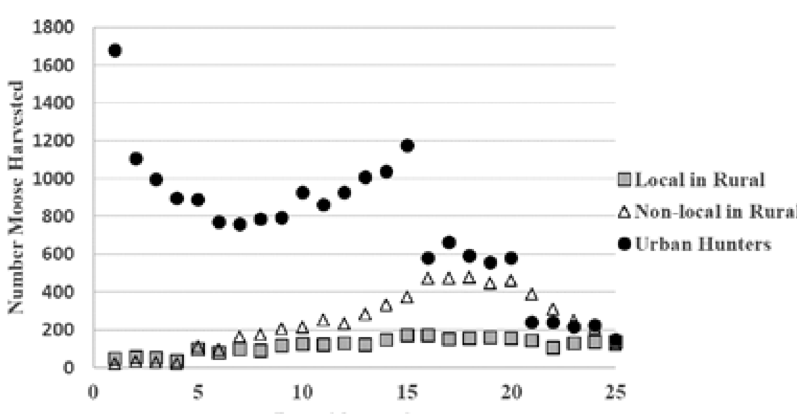

Fig. 3. The total daily number of moose harvested in September 2000–2016 by local, non-local, and non-resident hunters in a high-access urban hunting region, Alaska, USA.

across the region. Local and non-local hunters overlapped spatially ($P = 0.448$) but with differences in importance level among UCUs (Fig. 5). Spatial distribution of non-local hunter was similar ($P = 0.70$) in the early (2000–2008) and late study periods (2009–2016). Conversely, spatial distribution of local hunters changed ($P = 0.02$) as their proportional use declined in 5 UCUs and increased in 4 UCUs. Further, local and non-local hunters harvested a moose in similar locations in the early ($P = 0.43$) and late ($P = 0.47$) study periods, indicating that overlap existed across time.

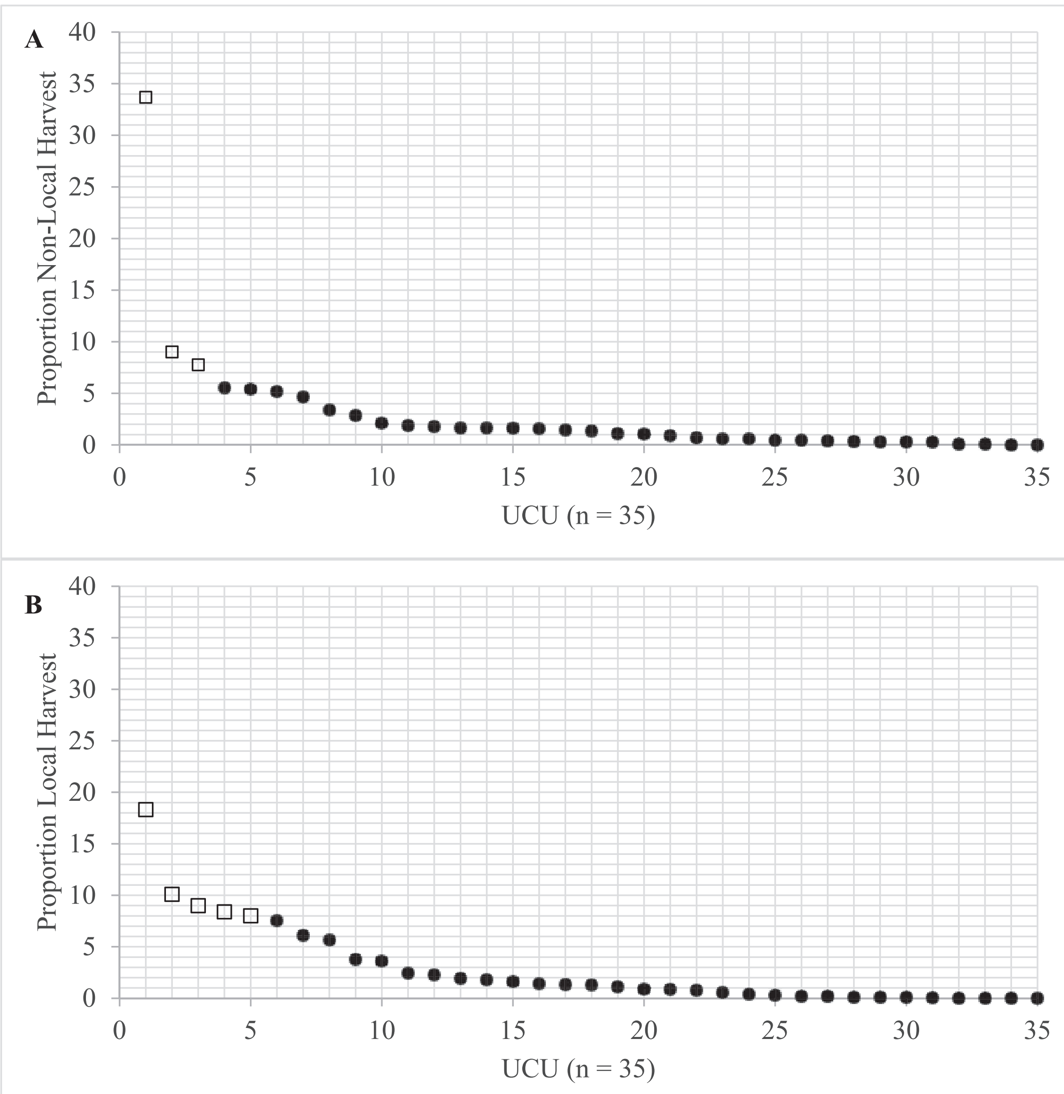

Fig. 4. Proportional use of UCUs by local (A) and non-local hunters (B) within the low-access rural hunting region, Alasaka, USA. The X-axis refers to the most used UCUs for each hunter type and not a specific sub-area; therefore, the UCU value does not necessarily correspond to the same location for local and non-local hunters. Data points displayed as boxes sum together UCUs that constituted 50% of harvest by local (n = 5) and non-local hunters (n = 3).

Hunter overlap scores ranged from 0 to 0.106 with a mean score of 0.010 (SD = 0.02) and median score of 0.003. In the rural region, high overlap existed in 12% of the hunting area, moderate overlap in 8%, and minimal overlap in the remaining 80% (Fig. 6). Twenty-seven UCUs had overlap scores less than the mean, 4 UCUs had scores ranging from 0.011 to 0.014, and 4 UCUs had the highest overlap scores of 0.033, 0.051, 0.054, and 0.106. The relative overlap index did not differ between the early and late study period ($P = 0.92$). Within the hunting season, the relative overlap index showed that the extent of overlap (by 5-day periods) within each UCU ranged from 0 to 0.017 (mean = 0.0005, SD = 0.0016) and was highest on 16–20 September (Fig. 7).

DISCUSSION

Our research focused on analyzing the spatial and temporal overlap between hunter groups because we assumed that the degree of overlap is directly related to the level of perceived competition. Our analyses indicate that rural and urban hunting regions exhibited different distributions of date-of-kill. The high-access urban region spiked soon after the opening of the hunting season, followed by steep decline and then moderate increase near the middle of the season, and then rapid decline; this pattern may reflect that specific regulations end on different dates (15, 20, 25, 30 September). Similar research with other species indicates that white-tailed deer (*Odocoileus virginianus*) harvest is most closely associated with day of hunting season (Hansen et al. 1986) and red deer (*Cervus elaphus*) harvest increases on weekends and moon phase (Rivrud et al. 2014). We speculate that warmer weather early in the season might create more comfortable conditions for urban hunters less reliant on a successful annual harvest. Or, the beginning of the season encompasses Labor Day weekend which provides urban hunters an extra hunting day in a region where employment is high relative to remote communities. "Opening day rush" may be a dominant factor in urban areas where there are higher numbers of hunters targeting a limited number of moose.

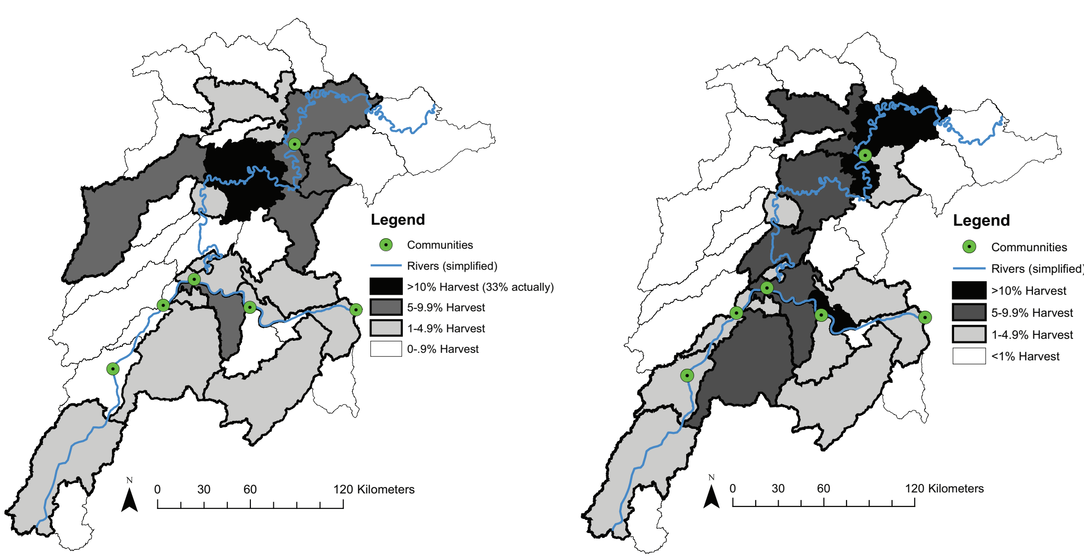

Fig. 5. Percent harvest by UCU in 2000–2016 by non-local (left) and local (right) hunters within the low-access rural hunting region, Alaska, USA.

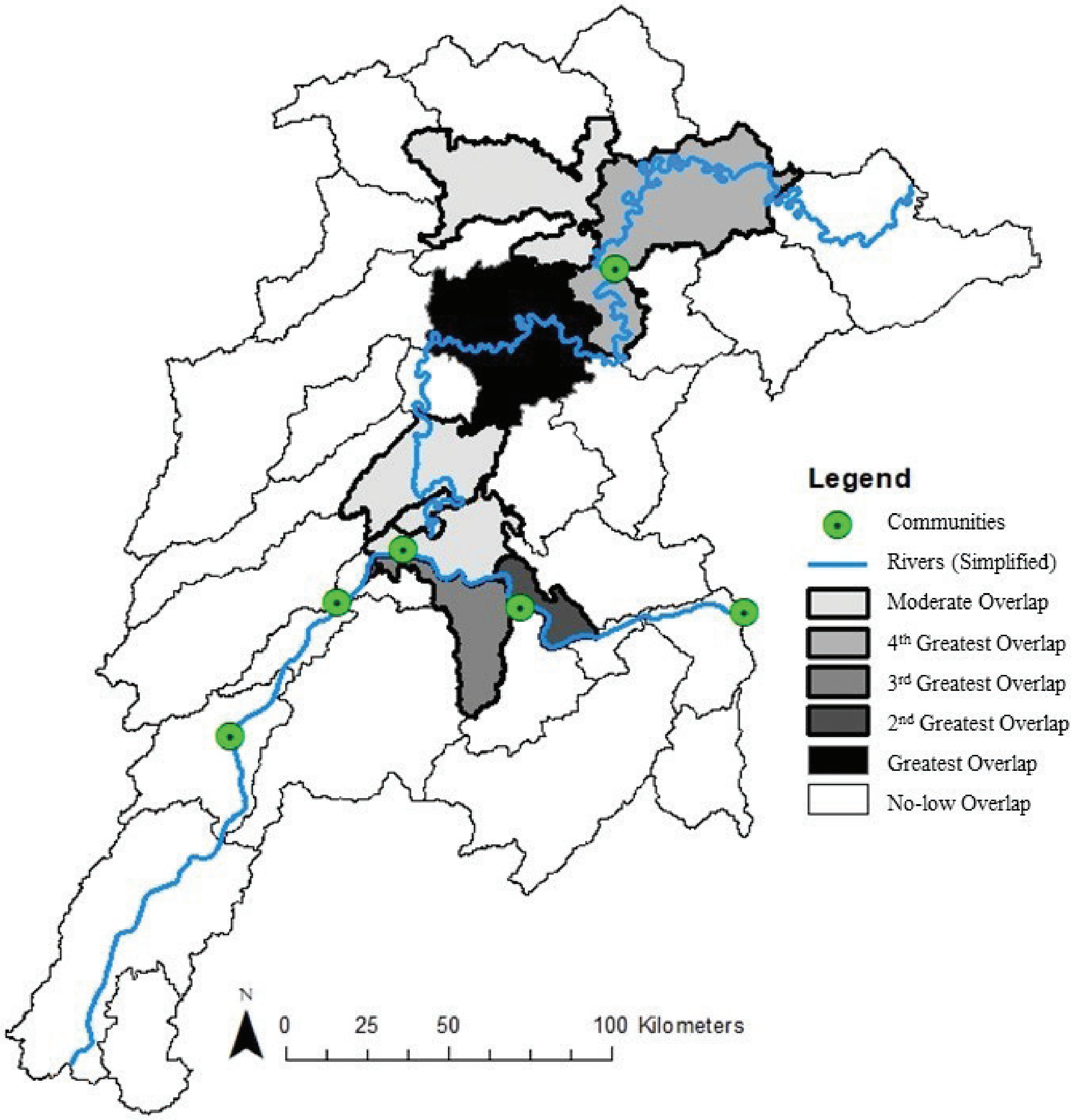

Fig. 6. Depiction of UCUs with the top 4 highest overlap scores, moderate overlap scores, and zero-low overlap scores in the low-access hunting region, Alaska, USA.

We speculate that hunting patterns in the low-access rural region are driven by biological and environmental conditions more so than in the high-access urban area with higher hunter numbers. Fewer hunter numbers/density in the rural region may afford hunters the opportunity to align their effort with ideal environmental conditions. Bull moose increase movement as rut approaches (Joly et al. 2015), with peak movement during the rut around 1–7 October (Brown et al. 2018) indicating that hunters may have a higher chance of encountering moose late in the season. Also, cooler temperatures in late September facilitate meat preservation in remote regions where several days may elapse between harvest and processing; lower ambient temperatures are critical as

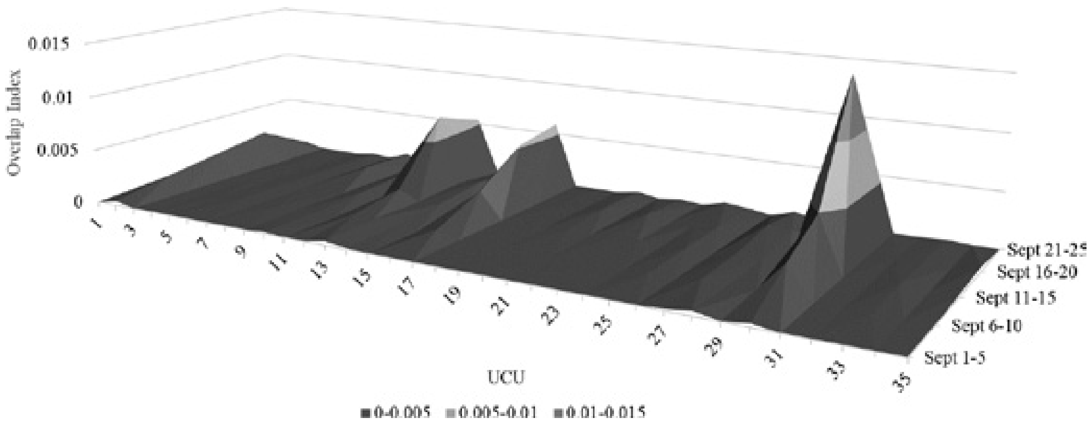

Fig. 7. 3D plot showing when and where overlap is greatest between local and non-local hunters in the low access rural hunting region, Alaska, USA. The X-axis refers to individual UCUs, y-axis to the hunter overlap scores, and z-axis to the time period within the hunting season. Colors help visualize scores.

meat begins to spoil at 4.4 °C (USDA 2011). Further, local hunters suggest that hunting moose is easier after leaf-fall in mid- to late September in Interior Alaska (Appendix A) because of improved sightability along river networks and sloughs. Due to traditionally lower employment opportunities in rural regions, some local hunters presumably have flexibility when selecting hunting dates.

Local and non-local hunters were not evenly distributed across the landscape as 50% of local harvest occurred in 5 UCUs, with the remaining 50% across 30 UCUs. Similarly, 54% of non-local harvest occurred in 3 UCUs with the remaining 46% in 32 UCUs. In the rural region we found that overlap was concentrated within 20% of the area, indicating that 80% of the area had minimal overlap. Figures 5 and 6 indicate that the greatest overlap and highest use by local and non-local hunters occurred in UCUs crossed by the Yukon and Koyukuk Rivers. Although tributaries exist throughout the area, these major rivers offer more consistent and safe access to moose. Overlap occurred later in the month, aligning with the peak harvest. Low overlap in the early season could reflect inferior weather conditions reducing hunt success or lower local participation. Local hunters may have more flexibility in their hunting dates whereas non-local hunters likely choose hunting dates in advance of the season because of the substantial time and effort needed to access the region. Also, some draw permits shorten the hunting season for non-resident hunters, therefore artificially bounding their hunting period. Our results indicated that local hunters changed hunt locations over time, but without further investigation, it is difficult to determine if this was a result of overlap, perceived competition, shifting moose densities, or other parameters.

The “availability framework” uses hunter accessibility, game abundance, and seasonal distribution of game to inform local management decisions, and is also useful to assess hunting opportunities (Brinkman et al. 2013). Consistent with this framework, our findings suggest that along with game supply (e.g., moose abundance and distribution), it is critically important to account for hunter access when exploring how hunting systems function. For example, our research shows concentrations of harvest mainly in UCUs with major navigable rivers (Fig. 5). Similarly, Lebel et al. (2012) found that higher levels of access increased the number of harvested white-tailed deer. Hunters in areas with different levels of accessibility may also have different perceptions of acceptable levels of crowding (Shelby et al. 1989). Due to the near complete reliance on waterways for access, we used cumulative total river length within each UCU to determine hunter density. Application in developed regions with uniform access could use road length, travel corridor length, or overall area as parameters. Identifying differences in regions with good and poor access may provide insight to employ local management strategies where hunter satisfaction is a concern.

Tensions with non-local hunters are often discussed as issues in rural communities, but the magnitude and scope of such attitudes and tensions have not been assessed quantitatively. Hunter survey research may provide insight into these characteristics and their influence (Brinkman 2018). Without hunter interviews, monitoring hunter interactions in the field, or conducting a robust moose behavioral study during the hunting season, we do not have estimates of the actual levels of competition. However, our findings support and inform future studies that may directly assess competition and its potential consequences.

Local hunters are generally more tolerant of other local hunters (Brinkman 2018). Future research might consider assessing proximity of harvest to communities, birth place of hunters instead of current address, and hunter expectations as to where other hunters will be encountered. For example, constructing maps with overlap index scores (see Fig. 2) would help local hunters distinguish areas of potential conflict with high numbers of non-local hunters. Additionally, "unexpected" overlap may increase hunter conflict where hunters expect solitude but encounter others.

Our ability to assess hunter competition was limited by the data that successful hunters provided on harvest reports. Because we were unable to assess overlap by unsuccessful hunters, the role of hunter effort in overlap and perceived competition is unknown. To fully understand competition and hunter satisfaction, we recommend that more data be collected from unsuccessful hunters, especially with regard to hunter effort. Questioning hunters about their own perceptions as to why they were unsuccessful (e.g., bad weather, too many people, varying levels of effort, too many predators) may help managers address the root of satisfaction issues.

This research focused on competition concerns of local hunters and we acknowledge that non-local hunters' perceived competition by non-local hunters was not assessed, and that they may feel negative impacts from competition or may not agree with or appreciate local-societal norms. A more inclusive survey should assess the perceived competition in a management area by all hunters – local, non-local, and non-resident. Yet, we provide novel information about previously untested hypotheses related to the issue of hunter competition. Our hunter overlap index can be modified and applied for different regions and game species to assess the existence and relative level of hunter competition. Because this overlap equation index does not include a temporal component, it would be important for researchers to assess the relative overlap score within salient time periods (Fig. 7).

MANAGEMENT IMPLICATIONS

To minimize hunter dissatisfaction, we recommend that game managers employ strategies to distribute hunters from areas with a relatively high overlap index scores, especially during the peak and latter half of the hunting season. We encourage altering current regulations, specifically lifting the prohibition of using aircraft for transportation into the KCUA with the caveat that aircraft use occur >1.6 km from the Yukon and Koyukuk River corridors. This should increase hunter distribution across the landscape, provide unique opportunities for non-local hunters, and reduce conflict with local hunters who seldom use airplane transport or travel > 1.6 km from a navigable river. We further recommend providing information about harvest hot spots and "high overlap" to help hunters avoid areas with historically high hunter density and potential competition. Ultimately, both individual hunters and agencies should adapt to alleviate hunter competition and optimize hunt satisfaction.

Our research provides a methodology to quantify hunter distribution which is broadly applicable in addressing concerns about hunter competition, a problem shared by many states and provinces. By using pre-existing data (i.e., harvest records) that nearly all wildlife management agencies collect, our approach can help managers identify where new strategies might be useful to modify hunter distribution to ease hunter conflict. Managers could alter the timing of hunts (e.g., staggered entry) or modes of access (e.g., open or close roads, motorized or non-motorized access) to redistribute hunter activity. We speculate that structured interviews with hunters given hunter distribution maps may provide insight regarding support for proposed novel and adaptive strategies. Management responses to objective information such as our hunter distribution analyses, that identify the location and causes of competition, should foster public acceptance and compliance with related management decisions.

ACKNOWLEDGMENTS

Our research was part of a larger project, University of Alaska Fairbanks's Community Research Partnerships for Supporting Sustainable Traditional Harvest Practices. Through this larger project, individual studies were designed to work collaboratively with communities to design objective, relevant, and important research related to hunting and fishing practices. Two entities, Koyukuk Traditional Council and Nulato Tribal Council, located in the rural GMUs partnered with us to address local research priorities related to hunter competition. We gratefully acknowledge Nulato Tribal Council (specifically A. Demoski), Koyukuk Traditional Council, Council of Athabascan Tribal Governments, and Tanana Chiefs Conference for their partnerships and input. Further, we thank K. Heeringa and the Community Research Partnerships for Supporting Sustainable Traditional Harvest Practices crew for their guidance and feedback. Our research was funded by the National Science Foundation (award 1518563) and NASA (award NNX15AT72A).

REFERENCES

Alaska Department of Fish and Game (ADF&G). 2016a. Interim reports moose – Year 2016. <https://secure.wildlife.alaska.gov/index.cfm> (accessed June 2018).

_____. 2016b. 2016–2017 Alaska Hunting Regulations, No. 56. <http://hunt.alaska.gov> (accessed March 2018).

_____. 2020. Moose hunting in Alaska: harvest statistics. <https://adfg.gov/index.cfm?adfg=moosehunting.harvest> (accessed July 2020).

Bath, A. J. 1995. The role of human dimensions in wildlife research in wildlife management. Ursus 10: 349–355.

Brabets, T. P., B. Wang, and R. H. Meade. 2000. Environmental and Hydrologic Overview of the Yukon River Basin, Alaska and Canada. Water-Resources

Investigations Report 99-4209. U.S. Geological Survey, Anchorage, Alaska, USA.

Brinkman, T. J. 2014. Alaska Sheep Hunter Survey: Resident Sheep Hunter Responses. Report for Alaska Department of Fish and Game, Fairbanks, Alaska, USA.

_____. 2018. Hunter acceptance of antlerless moose harvest in Alaska: importance of agency trust, proximity of hunter residence to hunting area, and hunting experience. Human Dimensions of Wildlife 23: 129–145. doi:10.1080/10871209.2017.1399486

_____, G. Kofinas, W. D. Hansen, F. S. Chapin III, and S. Rupp. 2013. A new framework to manage hunting: why we should shift focus from abundance to availability. The Wildlife Professional 7: 38–43.

_____, K. B. Maracle, J. Kelly, M. VanDyke, A. Firmin, and A. Springsteen. 2014. Impact of fuel costs on high-latitude subsistence activities. Ecology and Society 19: 18. doi:10.5751/ES-06861-190418

Brown, C. L., A. R. Brenner, H. Ikuta, E. H. Mikow, B. Retherford, L. J. Slayton, A. Trainor, J. Park, D. Koster, and M. L. Kostick. 2010. The harvest and uses of wild resources in Mountain Village, Marshall, Nulato, Galena, and Ruby, Alaska. Technical Paper Number 410. Alaska Department of Fish and Game, Fairbanks, Alaska, USA.

_____, K. Kielland, T. J. Brinkman, S. L. Gilbert, and E. S. Euskirchen. 2018. Resource selection and movement of male moose in response to varying levels of off-road vehicle access. Ecosphere 9(9): e02405. doi:10.1002/ecs2.2405

Decker, D. T., and L. C. Chase. 1997. Human dimensions of living with wildlife: a management challenge for the 21st century. Wildlife Society Bulletin 25: 788–795.

DeWilde, L., and F. S. Chapin III. 2007. Human impacts on the fire regime of Interior Alaska: interactions among duels, ignition sources, and fire suppression. 2007. Ecosystems 9: 1342–1353. doi:10.1007/s10021-006-0095-0

Ericcson, G. 2003. Of moose and man: the past, the present, and the future of human dimensions in moose research. Alces 39: 11–26.

Fix, P. J., and A. M. Harrington. 2012. Measuring motivations as a method of mitigating social values conflict. Human Dimensions of Wildlife 17: 367–375. doi:10.1080/10871209.2012.682325

Fuller, T. K. 1990. Dynamics of a declining white-tailed deer population in north-central Minnesota. Wildlife Monographs 110: 1–37.

Hammitt, W. E., C. D. McDonald, and M. E. Patterson. 1990. Determinants of multiple satisfaction for deer hunting. Wildlife Society Bulletin 18: 331–337.

Hansen, L. P., C. M. Nixon, and F. Loomis. 1986. Factors affecting daily and annual harvest of white-tailed deer in Illinois. Wildlife Society Bulletin 14: 368–376.

Hayes, S. G., D. J. Leptich, and P. Zager. 2002. Proximate factors affecting male elk hunting mortality in Northern Idaho. Journal of Wildlife Management 66: 491–499. doi:10.2307/3803182

Heberlein, T. A., and W. F. Kuentzel. 2002. Too many hunts or not enough deer? Human and biological determinants of hunter satisfaction and quality. Human Dimensions of Wildlife 7: 229–250. doi:10.1080/10871200214753

Hendee, J. C. 1974. A multiple-satisfaction approach to game management. Wildlife Society Bulletin 2: 104–113.

Jacob, G., and R. Schreyer. 1980. Conflict in outdoor recreation: a theoretical perspective. Journal of Leisure Research 12: 368–380. doi:10.1080/00222216.1980.11969462

Johnson, I., T. J. Brinkman, K. Britton, J. Kelly, K. Hundertmark, B. Lake, and D. Verbyla. 2016. Quantifying rural hunter access in Alaska. Human Dimensions of Wildlife 21: 240–253. doi:10.1080/10871209.2016.1137109

Joly, K., T. Craig, M. S. Sorum, J. S. McMillan, and M. A. Spindler. 2015. Variation in fine-scale movements of moose in the Upper Koyukuk River Drainage, Northcentral Alaska. Alces 51: 97–105.

Kluwe, J., and E. E. Krumpe. 2003. Interpersonal and societal aspects of use conflicts. International Journal of Wilderness 9: 28–33.

Kofinas, G. P., F. S. Chapin III, S. Burnsilver, J. I. Schmidt, N. L. Fresco, K. Kielland, S. Martin, A. Springsteen, and T. S. Rupp. 2010. Resilience of Athabascan subsistence systems to Interior Alaska's changing climate. Canadian Journal of Forest Research 40: 1347–1359. doi:10.1139/X10-108

Lebel, F., C. Dussaukt, A. Masse, and S. D. Cote. 2012. Influence of habitat features and hunter behavior on white-tailed deer harvest. Journal of Wildlife Management 76: 1431–1440. doi:10.1002/jwmg.377

McDowell Group. 2014. The Economic Impacts of Guided Hunting in Alaska. Prepared for Alaska Professional Hunters Association. McDowell Group, Anchorage, Alaska, USA.

Northern Economics Inc. 2006. The Value of Alaska Moose. Prepared for Anchorage Soil and Water Conservation District and the Alaska Soil and Water Conservation District, Anchorage, Alaska, USA.

Rivrud, I. M., E. L. Meisingset, L. E. Loe, and A. Mysterud. 2014. Interaction effects between weather and space use on harvesting effort and patterns in red deer. Ecology and Evolution 4: 4786–4797. doi:10.1002/ece3.1318

Ruddell, E. J., and J. H. Gramann. 1994. Goal orientations, norms, and noise-induced conflict among recreation users. Leisure Sciences 16: 93–104. doi:10.1080/01490409409513222

Saremba, J., and A. Gill. 1991. Value conflicts in mountain parks. Annals of Tourism Research 18: 155–172. doi:10.1016/0160-7383(91)90052-D

Schmidt, J. I., K. A. Hellie, and F. S. Chapin III. 2015. Detecting, estimating, and correcting for biases in harvest data. Journal of Wildlife Management 79: 1152–1162. doi:10.1002/jwmg.928

Shelby, B., and T. A. Heberlein. 1986. Carrying Capacity in Recreation Settings. University of Oregon Press, Corvallis, Oregon, USA.

_____, J. J. Vaske, and T. A. Heberlein. 1989. Comparative analysis of crowding in multiple locations: results from fifteen years of research. Leisure Sciences 11: 269–291. doi:10.1080/01490408909512227

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

Titus, K., T. L. Haynes, and T. F. Paragi. 2009. The importance of moose, caribou, deer, and small game in the diets of Alaskans. Pages 137–143 *in* R. T. Watson, M. Fuller, M. Pokras, and W. G. Hunt, editors. Ingestion of Lead from Spent Ammunition: Implications for Wildlife and Humans. The Peregrine Fund, Boise, Idaho, USA.

UnitedStatesDepartment of Agriculture (USDA). 2011. How Temperatures Affect Food. <https://www.fsis.usda.gov/wps/portal/fsis/topics/food-safety-education/get-answers/food-safety-fact-sheets/safe-food-handling/how-temperatures-affect-food/ct_index> (accessed October 2018).

U.S. Census Bureau. 2011. 2010 Census of Population and Housing. <http://live.laborstats.alaska.gov/cen/dparea.cfm> (accessed April 2018).

Vaske, J. J., M. P. Donnelly, K. Wittman, and S. Laidlaw. 1995. Interpersonal versus social-values conflict. Leisure Sciences 26: 1–11.

Woodford, R. 2014. What Are Draw Hunts? How They Work and Improving the Odds. Alaska Fish and Wildlife News. <http://www.ADF&G.alaska.gov/index.cfm?ADF&G=wildlifenews.view_article&articles_id=645.>.