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Response of Overwintering Caribou to Burned Habitat in Northwest Alaska

KYLE JOLY,[1] PETER BENTE[2] and JIM DAU[3]

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ABSTRACT. Caribou (*Rangifer tarandus granti*) use lichens, when available, as primary forage on their winter range. In boreal forest habitats, wildland fires effectively destroy lichens, and overwintering caribou are known to avoid burned areas for decades while lichen communities regenerate. However, little has been published about caribou response to burned habitat in tundra ecosystems. To assess the relationship between winter caribou distribution and burned areas, we instrumented Western Arctic Herd caribou with satellite telemetry collars and evaluated their locations in relation to recent burns of known age (≤ 55 years old) across northwestern Alaska. We analyzed caribou distribution for different habitat types (tundra and boreal forest), age categories of burns, and possible edge effects. We also reanalyzed the data, limiting available habitat to a uniform traveling distance (5658 m) from daily satellite locations. Using selection indices that compared caribou use of burns and buffers to their availability, we found that caribou strongly selected against burned areas within the tundra ecosystem. Recent burns were selected against at both large (range-wide) and intermediate (5658 m) spatial scales. Caribou particularly selected against 26- to 55-year-old burns and the interior (core) portions of all burns. We found that caribou were more likely to select burned areas in the late fall and early spring than midwinter. Increased fires in northwestern Alaska could decrease the availability and quality of winter habitat available to the herd over the short term (up to 55 years), potentially influencing herd population dynamics and reducing sustainable harvest levels. We recommend that fire managers consider caribou midwinter range condition and extent: however, management that achieves a mosaic pattern of fire history may benefit a wide array of species, including caribou. A better understanding of the current regional fire regime and the distribution of available winter range will be required before practicable management recommendations can be developed for this herd.

Key words: boreal forest, caribou, fire, habitat use, *Rangifer tarandus*, selection, tundra

RÉSUMÉ. Le fourrage principal du parcours d'hiver du caribou (*Rangifer tarandus granti*) est le lichen, lorsque celui-ci se trouve à sa disposition. Dans les habitats de forêt boréale, les feux de broussailles détruisent les lichens, au point où les caribous évitent, pendant des décennies l'hiver, les régions qui ont été brûlées afin de laisser le temps au lichen de se régénérer. Cependant, peu d'information a été publiée à l'égard de la réaction du caribou envers l'habitat brûlé des écosystèmes de la toundra. Afin d'évaluer la relation entre la répartition du caribou d'hiver et les régions brûlées, nous avons posé à un troupeau de caribous de l'Arctique de l'Ouest des colliers émetteurs à télémétrie par satellite et évalué leur emplacement par rapport à des régions brûlées récemment dont on savait à quand remontaient les incendies (≤ 55 ans) et ce, aux quatre coins du nord-ouest de l'Alaska. Nous avons analysé la répartition du caribou en fonction de types d'habitats différents (la toundra et la forêt boréale), de catégories d'âge des régions brûlées et d'effets de lisière possibles. De plus, nous avons réanalysé les données en prenant soin de limiter l'habitat disponible à une distance de déplacement uniforme (5 658 m) à partir des emplacements satellites quotidiens. Grâce aux indices de sélection comparant l'utilisation faite par les caribous des régions brûlées et des zones tampons et leur disponibilité, nous avons remarqué que le caribou délaissait fortement les régions brûlées dans l'écosystème de la toundra. Les régions brûlées récemment étaient rejetées tant à la grande échelle spatiale (l'ensemble du parcours) qu'à l'échelle intermédiaire (5 658 m). Plus particulièrement, le caribou se tenait loin des régions brûlées il y a 26 à 55 ans et des sections intérieures (au centre) de toutes les régions brûlées. Nous avons constaté que le caribou était plus susceptible d'opter pour les régions brûlées vers la fin de l'automne et au début du printemps qu'au milieu de l'hiver. Les incendies à la hausse dans le nord-ouest de l'Alaska pourraient avoir pour effet de diminuer la disponibilité et la qualité de l'habitat d'hiver à la disposition du troupeau à court terme (jusqu'à 55 ans), ce qui pourrait influencer la dynamique de la population du troupeau et réduire les taux de récoltes durables. Nous recommandons que les directeurs des incendies considèrent l'état et l'étendue du parcours du caribou en parcours d'hiver. Cela dit, une gestion donnant lieu à un dessin en mosaïque de l'historique des incendies pourrait avantager une vaste gamme d'espèces, dont le caribou. Il faudra avoir une meilleure compréhension du régime régional actuel des incendies et de la répartition du parcours d'hiver disponible avant que des recommandations de gestion réalisables puissent être faites pour ce troupeau.

Mots clés : forêt boréale, caribou, feu, utilisation de l'habitat, *Rangifer tarandus*, sélection, toundra

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[1] Bureau of Land Management, Fairbanks District Office, 1150 University Avenue, Fairbanks, Alaska 99709, USA; Kyle_Joly@blm.gov
[2] Alaska Department of Fish and Game, Division of Wildlife Conservation, Pouch 1148, Nome, Alaska 99762, USA
[3] Alaska Department of Fish and Game, Division of Wildlife Conservation, P.O. Box 689, Kotzebue, Alaska 99752, USA

INTRODUCTION

Slow-growing fruticose lichens, when available, are the primary forage used by overwintering caribou, *Rangifer tarandus granti* (Thompson and McCourt, 1981; Boertje, 1984; Saperstein, 1996; Thomas, 1998) and are critical for large migratory herds in northern climates (Klein, 1991). The quality and quantity of winter forage can affect fetal growth, birth weight and growth of calves, milk production, protein loss, and survivorship (White, 1983; Parker et al., 2005). Caribou forage lichens are highly susceptible to wildland fires (Auclair, 1983). In the boreal forest, caribou use burned areas less than they are available for decades after fire (Thomas et al., 1996; Arseneault et al., 1997; Joly et al., 2003), likely because of reduced lichen abundance (Thomas et al., 1996). Caribou response to burned habitat in tundra ecosystems is less understood (Ballard et al., 1997); only one preliminary study (Saperstein and Klein, 1992) has directly assessed this relationship.

Fire is a natural feature in the boreal forest (Lutz, 1956; Johnson and Rowe, 1975) that drives vegetative succession. Post-fire succession (Van Cleve and Viereck, 1981, 1983) and the effects of wildfire on forest pattern are well understood for the boreal forest (Bergeron and Dansereau, 1993), where recovery of caribou forage lichens occurs in late successional communities because they require long periods of time following fire or other disturbance to return to their original community type (Viereck and Schandelmeier, 1980; Klein, 1982; Thomas and Kiliaan, 1998). Increased frequency of fires may dramatically reduce the amount of preferred winter range available for caribou in the boreal forests of interior Alaska (Rupp et al., 2006).

Although tundra fires are generally uncommon and limited in extent (Wein, 1976; Payette et al., 1989), they are more common and larger in scale on the Seward Peninsula and in northwestern Alaska (Racine et al., 1985, 1987). Recovery of tundra ecosystems after fire has been investigated in northwestern and interior Alaska (Wein and Bliss, 1973; Hall et al., 1978; Racine, 1981; Racine et al., 1987, 2004; Jandt and Meyers, 2000), and these studies reveal that graminoids and shrubs return quickly after fire. Resprouting can occur within days, even as the leading edges of large fires are still producing flames (J. Dau, pers. obs.). In contrast, fruticose lichens in burned tundra habitat show little recovery 25 years post-burn (Racine et al., 2004; Jandt et al., in press). Although wildland fires destroy fruticose lichens, they increase overall vegetative diversity and productivity. Fire may produce short-term detrimental effects to overwintering caribou by removing lichens for up to 60 years (Miller, 1980; Thomas et al., 1996; Arseneault et al., 1997; Joly et al., 2003), but may also benefit caribou by stimulating growth of graminoids and shrubs used as forage in other seasons and by long-term rejuvenation of decadent lichen mats (Miller, 1980; Schaefer and Pruitt, 1991; Coxson and Marsh, 2001).

The Western Arctic Herd (WAH) has experienced sustained growth since a population low of 75 000 in 1976 (Dau, 2005a), and a photo-census in July 2003 estimated its numbers at 490 000 caribou. The herd ranges over most of northwestern Alaska (Fig. 1), and its winter range covers vast expanses of both tundra and boreal forest. The WAH is a critical resource for 40 communities within or adjacent to its range where subsistence is still the dominant way of life. Approximately 15 000 caribou are harvested from the herd each year by subsistence and sport hunters (Dau, 2003, 2005b). Additional knowledge of how wildfires affect caribou could greatly enhance land-use planning in this region.

Our primary goal was to analyze use by WAH caribou of recently (≤ 55 years) burned areas compared to more mature habitat (> 55 years old). We evaluated the use of recently burned areas over the herd's entire winter range, assessed use at a more localized scale, quantified differences in selection among habitat types and successional stages of burned areas, and analyzed the use of burn edges versus their core areas. We hypothesized that although caribou would exhibit a general avoidance of areas burned 55 or more years ago because forage lichens are lacking, they would use areas burned 1–25 years ago because graminoids and shrubs recover quickly after fire (Wein and Bliss, 1973; Racine et al., 1987, 2004; Jandt and Meyers, 2000). Our other goal was to provide land managers with recommendations for regional fire planning purposes.

STUDY AREA

The WAH ranges annually over 363 000 km^2 of northwestern Alaska (63–71˚ N and 148–166˚ W; Fig. 1; Davis et al., 1982; Dau, 2003). The core winter range extends roughly from the village of Kobuk on its northeastern side westward to the central Seward Peninsula and southward to the village of Unalakleet (Fig. 1; Davis and Valkenburg, 1978; Dau, 2003). Since 1985, at least portions of this core region have consistently been used as wintering grounds by the majority of the herd. However, the distribution and intensity of use have varied annually even within this preferred wintering area, and scattered groups occurred nearly throughout the entire annual range in any given year (Dau, 2003, 2005b). Winter die-offs occurred in 1994–95 and 1999–2000 outside the core winter range, just southeast of Point Hope (northwest of Kotzebue; Fig. 1; O'Hara et al., 1999, 2003; Dau, 2005a).

The entire winter range of the herd encompasses Arctic coastal plains, the Brooks Range and its foothills, the Nulato Hills, and the Seward Peninsula lowland ecosystems. Vegetation types include tussock (*Eriophorum* spp.) tundra, black spruce (*Picea mariana*) dominated boreal forest, and alpine communities. Extensive shrublands are present in riparian areas and in the transition zones between boreal forest, tundra, and alpine habitats. The core winter range is dominated by lowland, treeless tussock tundra (primarily *Eriophorum vaginatum*), but contains rolling hills up to 900 m elevation and large riparian

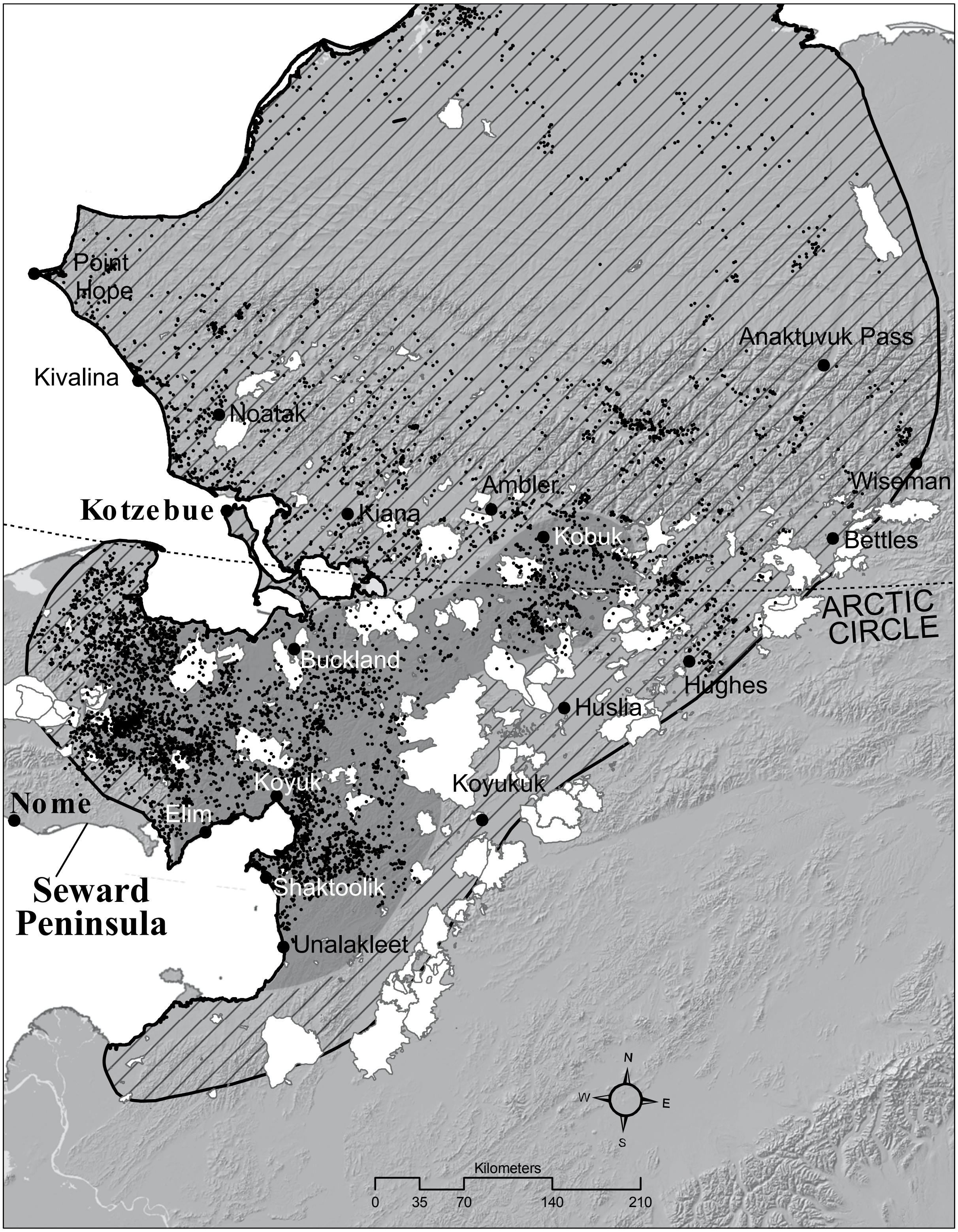

FIG. 1. Annual (hatched) range of the Western Arctic Herd caribou and the distribution of winter (October through April) locations (black points) of collared caribou between 1999 and 2005 in northwestern Alaska, USA (courtesy of the Alaska Department of Fish and Game). White polygons depict the distribution of recent burns (≤ 55 years old; 1950–2004) within the study area (courtesy of the Alaska Fire Service).

corridors. Terricolous lichens (*Cladina* spp., *Cetraria* spp.) and shrubs (*Betula nana*, *Empetrum nigrum*, *Ledum palustre*, *Vaccinium uliginosum,* and *V. vitis-idaea*) are important constituents of the tundra tussock community (Joly et al., 2007), whereas higher elevations support alpine communities and riparian corridors contain willows (*Salix* spp.), alder (*Alnus crispa*), and white spruce (*Picea glauca*). Boreal forest is more prevalent in the southern and eastern portions of the winter range. Mean annual precipitation is about 30–40 cm for the Kotzebue region, but varies extensively over the winter range as a whole (Alaska Climate Research Center, http://climate.gi.alaska.edu/). Snow cover, usually persisting from November through May, ranges from hard and crusted in wind-scoured areas to deep and soft in wind-protected locales. Ambient surface air temperatures can range from -50˚C during winter months to 30˚C during the peak of summer in areas away from the coast.

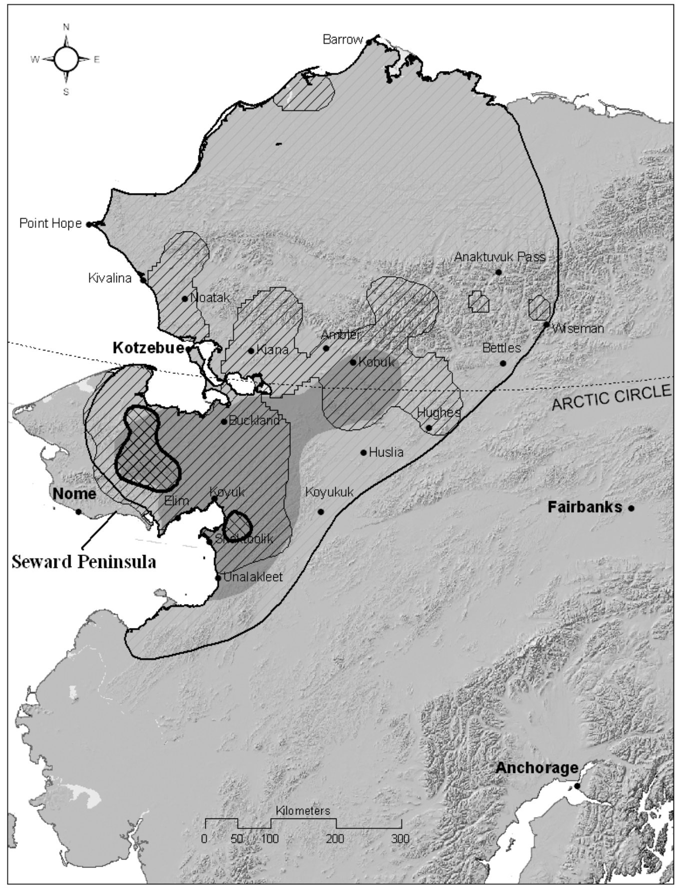

FIG. 2. Winter range, derived using kernel analysis, of the Western Arctic Herd during 1999–2005 in northwestern Alaska, USA. The 95% kernel is hatched and the 50% kernel is cross-hatched. The shaded area is core winter range and the dark outline is the perimeter of the herd's annual range as defined by the Alaska Department of Fish and Game.

METHODS

Mapping Fire History

We used the Bureau of Land Management-Alaska Fire Service's burn perimeter database records (http://agdc.usgs.gov/data/blm/fire/index.html), which date back to 1950, to map and age wildfires in northwestern Alaska (Fig. 1). Fires that affected less than 405 ha (1000 acres) were not mapped before 1993, when the mapping threshold was reduced to 40.5 ha (100 acres). We assigned fires to three different age classes (25 years or less, 26–55 years, or over 55 years) on the basis of regional patterns of lichen succession (Racine et al., 2004; Jandt et al., in press). The over 55-year-old category likely included some habitat where fires occurred during the last 55 years but went undetected, or where the burn was less than the mapping thresholds could detect.

Caribou Locations

Every year from 1998 through 2003, we captured and instrumented adult caribou with satellite collars (Telonics, Inc., Mesa, AZ) at Onion Portage while they were swimming across the Kobuk River during the fall migration (see Dau, 1997). Caribou were selected to be collared without regard to age, body condition, or maternal status, except that we did not collar 1) females less than 12 months old, 2) males that were less than 4–5 years old, or 3) caribou in very poor health from any cause. Location data were transmitted via satellite to an ARGOS receiving station (Service Argos, Inc. Landover, MD, USA) using four six-hour duty cycles repeated at intervals of four to six days during the winter season. We collected data, starting in 1999, from October through April for six consecutive years ending in 2005 and modified the dataset to integrate locations into a Geographic Information System (GIS). To avoid sampling bias, collared caribou were not considered randomly distributed throughout the herd. Consequently, they were excluded from the analyses until the autumn following their capture. For analysis, we used only a single daily location with quality indices of one, two, or three (ARGOS-derived categories of locational accuracy with errors < 1000 m) for each collared caribou. Fixed kernels (statistical method for estimating animal distributions, such as home range; Worton, 1989) were created with the Animal Movement extension (an add-on software package to GIS software; Hooge and Eichenlaub, 1998) to estimate the 95% and 50% utilization distributions (polygons delineating probability of use; Seaman and Powell, 1996) of location data.

Habitat Analysis

The interpretation of habitat-use analyses can be confounded by study design limitations, lack of independence among animals and locations, scaling issues, and delineations of available habitat (Johnson, 1980; Alldredge and Ratti, 1986, 1992; Porter and Church, 1987; Thomas and Taylor, 1990; Levin, 1992; Rettie and Messier, 2000). To reduce those potential errors, we used only one relocation per day per caribou and employed two spatial scales to estimate habitat availability. We used individual relocations as our observational units for these analyses. We initially evaluated caribou use of burned habitat across the herd's entire winter range, as defined by a minimum convex polygon (MCP), buffered by 10 km, around the caribou locations. The WAH winter range covered a vast area (see Results; Fig. 2), and although some caribou overwinter throughout most of the range, not all areas were equally and immediately accessible to collared caribou. This pattern violated assumptions of habitat use-availability analyses (Johnson, 1980; Alldredge and Ratti, 1986, 1992; Thomas and Taylor, 1990; Aebischer et al., 1993), so we reevaluated habitat use with a more restricted definition of available habitat. We created a circle with a radius of 5658 m that constituted a subset of the entire range that was reasonably accessible to individual caribou at the time the location was obtained (sensu Arthur et al., 1996). We assigned the radius to the equivalent of the 99th percentile of movements of overwintering caribou as determined by the analysis of caribou instrumented with Geographical Positioning System (GPS)-equipped radiocollars in eastern Alaska (Joly et al., 2003) because comparable data were not available for the WAH. The circle method generates more conservative estimates of habitat use than MCPs because broad-scale selection is factored into the analyses a priori (Joly et al., 2003). In other words, broad-scale avoidance of burned habitat (for example) is not a confounding variable for the circle methodology because the circles accounted only for habitat that was locally available to individual caribou.

We categorized habitat as either tundra or boreal forest on the basis of 1 km^2 AVHRR (Advanced Very High Resolution Radiometer) vegetation mapping. We investigated edge effects on habitat selection by comparing caribou use of four zones: 1) unburned habitat more than 500 m from the burn perimeter, 2) unburned habitat less than 500 m from the burn perimeter, 3) burned habitat within 500 m of the burn perimeter and 4) burned habitat within the core of the fire (> 500 m from the burn perimeter; sensu Neu et al., 1974). To evaluate use of burned areas, we calculated standardized selectivity indices and their 95% confidence intervals according to Manly et al. (1993). The selectivity indices were calculated using the following formula: $\hat{w}_i = o_i / \pi_i$, where o_i is the number of locations within habitat class i divided by the total number of locations, and π_i is the area of available habitat in class i divided by the amount of total available area. The indices were standardized, so they sum to one, using the following formula:

$$B_i = \hat{w}_i / \left(\sum_{i=1}^{I} \hat{w}_j\right)$$

We used analysis of variance (ANOVA) techniques to detect differences in the use of burned areas by sex (bulls versus cows) and time of year (early and late winter months versus midwinter months). All statistical analyses were performed using Statistix (Analytical Software, 2003), while ArcGIS (Environmental Systems Research Institute, 1999) was used to create MCPs, circles, and buffers and to determine the areal extent of habitat types, stand age-classes, and burns within these categories.

RESULTS

In total, 72 instrumented caribou (65 cows and 7 bulls) generated a total of 7048 locations during the six-year study period (average of 28 caribou per year; range 20–34 caribou per year; Fig. 1). Caribou locations were well distributed, encompassing an area of 360 763 km^2. The locations covered not only the area delineated as core winter range, but the majority of the annual range as well. Concentrated use of the winter range of the WAH from 1999 to 2005 corresponded well with the core winter range of the herd as defined by the Alaska Department of Fish and Game (ADFG; Fig. 2). However, the herd used areas farther west on the Seward Peninsula and south towards Shaktoolik more heavily during the study period than they had in the past. Besides greater use of these new areas, differences in the delineation of winter range could be attributed to the small number of satellite-collared caribou (< 0.03% of the herd per year) and the fact that the ADFG delineation was based on VHF telemetry and PTT data over a longer and different time period.

The number and extent of fires (Fig. 3a) in both tundra and boreal forest (Fig. 3b) has varied greatly among years since 1950. The 1970s were the decade with the most fire activity within the herd's winter range. Fire management strategies (suppression) and mapping parameters have changed markedly since 1950, precluding simple generalizations about the fire regime in northwestern Alaska.

Range-wide use of burned areas (including both boreal forest and tundra habitats) by bull caribou was insignificantly less than that of cows ($F_{1, 7047} = 3.07$, $p = 0.08$), so we pooled the data. We found caribou used recently burned areas (< 55 years old) less than they were available throughout their winter range (Fig. 4a). This was true even when we reduced available habitat to an area within 5658 m of their location (Fig. 4b). We also found that caribou use of burned tundra habitat was less than its availability (Fig. 4c). Range-wide use of burned areas between 26 and 55 years old was extremely low compared to its availability (Fig. 5). This was also true for the range-wide use of core areas of burns (> 500 m within a burn boundary; Fig. 6). Range-wide use of burned areas was significantly greater in early (October and November) and late (April) winter than in midwinter (December, January, February, and March; $F_{1, 6} = 12.3$, $p = 0.02$; Table 1).

DISCUSSION

Our finding that caribou used recently (< 55 years) burned habitat less than it was available at the scale of the

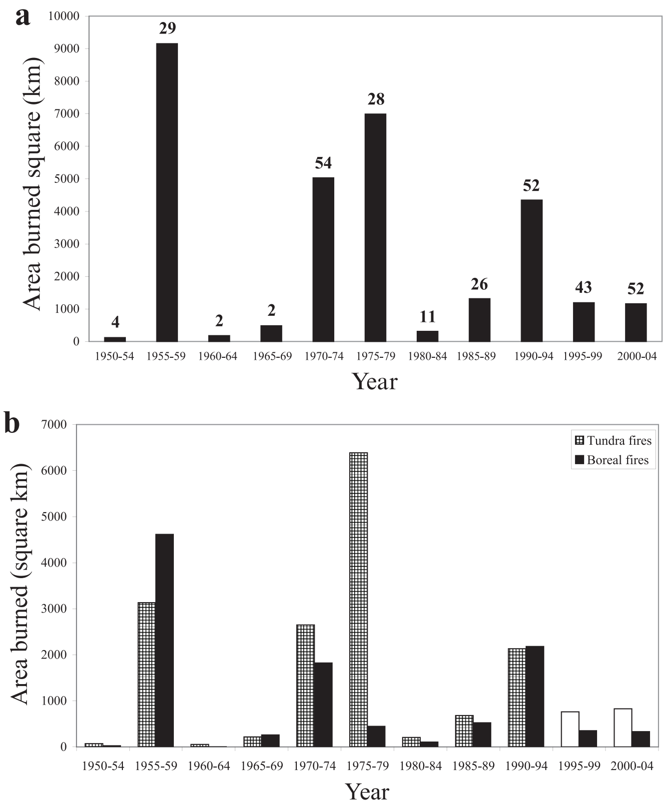

FIG. 3. a) Chronology of total acres burned during 1950–2005 in the winter range study area for the Western Arctic Herd in northwestern Alaska, USA. Numeric labels above bars indicate number of fires. b) Area burned by habitat type (tundra or boreal forest), in five-year intervals, 1950–2004.

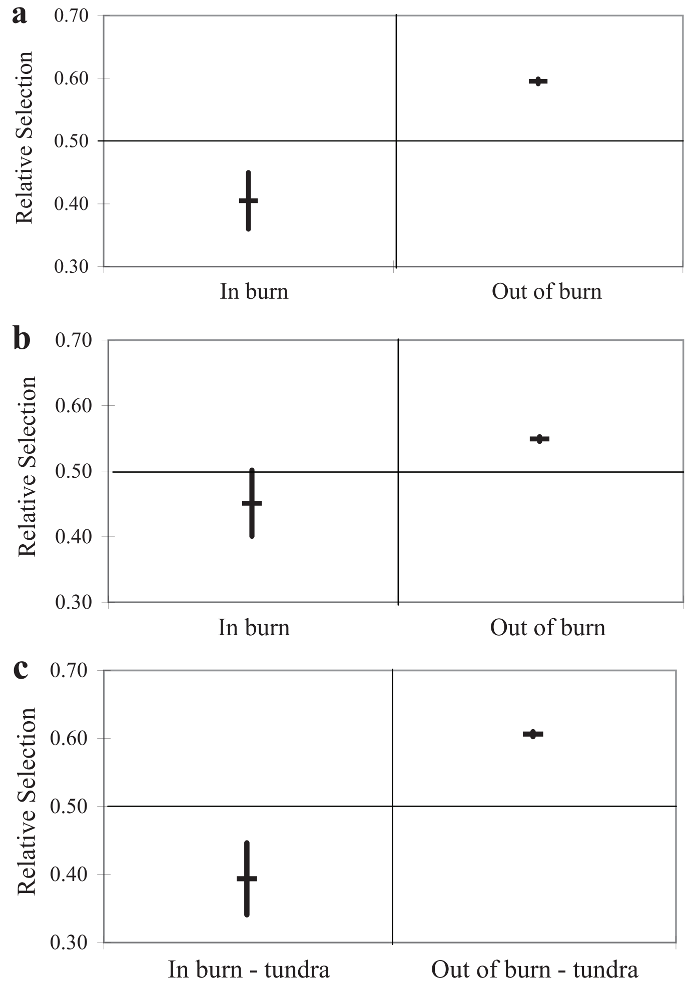

FIG. 4. Habitat selection indices (and 95% CI) for Western Arctic Herd caribou on their wintering grounds in northwestern Alaska, USA, 1999–2005. Available habitat was categorized as either recently burned (1–55 yrs, "In burn") or not recently burned (> 55 yrs, "Out of burn"). A selectivity index of 0.5 implies use in proportion to availability. a) Available habitat (boreal forest and tundra) determined by a Minimum Convex Polygon (MCP). b) Available habitat (boreal forest and tundra) determined by a circle with a 5658 m radius around the caribou location, c) Available habitat (tundra only) determined by a circle with a 5658 m radius around the caribou location.

entire winter range—a mosaic of both tundra and boreal forest habitat—held true even when available habitat was reduced to an area that was readily accessible to the caribou at the time they were relocated. Limited use by barren-ground caribou of recently burned boreal forest winter range has been documented in other studies (Thomas et al., 1996, 1998; Joly et al., 2003). However, we also found that caribou did not use recently burned tundra habitat as much as it was available. We believe that our analysis is the first large-scale study to confirm this relationship for tundra ecosystems, and our results concur with the findings of Saperstein and Klein (1992) and the observations of Ballard et al. (1997).

Overwintering caribou used burned habitat in midwinter in both boreal forest and tundra ecosystems less than it was available for 40–60 years, yet this pattern was not observed in our study area for 1–25-year-old burned areas or in early or late winter time periods. We believe this could occur for the following reasons. First, during early and late winter, the caribou may merely be migrating through burns as they transition between seasonal ranges or as they seek suitable winter range with more accessible food. Alternatively, reduced avoidance of this age-class during these periods may be the result of gaining access to vascular forage species that regenerate quickly and vigorously after being burned (Racine et al., 1987, 2004; Jandt et al., in press) or of finding improved cratering and feeding conditions when caribou encounter shallow or soft snow. Fecal pellet composition analyses have shown that lichens constitute 60–80% of the diet of caribou in this region (Saperstein, 1996; Jandt et al., 2003), which suggests the alternative hypothesis of access to vascular forage species is not supported. However, the diet of WAH caribou may be changing (Joly, unpub. data), so the relationship between forage availability, consumption, and population dynamics should be further investigated. Burns in the 26–55-year age class received less use than expected on the basis of availability throughout the winter range, perhaps because palatability of vascular species was diminished and the lichen biomass was insufficient to attract caribou (Viereck and Schandelmeier, 1980; Thomas and Kiliaan, 1998).

Our analysis revealed that caribou used buffer areas (both inside and outside burned areas) roughly in proportion to their availability throughout the winter range. This

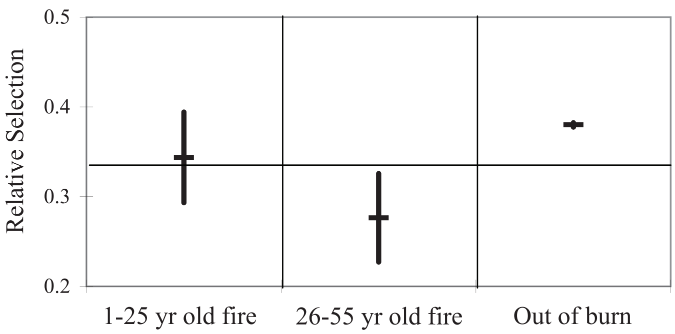

FIG. 5. Habitat selection indices (and 95% CI) for Western Arctic Herd caribou on their wintering grounds in northwestern Alaska, USA, 1999–2005. Available habitat (both tundra and boreal forest), as determined by a circle with a 5658 m radius around the caribou location, was categorized into three age classes (1–25, 26–55, and > 55 yrs) based on the last time the stand burned. A selectivity index of 0.33 implies use in proportion to availability.

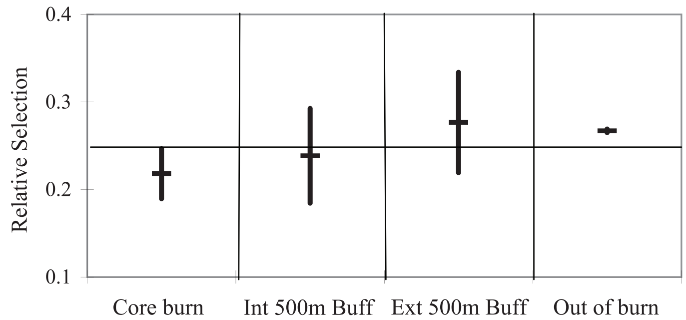

FIG. 6. Habitat selection indices (and 95% CI) for Western Arctic Herd caribou on their wintering grounds in northwestern Alaska, USA, 1999–2005. Available habitat (both tundra and boreal forest), as determined by a circle with a 5658 m radius around the caribou location, was classified into four categories: (1) within a recent (< 55 yrs) burn and > 500 m from the perimeter ("Core Burn"), (2) within a recent burn and < 500 m from the perimeter ("Int. 500 m"), (3) outside a recent burn but within 500 m of a burn perimeter ("Ext. 500 m"), or (4) > 500 m from a recent burn perimeter. A selectivity index of 0.25 implies use in proportion to availability.

suggests that caribou did not seek burn perimeters for foraging, predator avoidance, or other ecological benefits. Our finding of very low use of core burned areas (> 500 m within a burn perimeter) by caribou mirrored the findings of an analysis of caribou habitat use in interior Alaska (Joly et al., 2003). In addition to the lack of forage lichens, unfavorable snow conditions and deadfalls may also contribute to caribou avoidance of core burned areas in forested areas (Miller, 1980; Schaefer and Pruitt, 1991; Thomas et al., 1996; Joly et al., 2003).

Caribou do not use burned areas within boreal forest habitats as much as they are available for at least 40 years after a burn (Miller, 1980; Schaefer and Pruitt, 1991; Thomas, 1991; Thomas and Kiliaan, 1998; Joly et al., 2003), a period that coincides with the recovery time of key lichen forage species (Thomas et al., 1996; Thomas and Kiliaan, 1998). WAH caribou seek out and use areas with high lichen abundance, and their foraging has been implicated as an important causative factor in the significant decline of lichen cover in the region (Joly et al., 2007). We believe the low use of recently burned areas in tundra ecosystems is due primarily to low lichen availability as well. However, indirect impacts of burned areas on caribou, such as adverse snow conditions and increased predation, may also affect the use of these areas (Davis et al., 1978). The avoidance of recent burns by caribou may allow accelerated re-colonization of lichens by eliminating the detrimental effects of trampling and grazing (Lutz, 1956; Ahti and Hepburn, 1967; Pegau, 1969; Rowe et al., 1975; Kershaw, 1977). Fire may be required over the long term to maintain high productivity of early-succession forage lichen species and to destroy mosses that compete with senescent old-growth forage lichen mats (Miller, 1976; Schaefer and Pruitt, 1991; Coxson and Marsh, 2001).

Caribou habitat selection is influenced by wildland fire; however, the impacts on caribou range may be negative or positive depending on preexisting habitat type, season, and the spatial and time scales under investigation. There is considerable variability in how fire affects habitat and vice versa. An often overlooked but critical factor in the debate about detrimental effects to caribou winter range is the nature of the fires themselves: both the extent and the severity of burns are important factors. Physiography, age of vegetation (time since last burn), preexisting type of vegetation, climate, and local environmental conditions are all factors affecting fire recurrence and severity (Rowe et al., 1974; Johnson, 1992). Variability in these factors in turn allows for a high degree of variability in how fires affect habitat. The effect of fire on caribou is more complex than a simple dichotomy between burned and unburned (Schmiegelow et al., 2006). Differences in burn recurrence and severity can lead to differing occurrence and recovery periods among returning species (Racine et al., 1987). Islands of unburned habitat within a larger burn perimeter are common in wet or topographically diverse habitats, and caribou will use these unburned islands for foraging (Miller, 1976). Similar diversity occurs within the winter range of the WAH, which contains vast expanses of intermingled tundra and boreal forest habitats. Although fires are generally uncommon in tundra habitats (Wein, 1976), they appear to be more prevalent in the winter range of the WAH in northwestern Alaska (Racine et al., 1987). Frequent and extensive fires could greatly reduce the amount of old-growth winter range for caribou (Rupp et al., 2006). If the predictions of increased fires due to global warming come true (Rupp et al., 2000; McCoy and Burn, 2005), then the argument that fire is not detrimental to caribou because they can seek alternative range may become obsolete. However, it has been argued that a transition from lichen-dominated tundra to graminoid-dominated tundra may not be detrimental to caribou (van der Wal, 2006). The WAH may prove to be a good test case for this hypothesis.

MANAGEMENT IMPLICATIONS

Caribou are a critical subsistence resource for rural communities throughout northern North America, and land managers are concerned that extensive wildland fires

TABLE 1. Monthly use of burned habitat (both tundra and boreal forest) by caribou in the winter range of the Western Arctic Herd, northwestern Alaska, October 1999 – April 2005.

Month	Locations within Burns	Total # Locations	% Locations within Burns
October	120	1665	7.21
November	86	1406	6.12
December	55	990	5.56
January	26	766	3.39
February	14	680	2.06
March	22	717	3.07
April	56	824	6.80

may be detrimental to caribou winter range. This concern is heightened by predictions that global climate change will increase the extent and intensity of fires and thus affect vegetative communities (Rupp et al., 2000). If the extent of fire increases markedly in the North, the availability of alternative (unburned) winter range will be reduced (Rupp et al., 2006). For the WAH, these concerns are exacerbated by recent findings that lichen cover has declined within its range because of grazing and climate change (Joly et al., 2007). Our conclusion—complemented by other studies (Saperstein and Klein, 1992; Thomas et al., 1996, 1998; Joly et al., 2003) showing that caribou avoid recently (< 55 years old) burned areas, both in tundra and boreal forest during midwinter—should influence land managers to incorporate knowledge of caribou-fire ecology into fire management planning. We recommend defining the acceptable minimum amount of mature (> 55 years old) habitat and maximum average percentage of winter range allowed to naturally burn annually (see Beverly and Qamanirjuaq Caribou Management Board, 1994). When the average annual burn rate exceeds the desired level—whether from natural causes, human ignitions, or global climate change—suppression activities could be increased in subsequent years to limit the reduction of caribou winter range capacity. Of course, fire management decisions should not be based solely on caribou winter range conditions, as habitat management for other species (such as moose, *Alces alces*) should be considered. Furthermore, wildland fires have beneficial impacts on graminoids, forbs, and other forage that caribou, and other species, use during spring, summer, fall, and as our research indicates, even early and late winter. We acknowledge that not all fires are the same. Large and intense fires may be worse for caribou because they can reduce the recovery rate of both vascular and non-vascular caribou forage species; and as we have demonstrated, caribou avoid the core sections of larger burns for decades.

We believe that by allowing small fires to burn, managers may be able to create a mosaic of different-aged habitats that may benefit a wide array of species, including caribou. The cyclical nature of caribou populations and human harvest requirements also need to be factored into management decisions; however, further research into the fire regime of the region and the extent of potential winter range is required before developing specific fire management recommendations for the WAH.

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