The Impacts of Wildfire on Mountain Goats and Their Winter Range Habitats in a Coastal Ecosystem

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ABSTRACT: Over half of the world's population of mountain goats (*Oreamnos americanus*) occurs in British Columbia; BC has a global responsibility for the conservation of this species. Mountain goats are particularly vulnerable during the winter months, when deep snows restrict their movements and distribution, especially in wet coastal environments. During the summer of 2015, significant wildfires occurred in southwestern British Columbia covering approximately 15, 892 ha in total area. As a result of these wildfires, several legally protected mountain goat winter ranges were burned to varying degrees. There is concern that these wildfires will significantly impact the suitability of these winter ranges and negatively affect the survival of the mountain goat populations that depend on these habitats during the winter months. During February and March of 2016 and 2017, we conducted four replicate sets of helicopter surveys of 13 burned and 12 unburned winter ranges to evaluate the effects of wildfire on the local abundance of goats. Mountain goat winter ranges that were highly impacted by fire (≥75% of the forest area burned) were 75% less likely to be occupied and contained ≥80% fewer individuals. We found a positive and significant correlation between residual forest area and the number of mountain goats. This study revealed an important relationship between large-scale habitat perturbations and mountain goat populations in a coastal ecosystem.

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KEY WORDS British Columbia; coastal ecosystems; habitat impacts; mountain goat; *Oreamnos americanus;* population; wildfire.

Mountain goats (*Oreamnos americanus*) are present in most of the high mountain ranges of British Columbia (Shackleton 1999). Over half of the world's population of mountain goats occur in British Columbia, and BC has a global responsibility for the conservation of this species (Côté and Festa-Bianchet 2003). Mountain goats are a Blue listed species in British Columbia, meaning that these species have characteristics that make them particularly sensitive or vulnerable to human activities or natural events.

Mountain goats are highly sensitive to human disturbance (Festa-Bianchet and Côté 2008). Mountain goats may be negatively affected by such disturbances such as helicopter over flights, industrial activity, and human recreation (Foster and Rahs 1983, Côté 1996, Wilson and Shackleton 2001, Hurley 2004). Mountain goats are particularly vulnerable during the winter months, when deep snows restrict their movements and distribution, especially in coastal environments (Hebert and Turnball 1977, Dailey and Hobbs 1989, Fox et al. 1989, Wilson 2005). Mountain goats in coastal ecosystems are often associated with steep slopes on southerly aspects, and often with stands of old, large coniferous trees that provide snow interception, especially after significant snow events (Hebert and Turnball 1977, Fox et al. 1989, Taylor et al. 2006, Taylor and Brunt 2007).

In British Columbia, ungulate winter ranges are recognized as important components in the survival and persistence of ungulates. The BC Forest and Range Practices Act (FRPA) provides a legal mechanism for protecting ungulate winter ranges from timber harvest and associated activities. Winter ranges are intended to provide sufficient habitat for over-winter survival of mountains goats and other ungulate species. During the summer of 2015, significant wildfires occurred in the Sea to Sky District in southwestern British Columbia covering an area of 15,892 ha. These wildfires also burned several mountain goat winter ranges.

While the effects of prescribed and wildfire are well documented with ungulate species such as white-tailed deer (*Odocoileus virginianus*) where fire can be positive (e.g., Wood 1988) and negative (e.g., Lashley et al. 2015), there little is known about the effects of wildfire on mountain goats. The British Columbia Provincial Mountain Goat Plan (Mountain Goat Management Team 2010) has identified knowledge gaps in how mountain goats respond numerically or spatially to fire (prescribed fire or wildfire). This objective of this paper is to evaluate the impacts of wildfire on mountain goat populations in British Columbia.

STUDY AREA

Our sampling of the goat winter ranges occurred in southwestern British Columbia in two key studies areas: the Elaho River drainage (50° 08’N, 123° 31’W) and in the Upper Lillooet (50° 36’N, 123° 27’W) in the Sea to Sky Natural Resource District (Figure 1). Each area experienced significant burns due to wildfires during the summer of 2015. The Elaho burn was approximately 10,459 ha in size, while the Upper Lillooet burn was approximately 5,433 ha in extent.

The Sea to Sky Natural Resource District is approximately 1.1 million ha in size and its climatic influences are predominantly maritime, dominated by interior-cedar hemlock, coastal western hemlock, and mountain hemlock Biogeoclimatic Zones (https://www.for.gov.bc.ca/hre/becweb/).

METHODS

Data Collection

We conducted two helicopter reconnaissance flights per winter season over two years, one in February and one in March. Consistent with British Columbia’s Resource Information Standards Committee (RISC) standards (RISC 2002), we conducted these flights during mid-day (1000 to 1500 hours) when goats and tracks are most readily observed. We conducted the survey approximately two days after a snowfall, allowing time for tracks to accumulate, thereby increasing the likelihood of

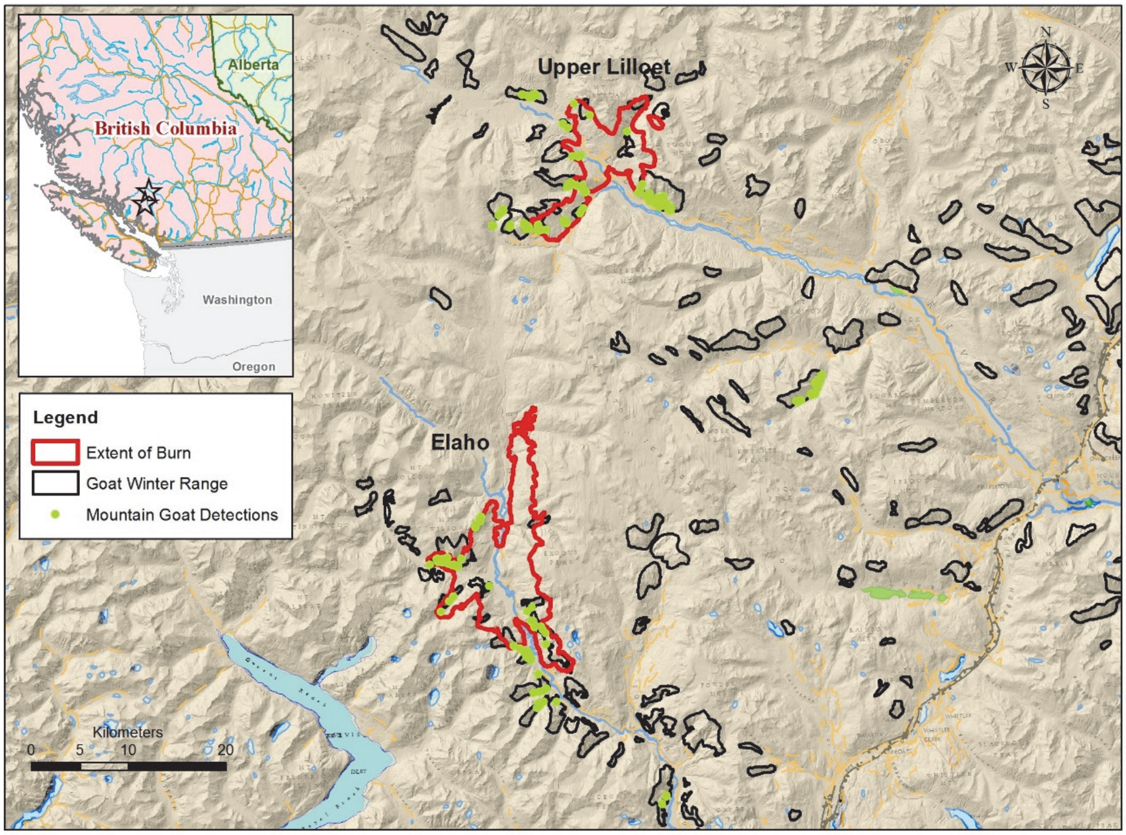

Figure 1. The two study areas, extent of the 2015 fires and mountain goat winter ranges. The green points indicate which winter ranges were sampled.

detection. An A-Star 350 helicopter was used to survey the affected goat winter ranges, with one observer in the front, and two in the rear of the helicopter. The pilot also served as a secondary observer. The observer in front served as the primary navigator, with one observer in the back as a secondary navigator using an iPad with preloaded with PDF maps and real-time GPS using Avenza Maps mobile app (http://www.avenza.com/pdf-maps). Waypoints of mountain goats (animals or tracks) and flightpaths were recorded using a Garmin GPS 60CSx. When a set of tracks was sighted, we attempted to estimate the number of tracks observed. This was often difficult due to tree cover and / or snowmelt on warm aspects and if multiple animals have used one location. We were confident that these tracks were from mountain goats, as these goat winter ranges did not overlap with winter ranges of black-tailed deer and moose (*Alces alces*), and bighorn sheep (*Ovis canadensis*) do not occur in this Region of British Columbia. In order not to double count the number of animals observed, tracks were only counted when goats were not directly observed in the close proximity or at all. We made efforts to locate animals, and when goats were encountered, the number of individuals were recorded and classified by age and sex (when possible), was tabulated. Mountain goats were classified as: billy (adult male), nanny (adult female), unknown adult and juvenile or kid (< 1 year old; Festa-Bianchet and Côté 2008). For this analysis, we only examined the total number of goats. Animal welfare was paramount during surveys, and an immediate assessment of potential danger was undertaken; if an animal was determined to be in a precarious location, the helicopter moved away immediately to increase the distance from the mountain goat and reduce the potential for displacement or disturbance, which affected successful age/sex classification in some instances subsets of mountain goat winter ranges (goat winter ranges) were sampled in each of the two study areas. This subset included goat winter ranges that were burned and unburned. Unburned ranges were chosen based on their relative location to the burned areas (adjacent), and also comparable in size and characteristics to the burned ranges. In the Elaho study area, we surveyed 14 goat winter ranges, with eight goat winter ranges burned (partially or completely) and six unburned. In the Upper Lillooet study area, we surveyed 11 goat winter ranges, six burned (partially or completely) and five unburned (Figure 1). Occupancy of these winter ranges were confirmed during the establishment of these winter ranges from 1995 to 2002 (Rochetta 2002).

We calculated the forested area (ha) prior to the burn using satellite imagery in each winter range. We examined each winter range polygon visually to assess the extent of the forested area burned (in percent) and estimated the residual forested area (ha) post burn as we did not have satellite imagery to estimate the full extent of the burn.

Data Analysis

For each goat winter range in which mountain goats were observed, the total number of animals, by age and sex (where available) was tabulated and for this analysis, all ages and sexes were pooled. Observations of mountain goat were not corrected for sightability as a correction factor has not been derived for winter surveys (Poole 2007, Rice et al. 2009). In all goat winter ranges, the numbers of tracks (fresh) were estimated, and this was especially important in goat winter ranges where few animals were sighted by many tracks were observed. In all goat winter ranges, linear density (*LD*) of mountain goats was calculated:

$$LD = \sum_i (G + T) \,/\, (\sum_i D$$

where *G* is the total number of goats sighted in winter range *i*, *T* is the number of goats estimated from tracks, and *D* is the distance (km) sampled in winter range *i*. We did not calculate goat densities because the sightability of goats in each winter range was highly variable, and the number of tracks acted as a surrogate for goat abundance (Collier et al. 2008). Mountain goat LD was calculated in each burn class category, percent of the forest cover burned: 0-25%, 25-50%, 50-75%, and 75-100%. To evaluate how *LD* differed between surveys in each year (e.g., February and March surveys) and between the two years, we used paired t-tests. We did this to determine of significant variability in goat abundance existed between surveys within a season (winter) and years.

We calculated the proportion of goat winter ranges occupied by goats in the winter ranges by burn class category: 0-25%, 25-50%, 50-75%, and 75-100% of the forest cover burned. For 100% occupancy, evidence of mountain goat presence (at least one animal or one set of tracks) had to be present.

To determine the relationship between mountain goat abundance and residual (post-fire) forested area (ha), we regressed the number of goats (in winter ranges where sightability was good; however we did not corrected for sightability) in a winter range against the residual patch size of trees remaining. The residual forested area is the forest cover remaining after the fires. We did this to determine at what forest patch the numbers of goats drop off precipitously. We did not regress *LD* as it is a measure of relative and not true goat abundance. We also did not examine the relationship between mountain goat occupancy and residual forested area size, as this relationship is binary and does not indicate at which point mountain goat abundance begins to decline significantly.

RESULTS

We surveyed 25 individual goat winter ranges in a total of four flights in February and March 2016 and 2017 (Figure 1). Thirteen were sampled in the Elaho study area, and 11 were sampled in the Upper Lillooet study area (Figure 1). In the Elaho study area, 8 goat winter ranges were burned, and 6 were unburned. In the Upper Lillooet study area, 6 goat winter ranges were burned, and 5 goat winter ranges were unburned.

The proportion of goat winter ranges occupied by goats was substantially less in areas where ≥75% of the forested area had burned (Figure 3). Goat winter ranges in <75% of the forest covered burned were all occupied in all four surveys, whereas in goat winter ranges with ≥75% of the forested area had burned, only 25% to 57% were occupied (Figure 3). The mean occupancy from the four surveys with ≥75% of the forested area burned was 0.37 ± 0.072, which is significantly less than winter ranges with <75% of the forested area burned (1.0 ± 1.0 vs 0.37 ± 0.072, $p<0.01$, t-test). However, in goat winter ranges where all of the forest cover was burned, none of these winter ranges were occupied in 2016 and in February 2017.

The *LD* of mountain goats was substantially less in areas where ≥75% of the forest canopy burned (Figures 2a and b). In 2016, goat winter ranges that were ≥75% burned had a *LD* >80% less than goat winter ranges that were <75% burned (4.8 ± 0.6 vs 0.7 ± 0.4 goats per km, t-tests, $p<0.001$). Similarly, in 2017 goat winter ranges that were ≥75% burned had a *LD* >90% less than goat winter ranges that were <75% burned (7.2 ± 1.2 vs 0.4 ± 0.1, t-tests, $p<0.001$). Paired t-tests indicated remarkable consistency between surveys within a season for 2016, where the *LD* did not differ, however in 2017, *LD* in the lowest percent burned class (0-25%) is significantly higher in 2017 (Figure 2b, $P<0.05$). The *LD* in burned classes from 25-100% did not differ statistically ($P>0.05$, $t = 1.92$) between surveys.

There is a significant correlation between the numbers of mountain goats (uncorrected abundance, not *LD)* on a winter range the residual forest area. All four surveys showed a positive and significant correlation between the number of mountain goats and residual forest area (Figure 4a-d). Generally residual forest area <50 ha appeared to have to least amount of goats in terms of absolute abundance (Figure 4a-d).

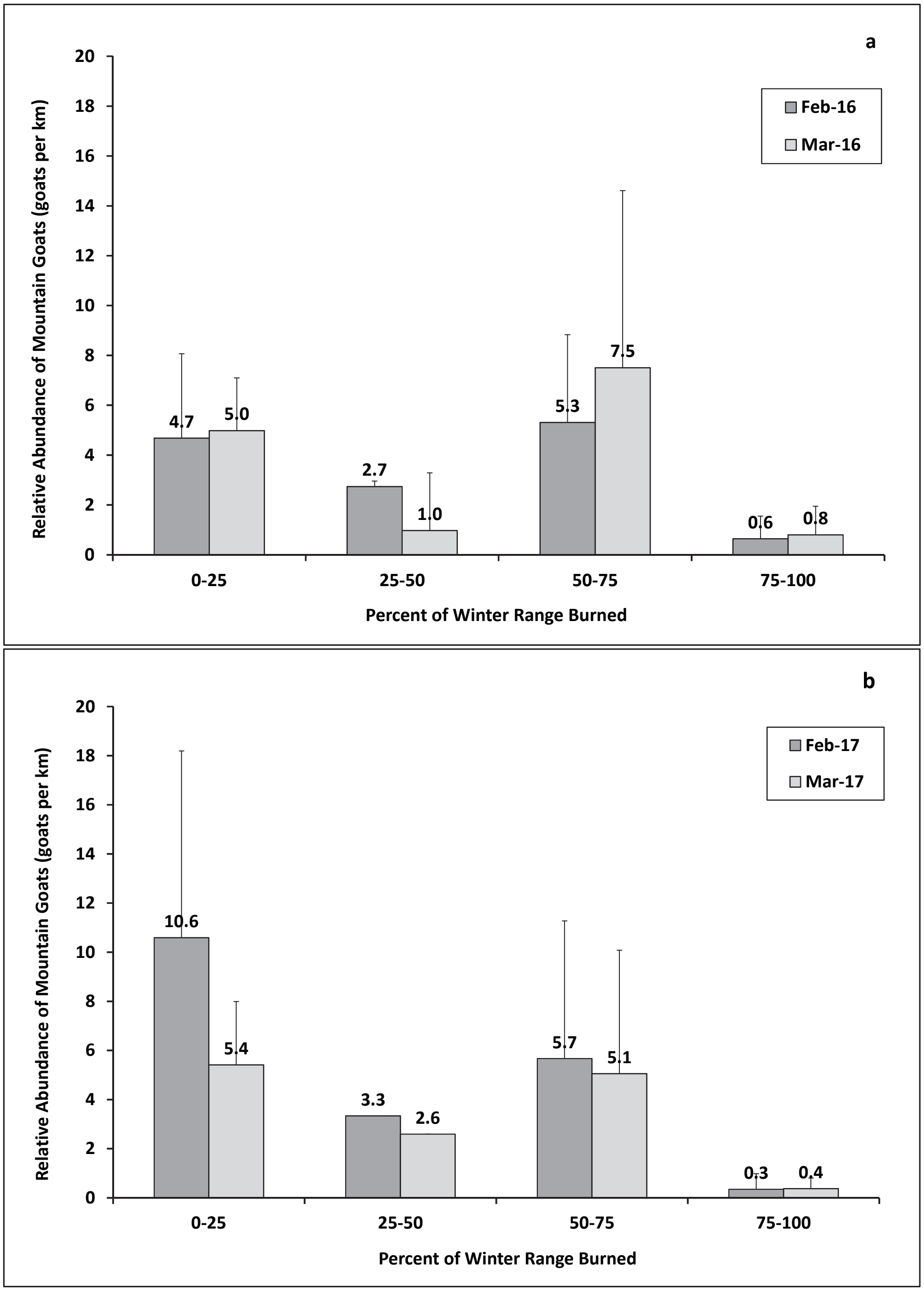

Figure 2. The relative abundance of mountain goats by burn class (percent of winter range burned ± SD) in 2016 (a) and 2017(a).

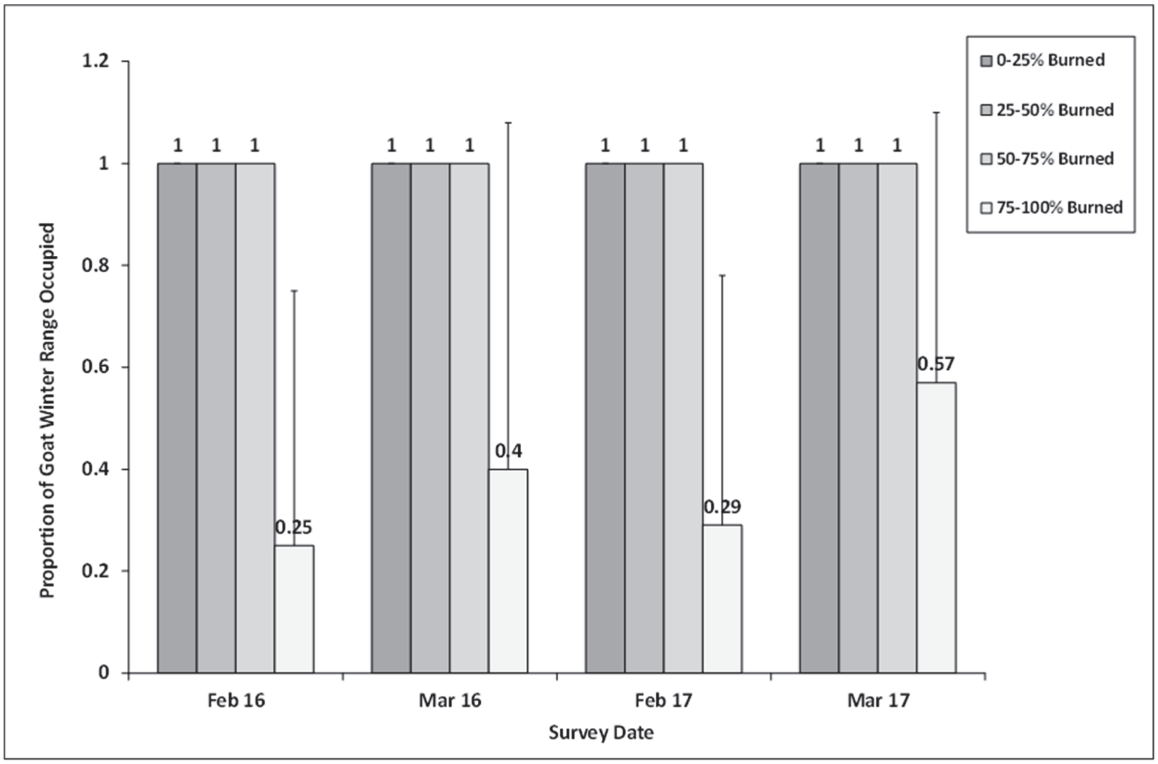

Figure 3. Proportion (± SD) of mountain goat winter ranges occupied by burn class.

DISCUSSION

The extensive fires in 2015 appear to have had a large impact on mountain goat occupancy and abundance affected winter ranges in southwestern British Columbia. Mountain goat winter ranges that were highly impacted by fire (≥75% of the forest area burned) showed 75% lower occupancy and 80% lower relative abundance. We found a positive and significant correlation between residual forest area and the number of mountain goats. Moreover, winter ranges highly impacted by fire were not occupied by goats. In some of these ranges where goats were detected, it was just one set of tracks, and this could have been an individual travelling from one winter range to the next. This is consistent with what is known about coastal mountain goat ecology, where canopy cover is required for snow interception in coastal ecosystems with high snow accumulation on goat winter range habitats. Snow depth can also affect forage availability, as deep snow can limit available forage, and the timing and duration of snow melt also influences the ability of goats to access forage (Hebert and Turnbull 1977, Fox et al. 1989, Wilson 2005).

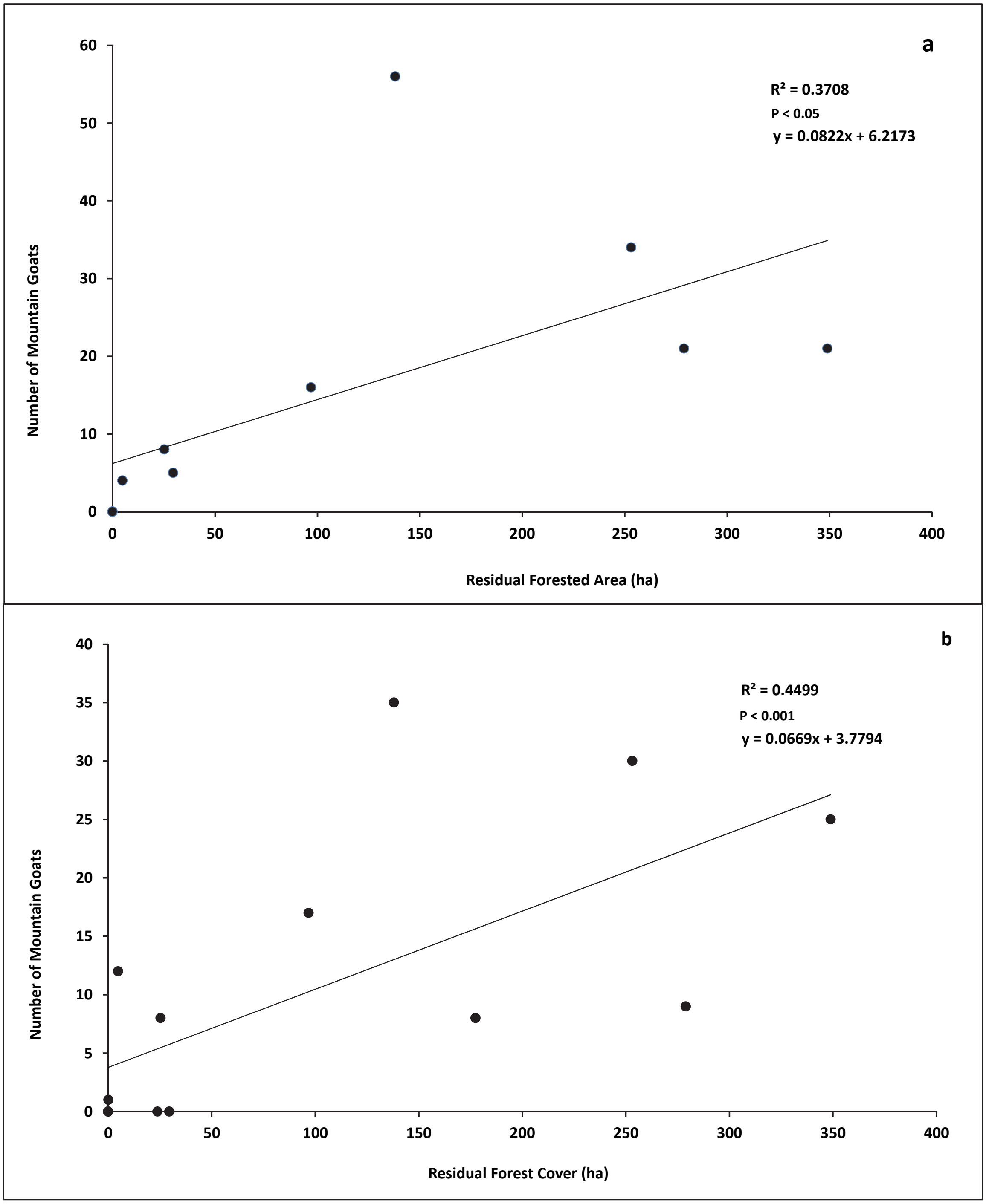

Figure 4. Correlations between the number of mountain goats and the residual forested area (ha) after the fires. Panels a-d represent the 4 survey dates, occurring in February 2016 (a), March 2016 (b), February 2017 (c), and March 2017 (d).

Mountain goats in coastal ecosystems have been shown to use more forested habitat than mountain goats in drier, interior ecosystems. Hebert and Turnball (1977) noted that goats in coastal ecosystems in British Columbia are restricted due to excessive snow depths and use lower elevations with forest cover to

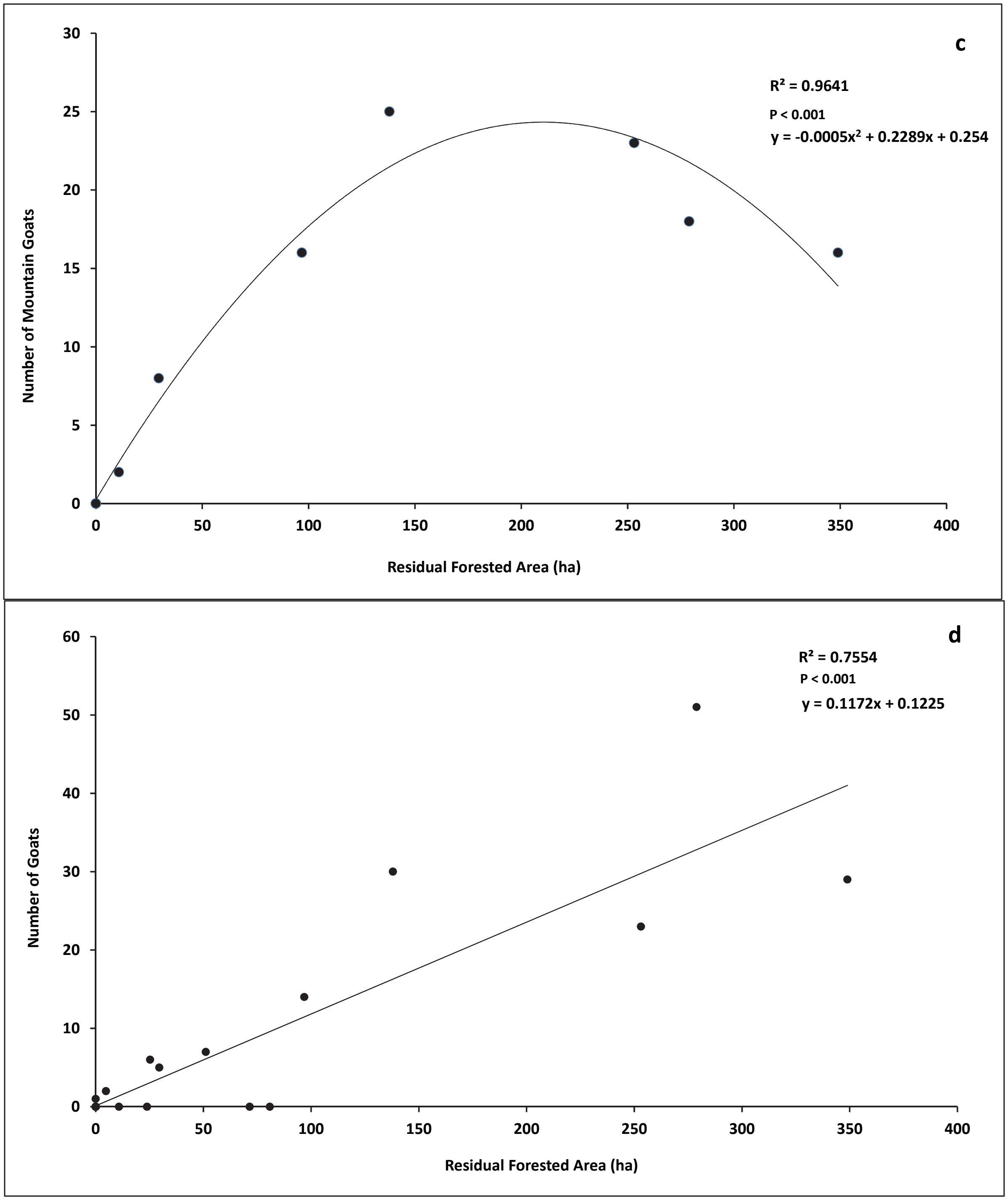

Figure 4 (continued). Correlations between the number of mountain goats and the residual forested area (ha) after the fires. Panels a-d represent the 4 survey dates, occurring in February 2016 (a), March 2016 (b), February 2017 (c), and March 2017 (d).

reduce snow depth. These authors also stated that mountain goats in coastal ecosystems are spatially more restricted and this affects group size due to harsh winter conditions (deep snows and limited cover and forage). Similarly, Fox et al. (1989) found that mountain goats in southeastern Alaska used habitats with old growth coniferous forest in lower elevations adjacent to steep escape terrain. These authors stated that the removal of old growth forest will reduce the forage availability due to the increased snow depth. A study in southeastern Alaska by White et al. (2012) confirmed that 95% of mountain goats monitored with GPS collars wintered in low elevation forested habitats.

We found that the number of mountain goats declined significantly with a decrease in forest area size. We suspect that as forest area on goat winter ranges decreases, the ability of a winter range to have higher densities of goats will also decrease due to lack of space and suitable forage in close proximity to escape terrain (Fox et al. 1989). We found some evidence where mountain goats could have possibly moved to adjacent unburned goat winter range, based on the substantial increase in the number of goats we observed. However, since we did not have any mountain goats radio collared in these study areas before the fires and we did not sample all of the winter ranges, it is unclear whether or not goats shifted their use to different winter ranges, or these goats had perished in the fires.

MANAGEMENT IMPLICATIONS

Mountain goats are restricted in their habitat use due to their need for steep and rugged escape terrain for predator avoidance. In coastal ecosystems, goats are further restricted by their winter requirements of old growth forested areas adjacent to escape terrain for snow interception and forage. The loss of this forest cover through fire appears to have disproportional impacts to mountain goats in these ecosystems, as patch size decreases this will decrease the number of goats a winter range can support, similar to a pattern observed for other species (e.g., Bender et al. 1998). To prevent further burning of these winter ranges, areas most susceptible to burning should be identified and if possible, apply aggressive firefighting practices to ranges that are burning.

It is unclear how mountain goats in the study areas use these burned areas during the summer months when snow is not limiting. Long-term population monitoring of these winter ranges and burned areas, combined with collaring a subset of mountain goats with GPS collars is required to evaluate seasonal habitat use and to understand the full impacts of the impacts of wildfires on mountain goat habitat use, seasonal movements, and long-term population trends.

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APPENDIX 1: MOUNTAIN GOAT WINTER RANGE (GWR) SIZE (HA), FOREST AREA PRIOR TO BURN (HA), PERCENT AREA BURNED (OBSERVED), AND FOREST AREA (HA) AFTER BURN

GWR # / Site #	GWR Size (ha)	Forest Area (ha) Prior to Burn	Percent Area Burned (Observed)	Forest Area (ha) After Burn
Elaho Study Area				
Shovelnose / 07	666.0	349.0	0	349.0
30	420.9	177.4	0	177.4
31	253.6	96.2	0	96.2
26	387.3	203.6	0	203.6
58	578.4	178.8	60	71.5
57	282.1	92.7	50	46.4
41	139.9	97.5	100	0.0
56	52.5	21.4	100	0.0
39	144.1	104.4	100	0.0
25	860.5	85.2	40	51.1
40	191.9	54.1	80	10.8
66	104	80.9	0	80.9
Clendenning Park[1]	NA	NA	65	NA
Roe Creek[1]	NA	NA	0	NA
MEAN	*340.1 ± 250.9*	*128.4 ± 87.5*	*44.2 ± 43.4*	*90.6 ± 105.3*
Upper Lillooet Study Area				
ME 3	1,410.8	184.0	25	138.0
ME 2	75.5	63.2	60	25.3
ME 4	357.6	5.0	5	4.8
UL10	307.1	23.8	0	23.8
UL11	40.8	29.5	0	29.5
UL12	150.8	91.5	100	0.0
UL13	156.8	42.4	100	0.0
UL8	353.8	253.1	0	253.1
UL19	165.8	15.4	99	0.154
RA7	1,121.4	281.8	1	278.9
Petersen Crk / RY8	719.7	96.8	0	96.8
MEAN	*441.8 ± 452.6*	*128.4 ± 87.5*	*35.4 ± 45.0*	*77.3 ± 103.3*

[1]Not a legally designated GWR