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THE IMPACTS OF WILDFIRE ON THE FUNCTIONING AND EFFECTIVENESS OF MOUNTAIN GOAT WINTER RANGES IN COASTAL AND COASTAL-TRANSITIONAL ECOSYSTEMS: A Five-Year Post-Fire Evaluation

PREPARED BY:
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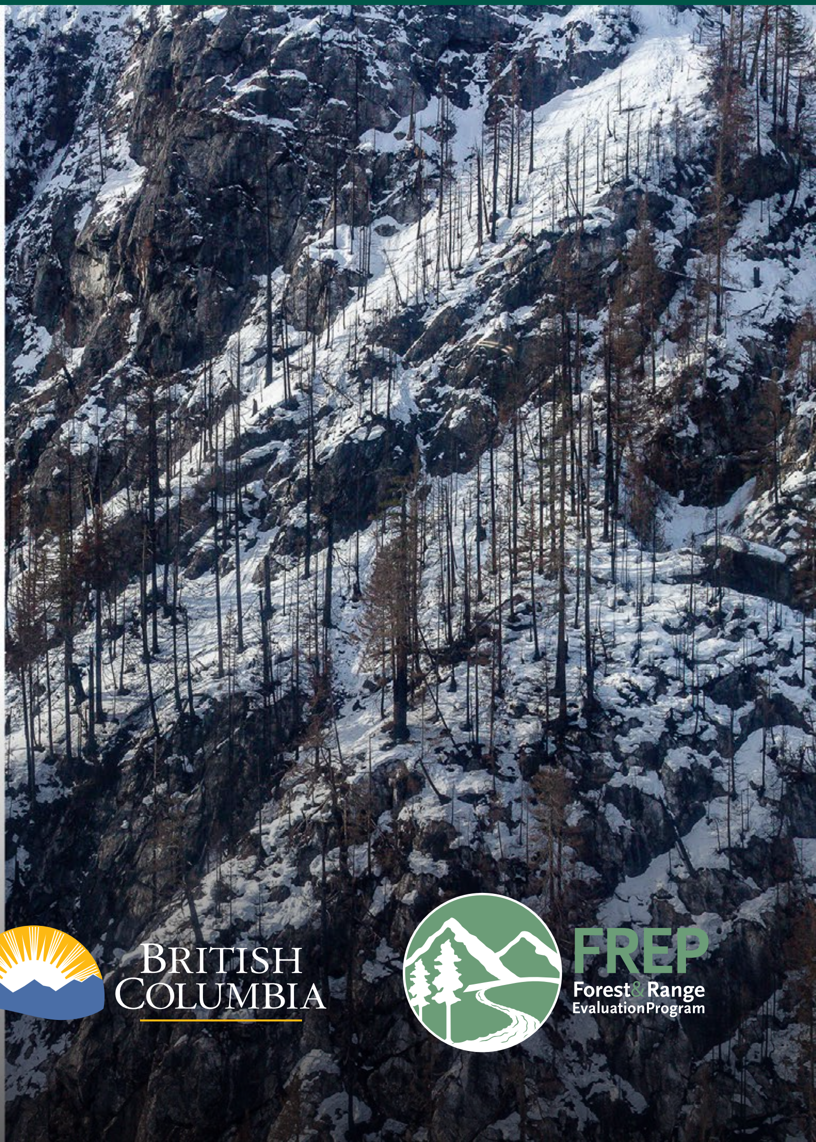

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This report is dedicated to Steve Rochetta who unfortunately passed away in November 2024 before the publication of this report.

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EXECUTIVE SUMMARY

Over half of the world's population of mountain goats (*Oreamnos americanus*) occur in British Columbia, and the province has a global responsibility for the conservation of this species. Mountain goats are particularly vulnerable during the winter months, when deep snow restricts their movements and distribution, especially in coastal environments. While the effects of disturbance on mountain goats resulting from such activities as helicopter use have been studied, the impacts of large-scale landscape perturbations, such as wildfires, is only just emerging.

During the summer of 2015, significant wildfires occurred in the Sea to Sky Natural Resource District, specifically in the Elaho and Upper Lillooet areas. As a result of these wildfires, several mountain goat winter ranges (MGWRs) were burned to varying degrees. There is a concern that these fires will significantly affect 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.

As part of the Forest Range and Evaluation Program (FREP), these burned MGWRs were evaluated for their functioning and effectiveness five years post-fire. The MGWRs were rated for their effectiveness and/or functioning using the following four categories:

1. Effective or Functioning
2. Functioning But at Risk
3. Functioning But at High Risk
4. Not Effective or Non-Functioning

In 2016, 2017, and 2021, a total of 25 individual MGWRs were surveyed in February and March. Of the 25 MGWRs, 13 were sampled in the Elaho study area, and 12 were sampled in the Upper Lillooet study area. In the Elaho study area, eight MGWRs were burned by wildfire (treatment), and five were unburned (control). In the Upper Lillooet study area, five MGWRs were burned by wildfire (treatment), and seven MGWRs were unburned (control). The observed percent burned is similar between the two areas, with the Elaho averaging 40.0%, and the Upper Lillooet averaging 35.4%. The residual forest patch size (polygon of forest cover remaining after the burn) is also similar between the two areas (98.4 and 114.8 ha, respectively). Burn severity ranged from medium-low to high in the Elaho and from low-medium to high in the Upper Lillooet.

Trends in mountain goat abundance using both the linear density (goats per km; *LD*) and count data for the Elaho study area show a statistically significant decline in the abundance metric from 62.5% to 37.9% between 2016 and 2021. Trends in mountain goat abundance in the Upper Lillooet show a general increase in both the *LD* and count data. Survey data from February and March in the Upper Lillooet indicate an increase in the *LD* from 5.5% to 30.1% between 2016 and 2021, with the increase observed in the March survey being statistically significant. Trends in the kid:adult ratios indicates that the Upper Lillooet has nearly double the proportion of kids versus the Elaho. Detection probabilities in the Elaho were lower in 2021 in all burn categories. For MGWRs that were sampled in all three years, detection probabilities in 2021 were half of previous years for the 50-75% and 75-100% burn categories. In the Upper Lillooet study area, there were no changes in the detection probabilities from 2016 to 2021.

In the Elaho study area, approximately 33% or more of the MGWRs were considered not effective or non-functioning, while approximately 27% of the MGWRs in the Upper Lillooet were considered not effective or non-functioning. This is primarily due to the elimination of >80% of the forested area within the MGWRs.

Overall, the abundance of mountain goats correlates strongly with residual forest patch size, meaning that as forested area within the MGWR decreases, so does the abundance of mountain goats. Monitoring methods for coastal mountain goats used by Nietvelt (2023) to quantify changes in abundance proved to be a robust way of examining these data, and in this case, habitat changes due to wildfire.

While post-fire reforestation via planting has been implemented in areas adjacent to the burned MGWRs, planting within the upper elevations of the MGWRs has not occurred. Natural regeneration within the MGWRs will need to be evaluated to determine if planting is required.

INTRODUCTION

Mountain goats (*Oreamnos americanus*) are present in most of the high mountain ranges of British Columbia (BC) (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; Festa-Bianchet and Côté 2008). Mountain goats are a blue-listed species, meaning that they are particularly sensitive or vulnerable to human activities such as helicopter disturbance (Côté 1996; Goldstein et al. 2005; Côté et al. 2013), industrial activities (Penner 1988), natural events such as wildfires and avalanches (Smith 1986; Nietvelt et al. 2018; Nietvelt et al. 2022; White et al. 2024), hunting (Hamel et al. 2006), climate-linked factors (White et al. 2024), and disease and parasites (Blanchong et al. 2018).

Mountain goats are vulnerable during the winter months, as deep snow restricts their movements and distribution, especially in coastal environments (Dailey and Hobbs 1989; Wilson 2005). Mountain goats in coastal ecosystems are commonly 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 (Gordon and Reynolds 2000; Taylor et al. 2006; Taylor and Brunt 2007; Nietvelt et al. 2022).

Changes to forest harvest regulations under the *Forest Practices Code of British Columbia Act* (FPC) and the *Forest and Range Practices Act* (FRPA) enabled the management of non-timber resource values such as ungulate winter ranges (UWRs). Ungulate winter ranges are defined as areas that contain habitat necessary to meet the winter habitat requirements of an ungulate species to ensure the survival and persistence of the species. Ungulate winter ranges established under the FPC and the Government Actions Regulation (GAR) of FRPA provide a legal mechanism for protecting these areas from timber harvesting and associated activities.

As part of FRPA, the Forest and Range Evaluation Program (FREP) supports the sustainable management of British Columbia's forest and range resources by monitoring and evaluating the condition of resource values and the effectiveness of resource practices in managing those resources. Under FRPA and FREP, managing the wildlife resource value involves monitoring UWRs and wildlife habitat areas (WHAs), and this monitoring is species specific (Erikson et al. 2009; Paige and Darling 2009). The FREP priority evaluation question for the wildlife resource value is:

> *Do ungulate winter ranges and wildlife habitat areas maintain the habitats, structures and functions necessary to meet the goals of the area and is the amount, quality and distribution of these areas contributing effectively with the surrounding land base (including protected areas and managed land base) to ensure the survival of the species now and over time?*

Effectiveness monitoring of UWRs and WHAs is crucial as these habitat designations have specific orders with a series of general wildlife measures (GWMs). Moreover, within an order it is not uncommon that these designations have different GWMs such as 100% retention (i.e., no forest harvest) versus conditional forest harvest. Once established, these designations need to be monitored and evaluated to ensure they are functioning in terms of habitat condition and species use and abundance (Erikson et al. 2009; Paige and Darling 2009). Changes to habitat condition need not be related to forest harvesting under FREP, as all disturbance, both natural and human, needs to be considered for any effectiveness evaluation (Paige and Darling 2009).

Erikson et al. (2009) outlined tools and approaches for evaluating the effectiveness of UWRs and WHAs using various types of disturbance indicators (factors), including catastrophic fires. The following four categories are taken and modified from Erikson et al. (2009) to describe whether a WHA or UWR is effective and/or functioning:

1. Effective or Functioning
2. Functioning But at Risk
3. Functioning But at High Risk
4. Not Effective or Non-Functioning

While these categories are well thought out and provide a qualitative ranking based on quantitative criteria, they have not been applied broadly to the evaluation of the effectiveness of UWRs and WHAs. Wilson (2012) created a conceptual model for mountain goat population dynamics illustrating the interaction of goats to habitat features. While informative, Wilson (2012) did not address the potential impacts of forest removal, either from harvest or fire, on mountain goats in a coastal ecosystem, but rather focused on fire suppression (Figure 1).

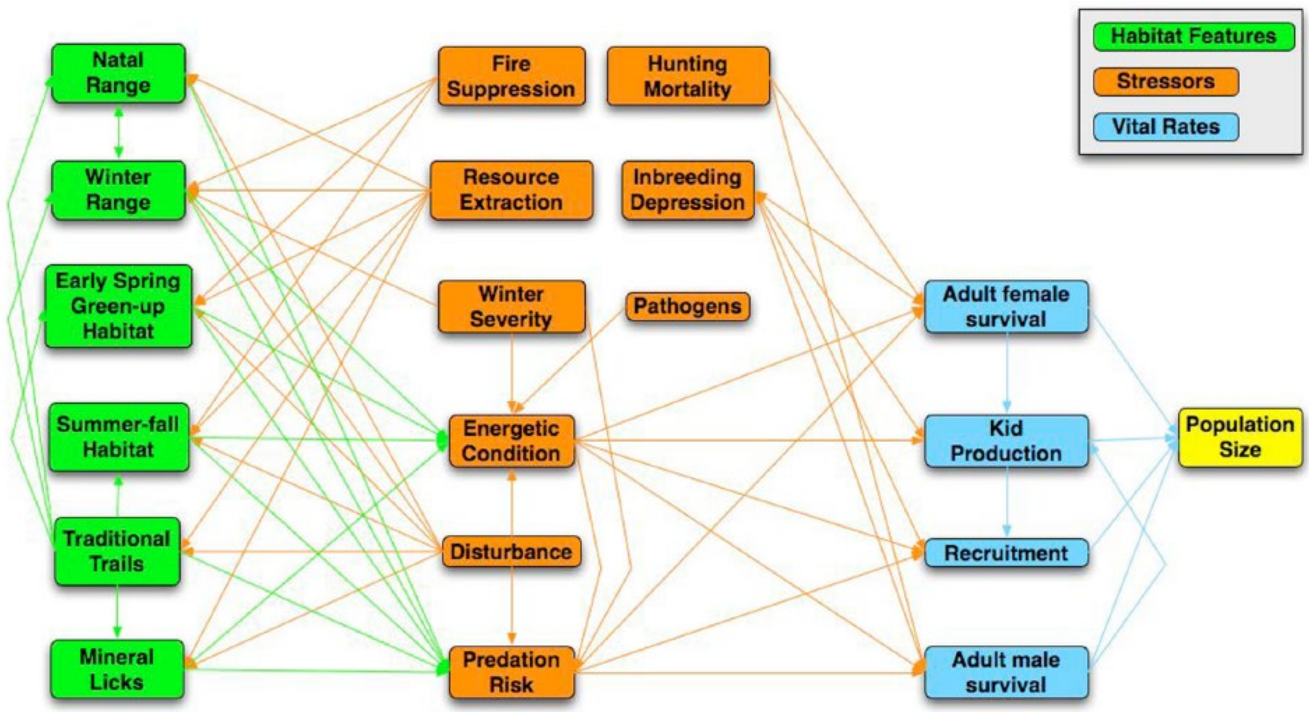

Figure 1. *A conceptual model of mountain goat population dynamics taken from Wilson (2012).*

While the effects of wildfire are well documented with ungulate species, such as mule deer ([*Odocoileus hemionus*]; e.g., Bristow et al. 2020) and elk ([*Cervus canadensis*]; e.g., Spitz et al. 2018), little is known about the effects of wildfire on mountain goats (Rolf and Lockard 1983). The BC Provincial Mountain Goat Plan (Mountain Goat Management Team 2010) states, *"little is known about whether mountain goats respond numerically or spatially to prescribed fire. There are many opportunities throughout the province to study this relationship with wildfire or, if an opportunity exists, with prescribed fire."*

During the summer of 2015, significant and catastrophic wildfires occurred in the Elaho and Upper Lillooet areas (Nietvelt et al. 2018). As a result of these fires, several mountain goat winter ranges (MGWRs) burned to varying degrees. Nietvelt et al. (2018) did a preliminary analysis on the impacts of these fires on the MGWR habitat and mountain goat abundance. These authors found that MGWRs with ≥75% of the forest area burned were 75% less likely to be occupied and contained ≥80% fewer individuals. These declines in mountain goats on the winter ranges were attributed to the elimination of mature trees that provide both snow interception and forage (e.g., arboreal lichen). Figure 2 illustrates the importance of mature trees to mountain goats in a coastal ecosystem.

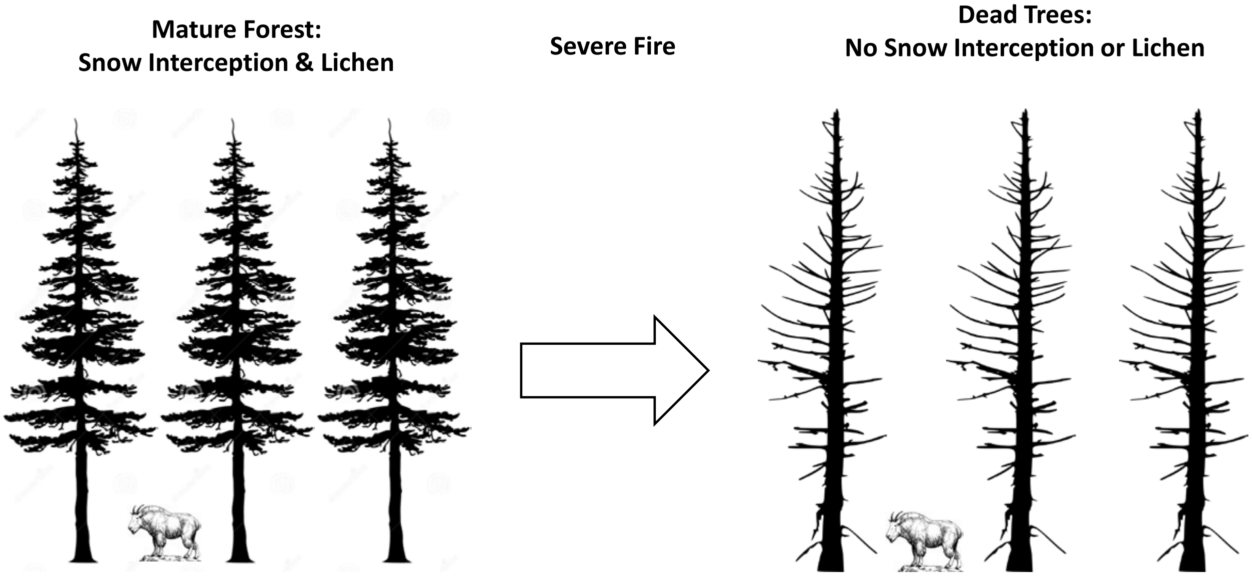

Figure 2. *An infographic illustrating the importance of mature forest as a source of snow interception and winter forage versus a severely burned forest with no snow interception or winter forage.*

In February and March of 2021, these MGWRs were resurveyed using the same methods as Nietvelt et al. (2018) in both the Elaho and Upper Lillooet study areas. As it had been just over five years since the 2015 fires (and initial follow-up surveys in 2016 and 2017), it was an opportunity to continue monitoring these MGWRs for trends in mountain goat use and abundance over the long-term in five-year intervals to evaluate effectiveness and functioning. For this analysis, methods for quantifying abundance, use, and habitat alteration followed Nietvelt et al. (2018) and Nietvelt (2023). This analysis also implemented the effectiveness and functioning criteria proposed by Erikson et al. (2009) which allows for a more through evaluation of whether a winter range is effective and functional with quantifiable criteria at different scales.

The objectives of this effectiveness evaluation are five-fold:

1. Resample the MGWRs assessed by Nietvelt et al. (2018) as part of an approximate five-year monitoring interval using a subset of burned (treatment; gradient in percent of trees burned) and unburned (control) MGWRs.
2. Examine trends in mountain goat abundance from 2016 to 2021 in two areas (Elaho and Upper Lillooet) in the South Coast that experienced catastrophic fires using methods developed by Nietvelt (2023).
3. Relate the abundance of mountain goats to the residual tree patch size in each MGWR as per Nietvelt et al. (2018) and Nietvelt (2023) to create predictions in abundance.
4. Use these data on trends in abundance, expected abundance on MGWRs, and impacts to the habitat to classify the effectiveness and functioning of each MGWR sampled and use these empirical criteria for future monitoring and evaluations.
5. Use the results from this evaluation to help refine a standardized approach to evaluating the effectiveness and functioning of MGWRs in coastal and coastal-transitional ecosystems.

Considering the rapid pace of climate change and the increase of wildfires in British Columbia since the mid-2000s (Parisien et al. 2023), it is important to fill in these data gaps on the short- and long-term impacts of wildfire on wildlife and their habitats to evaluate the potential for reforestation and recovery.

STUDY AREAS

Sampling of the MGWRs occurred in the Elaho River drainage and the Upper Lillooet (Boulder and Meager Creeks) drainage in the Sea to Sky Natural Resource District. Each area experienced significant burns due to wildfires during the summer of 2015. The Elaho burn is approximately 10,459 ha in size, while the Upper Lillooet burn is approximately 5,433 ha in extent (Figure 3).

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[1] (Figure 4). The Elaho study area has a much higher snow water equivalent (SWE) as compared to the Upper Lillooet (>1,000 mm versus 550 mm[2]). The SWE measures the amount of water contained in the snowpack, considering the snow density. For example, if the snowpack melted, the SWE would represent the depth of water that would be produced.[3] As such, the Elaho is more coastally influenced than the Upper Lillooet, which may be considered coastal-transitional.

The MGWRs in the Elaho were legally established in 2007 as part of the TFL 38 ungulate winter range order u-2-007 and encompasses a total of 12,617 hectares. The MGWRs in the Upper Lillooet were legally established in 2003 as part of the SOO TSA ungulate winter range order u-2-002 and encompasses 48,474 hectares.[4]

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1 https://www.for.gov.bc.ca/hre/becweb/
2 https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-science-data/water-data-tools/snow-survey-data
3 https://www.climatehubs.usda.gov/hubs/northwest/topic/snow-water-equivalent-swe-its-importance-northwest
4 https://www.env.gov.bc.ca/wld/frpa/uwr/approved_uwr.html

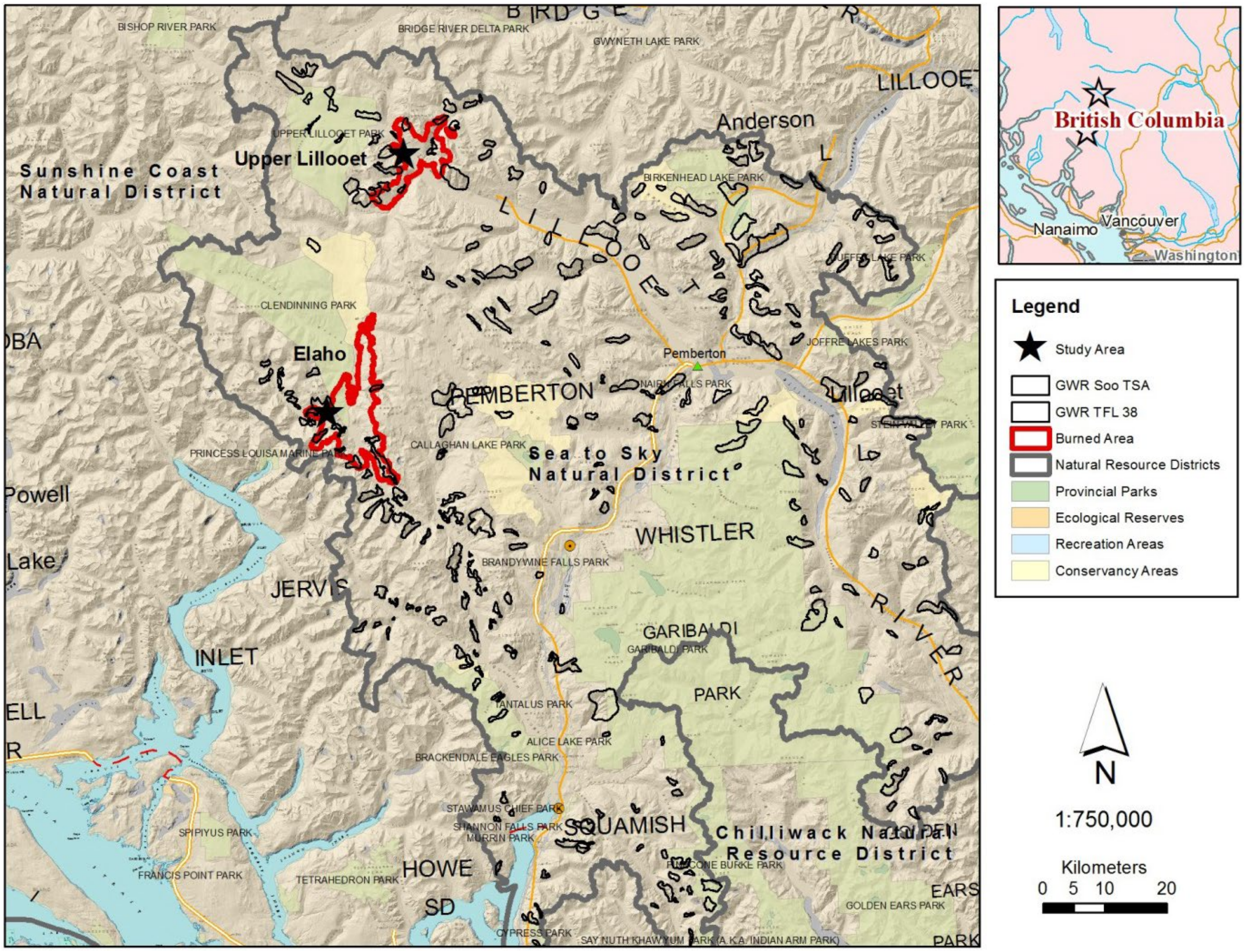

Figure 3. *Study areas: Elaho and Upper Lillooet, Sea to Sky Natural Resource District, South Coast. Note the extent of the burned areas (outlined in red).*

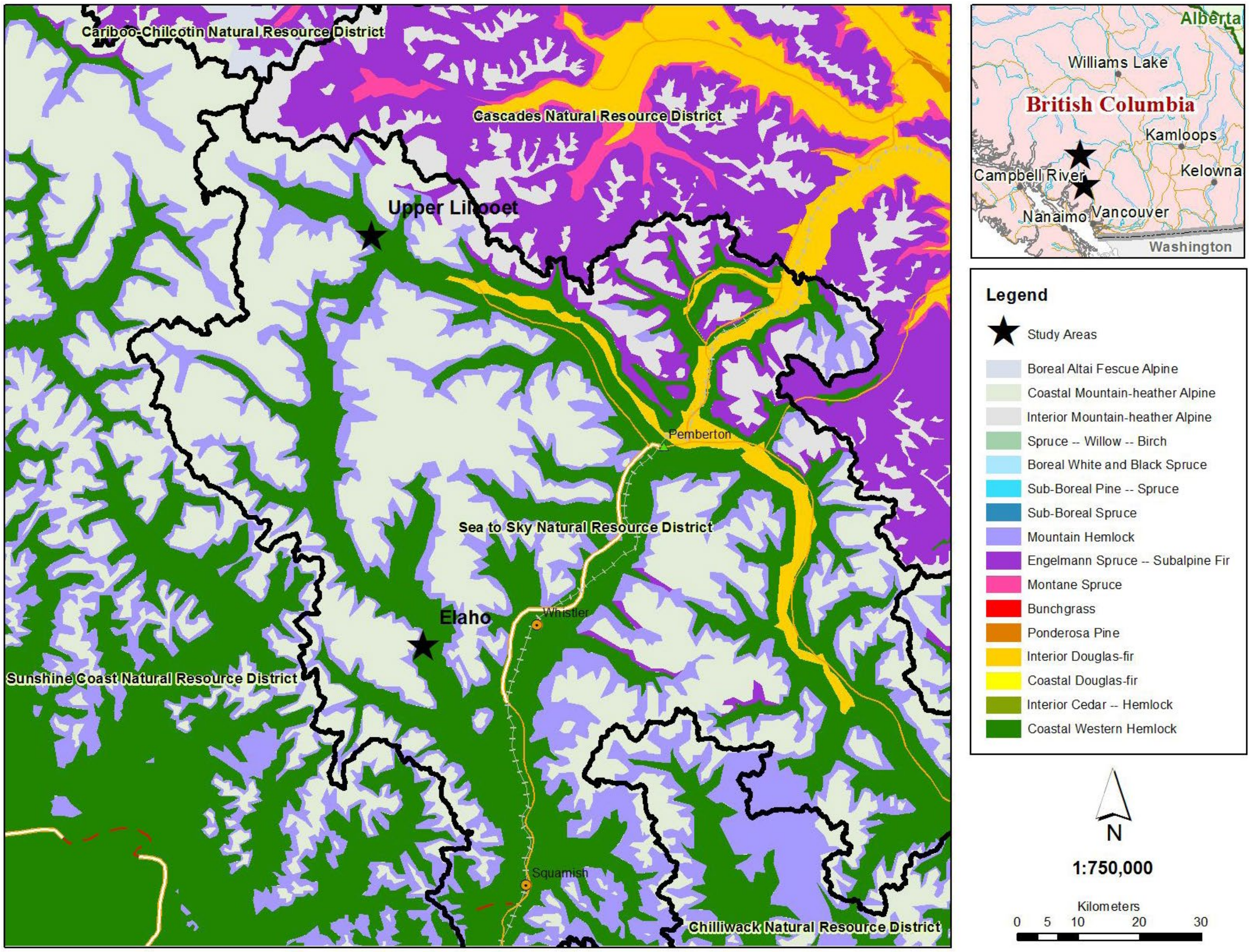

Figure 4. *Biogeoclimatic zones, Sea to Sky Natural Resource District, South Coast.*

METHODS

Data Collection

A subset of mountain goat winter ranges (MGWRs) was sampled in both study areas after the 2015 wildfires. These included MGWRs that were burned by wildfire (treatment) and those considered unburned (≤ 5% burned; control). In the Elaho study area, there were eight MGWRs that were burned (partially or completely) and five unburned (N = 13 total), and in the Upper Lillooet study area, there were five MGWRs that were burned (partially or completely), and seven unburned (N = 12 total).

Each MGWR polygon was visually examined during the inventory flights to assess the extent of the forested area burned (in percent). This was essential as the burn severity estimate (derived from Landsat Thematic Mapper data; see Mountain Goat Abundance Analysis) may not provide an accurate representation of the percent of the forested area burned in each MGWR. The residual forest patch size in hectares (ha) was used as a surrogate for the habitat attributes required by mountain goats in the winter as this terrain is extremely difficult and dangerous to measure on the ground due to the steep nature of the terrain (Taylor and Brunt 2007).

Resource Inventory Standards Committee (RISC) methodology (RISC 2002) was used as a starting point. These methods are reported in Nietvelt et al. (2010), Nietvelt (2012), Nietvelt (2023), and Nietvelt et al. (2018). Two helicopter flights per year were conducted: February and March in 2016, 2017, and 2021. The flights were conducted during mid-day (10:00 to 15:00 hours) when goats and/or tracks are most easily observed. The surveys were conducted approximately 2-3 days after a snowfall, allowing time for tracks to accumulate. This increases the likelihood of detecting goat presence and of identifying the distribution of use among habitat types. An A-Star 350 helicopter was used (not a RISC standard) for all these flights. For navigating to and within the MGWRs, an iPad (© Apple Inc.) preloaded with PDF maps and real-time GPS using Avenza Maps mobile app (http://www.avenza.com/pdf-maps), with waypoints of mountain goat observations (animals or tracks) and flightpaths recorded using a Garmin GPS 60CSx. Paper maps were also used for navigation and as a backup in the event the iPad failed to operate.

As per Nietvelt (2023), when a set or sets of tracks were encountered with or without actual mountain goats visible, the number of track-sets were documented. When mountain goats (actual animals) were observed, individuals were counted and classified by age and sex. Age and sex classification are as follows: adult females, adult males, juveniles (when possible), kids, and/or unknown adult (Smith 1988; Jex 2007b; Nietvelt et al. 2010). This combination of mountain goats plus tracks served as an index of abundance (see Mountain Goat Abundance Analysis; Nietvelt 2023).

Animal welfare during detections was paramount, and an immediate assessment of potential hazards was undertaken. If an animal was determined to be in a precarious location, the helicopter immediately moved away and, at times, this may have affected classification.

Mountain Goat Abundance Analysis

Several metrics were used to quantify mountain goat abundance, use and trend, and how these relate to the impacts of the 2015 fires. A linear density (*LD*) was the primary metric used to quantify mountain goat use of winter ranges and trends in abundance (see Nietvelt et al. 2018; Nietvelt 2023). Linear density is calculated as follows:

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

Where *G* is the total number of goats sighted in winter range *i*, *T* is the number of goat track-sets, and *D* is the distance (km) sampled in winter range *i*. As the sightability of actual mountain goats in each winter range was highly variable and mountain goats are often not sighted, the calculated *LD* integrated both the number of goats seen and the number of tracks and acted as a measure for goat abundance (O'Donoghue et al. 1997; Bayne et al. 2008; Collier et al. 2008; Johnson 2008). Nietvelt (2023) found that the *LD* is a useful metric for examining mountain goat population trends over time as it has lower variance than raw counts and strongly correlates to mountain goat density (goats per km^2). The *LD* compensates for the lack of mountain goats observed by supplementing those observations with counted track-sets and is necessary for surveying smaller geographic areas, in this case, MGWR polygons. Estimating mountain goat abundance is normally measured and evaluated across a larger area such as a region, wildlife management unit (WMU), or population unit (RIC 2002). Inventories over such a large area will miss groups of animals (namely smaller groups), and as such a sightability correction factor is applied to get a better population estimate (e.g., Poole 2007; Rice et al. 2009).

The total observed count of mountain goats on each MGWR were used as another measure of abundance. These counts were not corrected for sightability as there has not been a correction factor developed for winter surveys of mountain goats or at this spatial scale (e.g., Rice et al. 2009). Furthermore, in coastal ecosystems, mountain goats (actual animals) might not be sighted on all winter ranges due to tree canopy cover (Nietvelt et al. 2018; Nietvelt 2023), hence a sightability correction factor would not be useful when measuring abundance on a MGWR scale but can be used on a larger management unit scale such as a WMU (Mountain Goat Management Team 2010).

The kid:adult[5] ratio was calculated to examine differences in recruitment in both study areas, and in some cases a low kid:adult ratio might contribute to a potentially declining population if adult survival is not adequate to maintain a stable or growing population (Hatter and Bergerud 1991; Nietvelt 2023). This ratio is often reported as kids per 100 adults.

As per Nietvelt (2023) mountain goat densities (goats per km^2) were calculated for MGWRs where actual goats were observed (not just tracks). This density calculation used the area of the delineated winter range (in km^2) as the denominator and allowed for a coarse comparison of mountain goat populations between both areas and known densities of goats in coastal ecosystems. The main caveat is that delineated MGWRs do not capture the entire extent of mountain goat habitat, hence the densities reported here are likely higher than what has been reported in previous studies where densities were estimated during the summer months, for example, when mountain goats have larger home ranges (Nietvelt 2023).

[5] Adults include billies, nannies, and juveniles (if counted).

The probability of detecting mountain goats on a winter range was calculated (*Prj*), where detection is binary (detected or not detected: 1 or 0) and is conducted over *j* surveys (MacKenzie et al. 2002). A simple mathematical calculation was performed to calculate the probability of detection for an individual MGWR:

$$Pr_j = \frac{(D_{j1} + D_{j2} \ldots)}{K}$$

Where *Dj* is the detection (1 or 0) per survey (*j*), and *K* is the total number of surveys (in this case flights) in one season (MacKenzie et al. 2002).

Once detection probability (*Prj*) was calculated for a given area, it is classified by the extent of forest cover burned (0-25%, 25-50%, 50-75%, and 75-100%) for each MGWR in both study areas. Trends in detection probabilities were compared temporally within and across both study areas to quantify potential change.

Crude estimates of population trend were calculated using the *LD* and count data. The lambda value, λ, is a measure of the population growth rates. A λ value of 1.0 means the population is stable, <1.0 the population is declining, and >1.0 the population is growing (Snider and Brimlow 2013). To calculate the intrinsic rate of increase, *r*, it is simply:

$$r = ln(\lambda)$$

Voronov (2005) described how to calculate the intrinsic rate of increase of a population on a per capita basis at each instant of time. The intrinsic rate of increase, *r*, and the population growth rate, λ, for this study can be calculated from inventory data (*LD* and count) using the following equations:

$$r = \frac{ln[(N_2/N_1)]}{(t_2 - t_1)}$$

This formula calculates the intrinsic rate of increase, *r* (Voronov 2005). In this equation, *N1* is the initial population at time *t1*, and *N2* is the resultant population at the end of time *t2*. To calculate λ, it is the exponent of *r*:

$$\lambda = exp\ (r)$$

When λ is known, another equation, known as the *R/M* equation, can be used to estimate adult female survivorship, *S* (Hatter and Bergerud 1991). The R/M equation is as follows:

$$\lambda = \frac{S}{1 - R}$$

where *R* is the recruitment (kid:adult ratio), *S* is usually the estimated female goat Kaplan-Meier (K-M) survivorship calculated from the radio collared sample (Kaplan and Meier 1958). The R/M equation can be rearranged to solve for *S*, and for the Elaho and Upper Lillooet, the *S* can be calculated to identify the point at which the population will be stable (i.e., λ = 0). Summer or fall flight data was also used to examine kid:adult ratios in population units where these MGWRs occur to examine whether problems exist with kid productivity versus survivorship, hence recruitment (Festa-Bianchet et al. 1994; Nietvelt 2023).

Power analysis was used to estimate the sample size needed at a specified probability (power = 1 – β) to determine (at the α level) if there is a significant difference or effect (effect size; Gerrodette 1987; Johnson 1999). The power analysis was performed using winter flight data to find the statistical power at the given number of winter ranges and known population variance (note: the sample unit is a series of MGWRs in a predefined area; Nietvelt 2023). The results of the power analysis from the 2016 and 2017 surveys were used to determine whether trends (increasing or decreasing) in mountain goat abundance (*LD*) had enough power to detect an actual increase or decrease. This was done at a significance level of 80% and 90% (α = 0.20 and 0.10 or an 80% and 90% chance of detecting an effect). Adequate power should at least be 0.80 and 0.90 for 80% and 90% significance levels, respectively (Schieck 2002). It is important to understand the limitations of these data when quantifying changes in the observed and estimated mountain goat use of winter ranges through time, hence a power analysis is crucial (Cohen 1988; Thomas and Krebs 1997; Schieck 2002; Herbers et al. 2007; Nielsen et al. 2009). The power analysis was performed using the package *pwr* in R (R Core Team 2024: https://cran.r-project.org/web/packages/pwr/pwr.pdf).

Related to the power analysis is the coefficient of variation (*CV*), a statistical measure of the relative dispersion of data points in a data series around the mean (Patel et al. 2001). The *CV* is a ratio of the standard deviation (σ) and the mean (μ) and standardized as a percent, meaning that variances from different values can be compared. The *CV* is calculated as follows as a percent:

$$CV = \left(\frac{\sigma}{\mu}\right) \times 100$$

Therefore, the higher the *CV*, the greater the variance in these data. The *CV* was calculated for each survey averaging the *LD* for all MGWRs in the survey as well as repeated surveys of an individual MGWR.

Burn Severity

Burned Area Reflectance Classification (BARC) is a satellite-derived map of post-fire vegetation condition (Hudak et al. 2004; Keeley 2009) and was used to classify burn severity after the 2015 burns.

Burn severity was classified into four categories:

- *Unchanged*: the area after the fire was indistinguishable from pre-fire conditions. This does not always indicate the area did not burn.
- *Low*: areas of surface fire with little change in cover[6] and little change in cover and mortality of the dominant vegetation.
- *Moderate*: a mixture of effects on the dominant vegetation between low and high.
- *High*: areas where the canopy has high to complete consumption.

As mentioned previously in the Data Collection section, residual patch size was estimated visually during the inventory flights where the percent of the MGWR burned was estimated. The forested area (hectares) of the MGWR prior to the burn was estimated using the Vegetation Resources Inventories (VRI)[7] layer from the BC Data Warehouse. To calculate residual patch size, the calculation is simply,

Residual Patch Size = Forest Area Before X Proportion of Forest Burned

[6] Cover = tree cover in this case.
[7] https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-inventory

Mountain Goat Abundance and Habitat Relationships

As demonstrated by Nietvelt et al. (2018) and Nietvelt (2023), there is a strong correlation between forest patch size and abundance. One factor that was not considered was the amount of escape terrain in each MGWR, and how this might be an additional variable to predict mountain goat abundance using these inventory data. Escape terrain is defined as steep slopes (>40°) on warm aspects (135° to 285°; e.g., Lele and Keim 2006; Nietvelt et al. 2022). Slope and aspect were calculated from the digital elevation model (DEM), reclassified to slopes >40° and aspects from 135° to 285°, exported to vector files, then intersected in ArcMap (©ESRI). The area (ha) of the escape terrain was calculated in each MGWR.

The number of mountain goats (raw counts) and the *LD* was regressed (linear) against forest patch size as well as forest patch size + escape terrain area in both study areas in all years. For the regression, the intercept was set at zero since the lowest measure of abundance on a MGWR or a population is zero and not a negative value (cannot have a population less than zero). The regression equations are as follows:

$$Y = b_1 X_1$$

and

$$Y = b_1 X_1 + b_2 X_2$$

The dependent variable, Y, would be either the number of mountain goats or the *LD*, X_1 is the residual forest patch size, X_2 is the escape terrain area, and b_1 and b_2 are the estimated regression coefficients. The regression analysis was calculated in R using the function *lm* (R Core Team 2024). These regression equations were used to calculate the expected mountain goat abundance (*LD* and number of mountain goats) *prior* to the wildfires in each MGWR as adequate baseline data were not available.

Evaluation of MGWR Effectiveness

Erikson et al. (2009) outlined approaches for effectiveness evaluations on wildlife for ungulate winter ranges (UWRs) and wildlife habitat areas (WHAs). These authors identified several indicators (factors) to evaluate the effectiveness of UWRs and WHAs, which included various types of disturbance (e.g., catastrophic fires). Erikson et al. (2009) defined whether a WHA or UWR was effective or functioning using the following criteria which were adopted and modified for this analysis:

Effective or Functioning:

a) Habitat conditions within the UWR/WHA are likely to remain suitable/stable or possibly improve.

b) Key habitat features will likely be maintained in abundance.

c) The UWR/WHA continues to be used by species and populations appear stable.

d) The WHA is likely to withstand changes from all but catastrophic events.

Functioning But at Risk:

a) Habitat conditions within the UWR/WHA may be stable or result in short-term population declines.

b) Key habitat elements may be limiting productivity.

c) The UWR/WHA may not withstand disturbances.

Functioning But at High Risk:

a) Habitat conditions within or surrounding the UWR/WHA are likely to result in a population decline.

b) Key habitat elements are limiting productivity.

c) The UWR/WHA is unlikely to withstand disturbances.

Not Effective or Non-Functioning:

a) Habitat conditions within or surrounding the UWR/WHA are likely resulting in significant population declines.

b) The species will likely be extirpated from the UWR/WHA.

c) The UWR/WHA is acting as a population sink.

d) Successful immigration is unlikely.

Each MGWR was evaluated using several criteria outlined by Erikson et al. (2009) and the analyses described above. Each study area was also evaluated based on whether the MGWRs overall were considered currently functioning or effective. The metrics in Table 1 were applied to both study areas and each MGWR individually.

Table 1. *Metrics used to evaluate MGWR effectiveness and function*

Indicator	Metric	Spatial Scale	Temporal Scale
Mountain Goat Abundance	• *LD* trend (λ and *r*) and statistical power (1-β) • Count data trend (λ and *r*) • Detection probability	• Study Area and Individual MGWR	• More Than One Survey Year
Mountain Goat Abundance	• Expected versus observed abundance (*LD*) and number of mountain goats in each MGWR derived from a regression equation • Mountain goat densities, goats per km^2	• Individual MGWR	• Single Year or Multi-Year
Population Characteristics	• Kid:adult ratios • Ratios can be used in trend analysis	• Study Area	• Single Year or Multi-Year
MGWR Habitat Condition	• Percent of trees in the MGWR burned • Residual forest patch size (ha) within the MGWR, pre- and post-fire	• Study Area and Individual MGWR	• Single Year or Multi-Year

RESULTS

In 2016, 2017, and 2021 a total of 25 individual MGWRs were surveyed in February and March (Tables 2 to 4). Of the 25 MGWRs, 13 were sampled in the Elaho study area and 12 were sampled in the Upper Lillooet study area. In the Elaho study area, eight MGWRs were burned by wildfire (treatment), and five were unburned (control; Table 2). In the Upper Lillooet study area, five MGWRs were burned by wildfire (treatment), and seven MGWRs were unburned (control).

The percentage of the winter range burned varied from zero to 100% in both study areas (Tables 2 to 4). The observed percent burned is similar between the two areas, with the Elaho averaging 40.0% and the Upper Lillooet averaging 35.4% (Tables 3 and 4). Residual forest patch size (polygon forest cover after burn) is also similar between the two areas (98.4 and 114.8 ha, respectively). Burn severity ranged from medium-low to high in the Elaho and from low-medium to high in the Upper Lillooet (Table 2, Figures 5 and 6).

***Table 2.** MGWRs sampled by group (treatment or control) for both Elaho and Upper Lillooet study areas*

Elaho			
UWR Unit No.	**% Burned (Observed)**	**Burn Severity**	**Group**
7	0	NA	Control
30	0	NA	Control
31	0	NA	Control
26	0	NA	Control
58	60	Medium	Treatment
57	50	Medium-High	Treatment
41	100	High	Treatment
56	100	High	Treatment
39	100	High-Medium	Treatment
25	40	Medium-High	Treatment
40	80	Medium-High	Treatment
66	0	NA	Control
Clendenning Park	65	Medium-Low	Treatment
Total			**Treatment = 8, Control = 5 N = 13**
Upper Lillooet			
UWR Unit No.	**% Burned (observed)**	**Burn Severity**	**Group**
ME 3	25	Medium-Low	Treatment
ME 2	60	Medium-High	Treatment
ME 4	5	NA	Control
UL8	0	NA	Control
UL10	0	NA	Control
UL11	0	NA	Control
UL12	100	Low-Medium	Treatment
UL13	100	High-Medium	Treatment
UL19	99	Medium-High	Treatment
RA7	1	NA	Control
RY8	0	NA	Control
RY2	0	NA	Control
Total			**Treatment = 5, Control = 7 N = 12**

Table 3. MGWRs sampled (X) in the Elaho and forest cover before and after the 2015 fires (mean ± SD)

UWR Unit No.	Forest Cover (ha) Prior to Burn	% Burned (Observed)	Polygon Forest Cover (ha) After Burn	Polygon Size (ha)	UWR Sampled (X)					
					2016 Feb	2016 Mar	2017 Feb	2017 Mar	2021 Feb	2021 Mar
7	349.0	0	349.0	666.0	X	X	X	X	X	X
30	177.4	0	177.4	420.1	X	X	-	X	X	X
31	96.2	0	96.2	253.6	X	X	X	-	-	X
26	203.6	0	203.6	387.3	X	X	X	X	X	X
58	178.8	60	71.5	579.0	X	X	X	X	X	X
57	92.7	50	46.4	282.1	X	X	X	-	-	-
41	97.5	100	0	139.9	X	X	X	X	X	X
56	21.4	100	0	52.5	X	-	X	X	X	X
39	104.4	100	0	144.1	X	-	X	X	X	X
25	85.2	40	51.1	860.5	X	X	X	X	X	X
40	54.1	80	10.8	191.9	X	X	X	X	X	X
66	80.9	0	80.9	104.0	-	X	X	X	X	X
Clendenning Park	NA	65	NA	NA	X	-	X	-	X	X
Mean / Total	**129.0 ± 87.2**	**40.0 ± 45.1**	**98.4 ± 105.2**	**324.7 ± 260.2**	**12**	**10**	**12**	**10**	**11**	**12**

Table 4. MGWRs sampled (X) in the Upper Lillooet and forest cover before and after the 2015 fires (mean ± SD)

UWR Unit No.	Forest Cover (ha) Prior to Burn	% Burned (Observed)	Polygon Forest Cover (ha) After Burn	Polygon Size (ha)	UWR Sampled (X)					
					2016 Feb	2016 Mar	2017 Feb	2017 Mar	2021 Feb	2021 Mar
ME 3	184.0	25	138.0	1,410.8	X	X	X	X	X	X
ME 2	63.2	60	25.3	75.5	X	X	X	X	X	X
ME 4	5.0	5	4.8	357.6	X	X	X	X	X	X
UL8	253.1	0	253.1	353.8	X	X	X	X	X	X
UL10	23.8	0	23.8	307.1	X	X	X	X	X	X
UL11	29.5	0	29.5	40.8	X	X	X	X	X	X
UL12	91.5	100	0.0	150.8	-	X	X	X	X	X
UL13	42.4	100	0.0	156.8	-	X	X	X	X	X
UL19	15.4	99	0.15	165.8	-	X	X	X	X	X
RA7	281.8	1	278.9	1,121.4	X	X	X	X	X	X
RY8	96.8	0	96.8	719.7	X	-	X	X	X	X
RY2	527.3	0	527.3	762.8	-	-	-	-	-	X
Mean / Total	**134.3±154.8**	**35.4 ±**	**114.8±163.0**	**468.6±441.3**	**8**	**10**	**11**	**11**	**11**	**12**

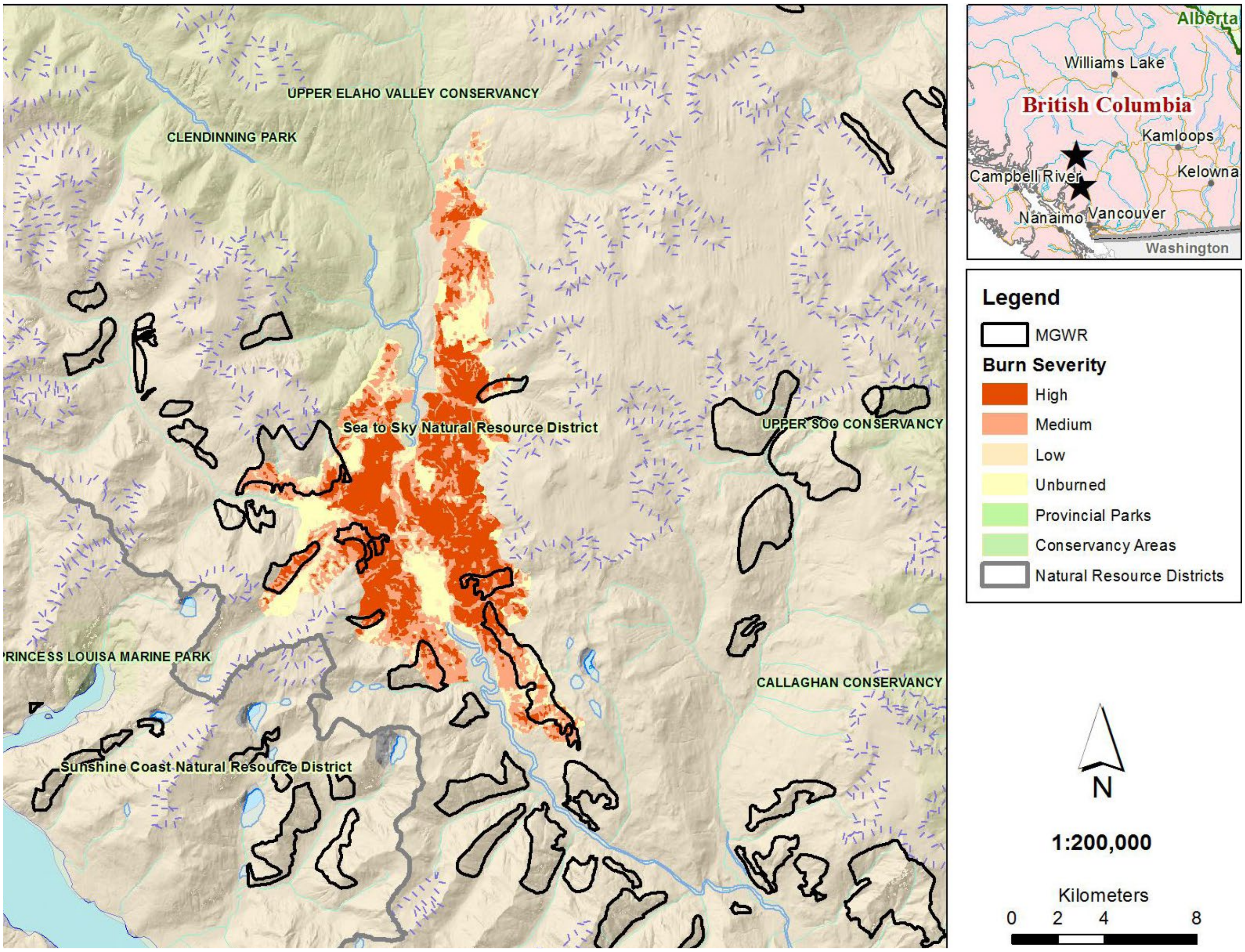

Figure 5. *Burn severity and MGWRs in the Elaho study area.*

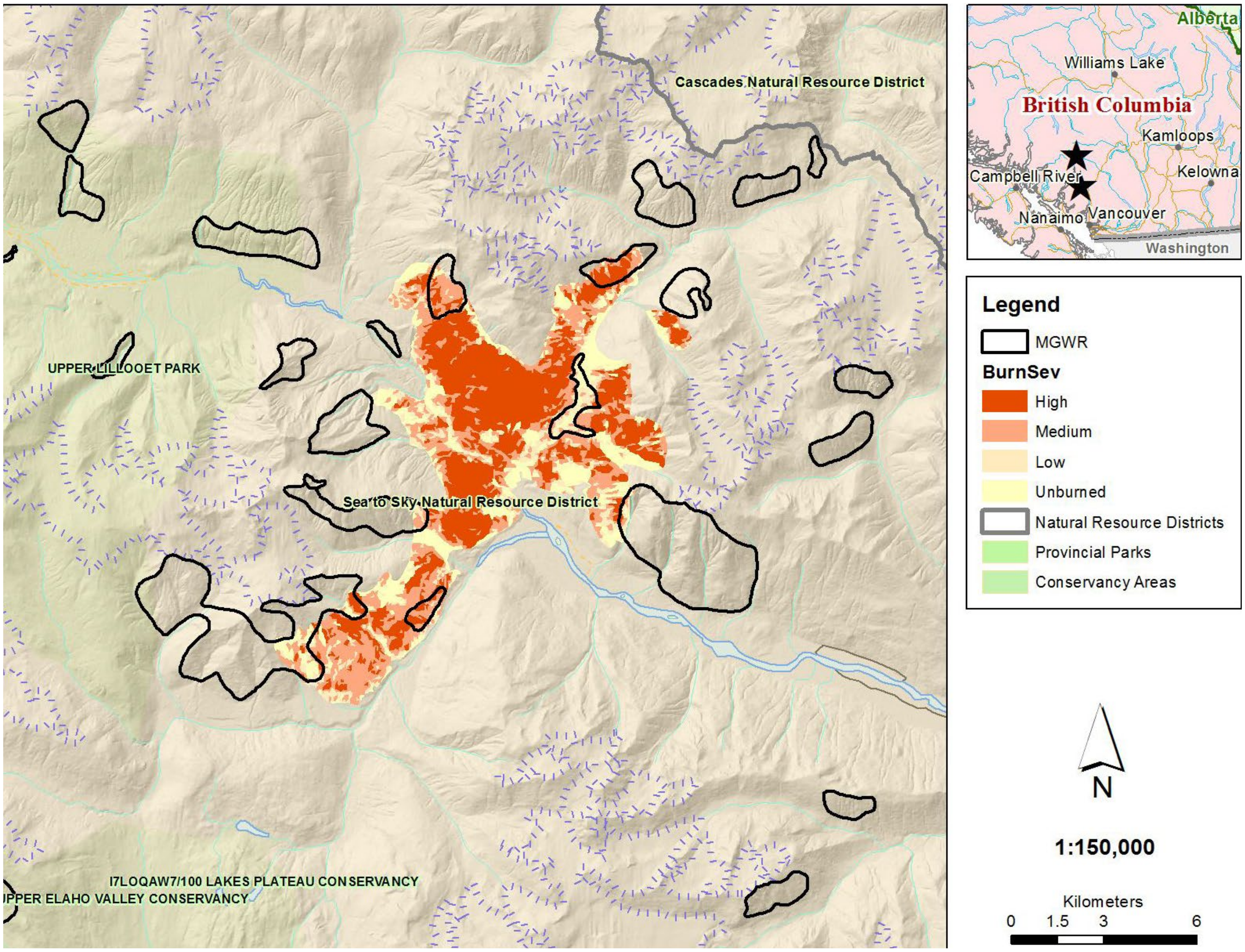

Figure 6. *Burn severity and MGWRs in the Upper Lillooet study area.*

Elaho Study Area: Abundance Trends

Trends in mountain goat abundance using both the *LD* and count data for the Elaho study area show a decline (Figure 7). There is a strong correlation between the *LD* and count data with values of 0.998 and 0.976, respectively, and both follow the declining trend. Declines in the Elaho using both February and March survey data (independently) indicate a statistically significant decline in the *LD.* Specifically, declines ranges from 62.5% to 37.9%, depending on survey month, between 2016 and 2021 (Table 5). Lambda (λ) values for February and March surveys using the count data are <1.0 (0.82 and 0.91), with an intrinsic rate of change, r, of -0.20 and -0.10 (Table 6). The *LD* data indicate a much steeper rate of decline, with λ values of 0.65 and 0.86, and associated r values of -0.43 and -0.16.

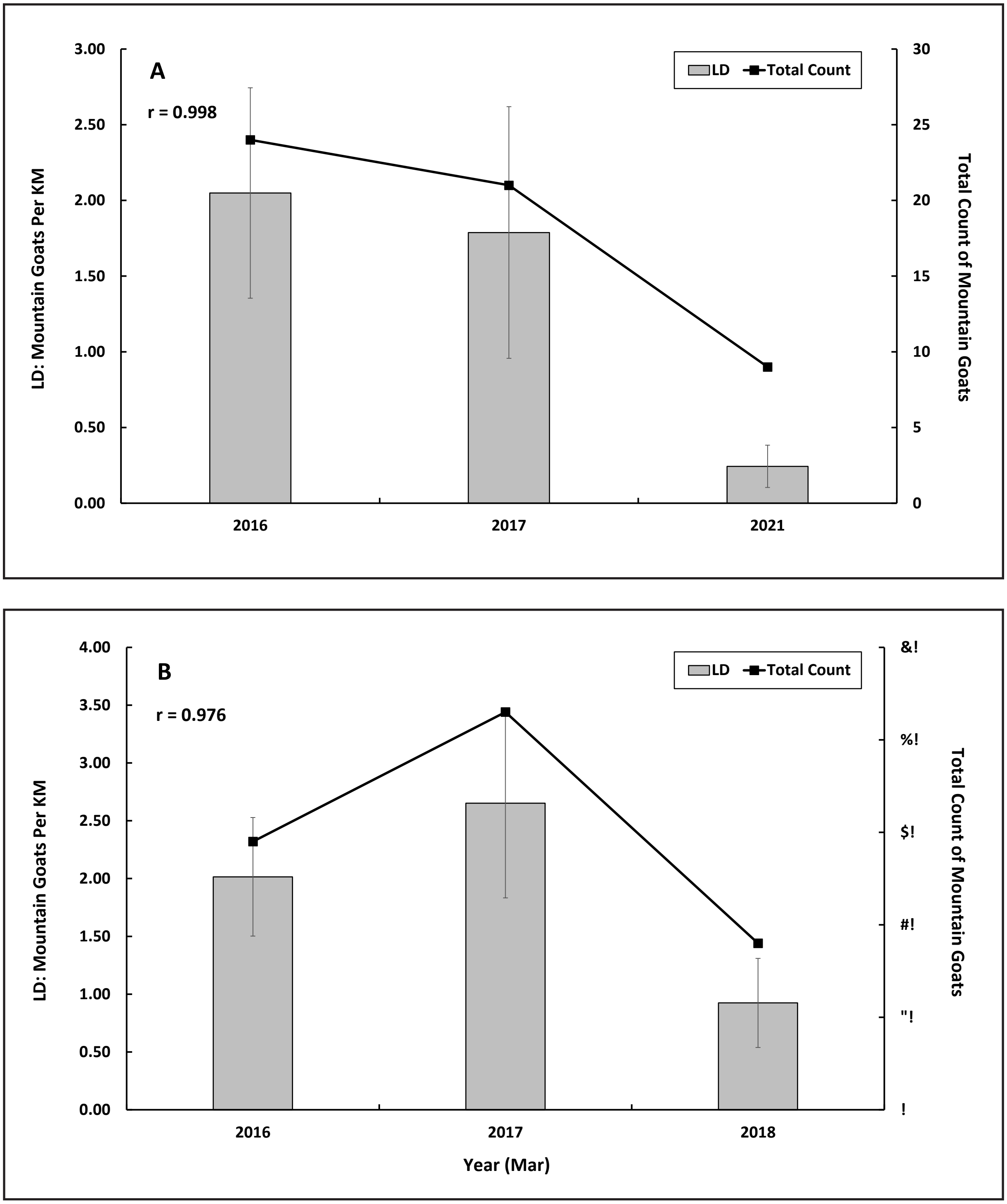

Figure 7. *Trends in the linear density (LD ± SE) and count data, Elaho, 2016-2021 (A = February survey, B = March survey). The r value is a correlation between LD and count data.*

***Table 5.** Summary of trends in mountain goat abundance (LD and total count data) and statistical power in the Elaho, 2016 to 2021*

Survey Month	Percent Change (*LD*)	CV (%)[1] (*LD*)	Percent Change (Count)	Statistical Power (*LD*) Two-Tailed		Statistical Power (*LD*) One-Tailed	
				0.10	*0.20*	*0.10*	*0.20*
Feb	-81.8%	95.9%	-62.5%	70.0%	**83.4%**	**83.4%**	**93.4%**
Mar	-54.1%	72.0%	-37.9%	60.9%	**76.4%**	**76.4%**	**89.1%**

[1]CV is calculated from the 2016 data.

***Table 6.** Summary of trends in mountain goat abundance (LD and total count data) as expressed as the intrinsic rate of increase (r) and population growth (λ) in the Elaho, 2016 to 2021*

Month	Population Data				*LD*		
	r	Lambda (λ)	Kid:Adult	Trend	r	Lambda (λ)	Trend
February	-0.20	0.82	0.15	Declining	-0.43	0.65	Declining
March	-0.10	0.91	0.17	Declining	-0.16	0.86	Declining

Four individual MGWRs in the Elaho had declines in the *LD* between 2016 and 2021, and two of these were statistically significant, meaning that these results had adequate statistical power (Table 7). The three other winter ranges[8] showed an increase, with two having statistically significant (i.e., enough statistical power) increases in the *LD*. Between 2017 and 2021, seven of the MGWRs showed declines, with four of these being statistically significant (Table 8). Only one MGWR had an increase in the *LD*. Overall, from 2016 to 2021, five of the six (83.3%) MGWRs exhibited a decline in *LD*, with three of these four being considered statistically significant (Table 9). In comparison, count data only identified two of the MGWRs as having a decline. Similarly, from 2017 to 2021, six of the seven (85.7%) MGWRs showed a decline using the *LD* data, with four of these being statistically significant (Table 10). Count data indicated that only three of the seven (42.9%) MGWRs showed a decline. A summary of the *LD* and count data are in Tables 11 and 12.

[8] Only MGWRs that were sampled twice in a season could be compared for trends; while 8 MGWRs were burned in the Elaho, only 7 were sampled twice in the same season.

Table 7. *Summary of trends in the mean mountain goat abundance (LD and count) on individual MGWRs in the Elaho, surveys 2016 to 2021*

MGWR	Percent Change (*LD*)	CV (%)[1] (*LD*)	Percent Change (Count)	Statistical Power (*LD*) Two-Tailed		Statistical Power (*LD*) One-Tailed	
				0.10	*0.20*	*0.10*	*0.20*
7	-90.7%	12.3%	-84.7%	0.92	**1.00**	**1.00**	**1.00**
30	-91.6%	110.0%	-100.0%	0.15	0.30	0.30	0.54
26	-56.7%	54.4%	0.0%	0.19	0.36	0.36	0.63
58	-96.0%	42.3%	0.0%	0.38	0.68	0.68	**0.94**
41	+100.0%	0.0%	+100.0%	**1.00**	**1.00**	**1.00**	**1.00**
40	+100.0%	15.7%	0.0%	**0.84**	**0.99**	**0.99**	**1.00**
25	-68.2%	66.6%	+333.3%	0.17	0.32	0.32	0.58

[1]Based on 2016 data.

Table 8. *Summary of trends in mountain goat abundance (LD) on individual MGWRs in the Elaho, surveys 2017 to 2021*

MGWR	Percent Change (*LD*)	CV (%)[1] (*LD*)	Percent Change (Count)	Statistical Power (*LD*) Two-Tailed		Statistical Power (*LD*) One-Tailed	
				0.10	*0.20*	*0.10*	*0.20*
7	-62.1%	40.9%	-84.4%	0.26	0.50	0.50	**0.80**
30	-92.5%	-	-100.0%	-	-	-	-
26	-66.8%	10.7%	+50.0%	**0.89**	**1.00**	**1.00**	**1.00**
66	-100.0%	113.1%	-100.0%	0.16	0.32	0.32	0.57
58	-54.2%	0.0%	0.0%	**1.00**	**1.00**	**1.00**	**1.00**
41	+176.0%	141.4%	-300.0%	0.22	0.41	0.41	0.70
40	-100.0%	141.4%	-100.0%	0.14	0.26	0.26	0.49
25	-27.5%	17.7%	+62.5%	0.28	0.52	0.52	**0.82**

[1]Based on 2017 data.

Table 9. *Summary of trends in mountain goat abundance on MGWRs in the Elaho surveys, 2016 to 2021*

Count Data				*LD*				
MGWR	r	λ	Trend	MGWR	r	λ	Trend	1-β[1]
7	-0.48	0.62	**Declining**	7	-0.43	0.65	**Declining**	**High**
26	0.00	1.00	Stable	26	-0.17	0.84	Declining	Low-Moderate
66	NA	NA	NA	66	NA	NA	NA	NA
58	-2.16	0.11	**Declining**	58	-0.65	0.52	**Declining**	**High**
41	1.98	7.25	Increasing	41	2.10	7.90	**Increasing**	**High**
40	0.00	1.00	Stable	40	-2.38	0.09	**Declining**	**High**
25	0.29	1.34	Increasing	25	-0.19	0.83	Declining	Low-Moderate
Trend	**N**	**%**		**Trend**	**N**	**%**		
Declining	2	33.3%		**Declining**	**5**	**83.3%**		
Increasing	2	33.3%		Increasing	1	16.7%		
Stable	2	33.3%		Stable	0	0.0%		
TOTAL	**6**	**100.0%**		**TOTAL**	**6**	**100.0%**		

[1]Statistical power; see Table 6 for details.

Table 10. *Summary of trends in mountain goat abundance on MGWRs in the Elaho surveys, 2017 to 2021*

Count Data				*LD*				
MGWR	r	λ	Trend	MGWR	r	λ	Trend	1-β[1]
7	-0.47	0.63	**Declining**	7	-0.50	0.61	**Declining**	**Moderate-High**
26	0.10	1.11	Increasing	26	-0.38	0.68	**Declining**	**High**
66	-2.88	0.06	**Declining**	66	-3.54	0.03	**Declining**	Low-Moderate
58	-2.70	0.07	**Declining**	58	-0.81	0.45	**Declining**	**High**
41	0.35	1.41	Increasing	41	0.26	1.29	Increasing	Low-Moderate
40	-2.30	0.10	**Declining**	40	-2.25	0.11	**Declining**	Low-Moderate
25	0.12	1.13	Increasing	25	-0.22	0.80	**Declining**	Moderate-**High**
Trend	**N**	**%**		**Trend**	**N**	**%**		
No. Declining	4	57.1%		Declining	6	85.7%		
No. Increasing	3	42.9%		Increasing	1	14.3%		
No. Stable	0	0.0%		Stable	0	0.0%		
TOTAL	**7**	**100.0%**		**TOTAL**	**7**	**100.0%**		

[1]Statistical power; see Table 7 for details.

Table 11. *Linear densities (LD) on each of the MGWRs sampled in the Elaho, 2016, 2017 and 2021*

MGWR	*LD* Feb 2016	*LD* Mar 2016	*LD* Feb 2017	*LD* Mar 2017	*LD* Feb 2021	*LD* Mar 2021
7	3.23	3.85	2.46	4.46	0.22	1.69
30	0.56	4.44	-	5.56	0.00	1.88
26	4.29	1.90	6.67	5.71	0.77	2.05
66	-	1.05	14.21	1.58	0.00	0.00
58	2.95	1.59	0.23	0.23	0.00	0.21
41	0	0	0.00	1.09	0.00	3.00
56	0	-	0.00	0.00	0.00	0.00
39	0.00	-	-	0.36	0.00	0.00
40	1.29	1.61	1.61	0.00	0.00	0.00
25	4.63	1.67	3.33	2.59	0.96	3.33
31	1.84	1.38	6.91	-	-	1.90
57	0.86	0.29	1.43	-	-	-

Table 12. *Count data (number of goats observed) on each of the MGWRs sampled in the Elaho, 2016, 2017 and 2021*

MGWR	Count Feb 2016	Count Mar 2016	Count Feb 2017	Count Mar 2017	Count Feb 2021	Count Mar 2021
7	21	25	16	29	3	4
30	0	8	-	5	0	0
26	2	1	0	2	0	3
66	-	1	2	0	0	0
58	1	0	0	0	0	0
41	0	0	0	1	0	4
56	0	-	0	0	0	0
39	0	-	0	0	0	0
40	0	0	2	0	0	0
25	1	2	1	7	6	7
31	2	1	4	-	-	2
57	1	0	0	-	-	-

Upper Lillooet Study Area: Abundance Trends

Trends in mountain goat abundance in the Upper Lillooet show a general increase in both the *LD* and count data (Figure 8). There is a strong correlation between the *LD* and count data with values of 0.87 and 0.92, respectively. Declines in the Upper Lillooet using both February and March survey data separately indicate an increase in the *LD* from 5.5% to 30.1% between 2016 and 2021, with the increase observed in the March survey being statistically significant (α = 0.80, one-tailed; Table 13). The count data had a greater percent change than the *LD* with an increase from 16.7% to 41.1%. The λ values for the count data are >1.0 (1.03 and 1.11) with intrinsic rates of change of 0.03 and 0.11 (Table 14). The λ values for the *LD* are >1.0 as well (1.01 and 1.05), with the intrinsic rates of change lower at 0.01 and 0.05, respectively.

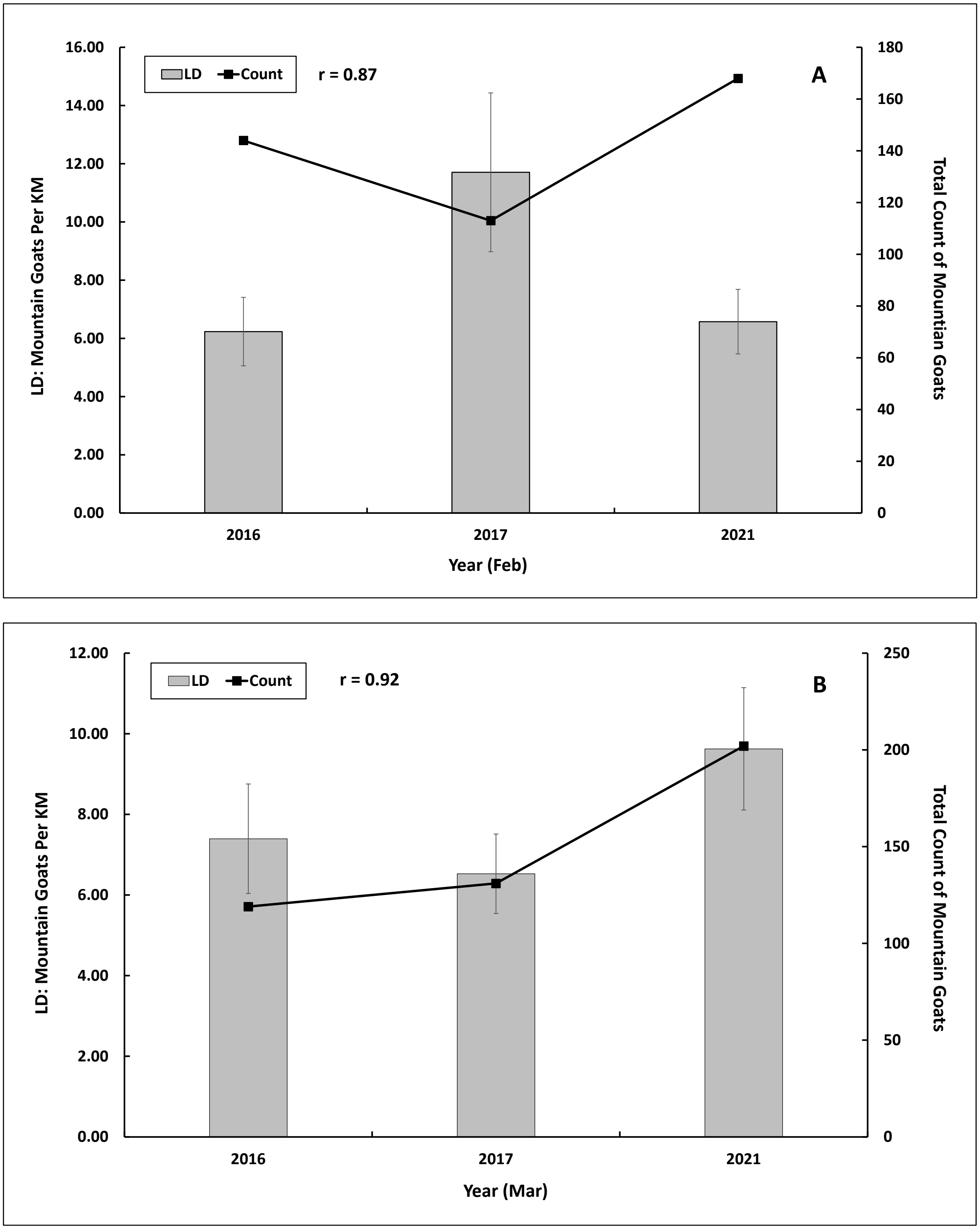

Figure 8. *Trends in the linear density (LD ± SE) and count data, Upper Lillooet, 2016-2021 (A = February survey, B = March survey). The r value is a correlation between LD and count data.*

Table 13. Summary of trends in mountain goat abundance (LD and total count data) and statistical power in the Upper Lillooet, 2016 to 2021

Survey Month	Percent Change (*LD*)	CV (%)[1] (*LD*)	Percent Change (Count)	Statistical Power (*LD*) Two-Tailed		Statistical Power (*LD*) One-Tailed	
				0.10	*0.20*	*0.10*	*0.20*
Feb	5.5%	53.4%	16.7%	8.3%	15.6%	15.6%	28.8%
Mar	30.1%	52.0%	41.1%	43.6%	60.3%	60.3%	77.6%

[1]CV is calculated from the 2016 data.

Table 14. Summary of trends in mountain goat abundance (LD and total count data) as expressed as the intrinsic rate of increase (r) and population growth (λ) in the Upper Lillooet, 2016 to 2021

Month	Population Data				*LD*		
	r	Lambda (λ)	Kid:Adult	Trend	*r*	Lambda (λ)	Trend
February	0.03	1.03	0.31	Increasing	0.01	1.01	Increasing
March	0.11	1.11	0.35	Increasing	0.05	1.05	Increasing

Using the *LD* data from 2016 to 2021, three of the MGWRs showed a decline, while four showed an increase (Table 15). Two of the three declining MGWRs were statistically significant, and three of the four increasing MGWRs were also statistically significant. Between 2017 and 2021, six MGWRs showed declines based on *LD* data, with two of these being considered statistically significant (Table 16). Three MGWRs showed an increase (*LD* data), with one of these three being statistically significant. Overall, from 2016 to 2021, three of the eight (37.5%) MGWRs had a declining trend for both the *LD* and count data, with two being statistically significant (Table 17). Four (50%) of the MGWRs showed an increase, with three of these being statistically significant (*LD* data). Trends from 2017 to 2021 in the Upper Lillooet study area revealed six (66.7%) of the MGWRs showing a decline, with two of these being statistically significant (*LD* data). The count data for these MGWRs showed three (33.3%) with a decline (Table 18). Three (33.3%) of the MGWRs showed an increase; however, only one was statistically significant. A summary of the *LD* and count data are in Tables 19 and 20.

Table 15. *Summary of trends in mountain goat abundance (mean of LD and count) on individual MGWRs in the Upper Lillooet, 2016 to 2021*

MGWR	Percent Change (*LD*)	CV (%)[1] (*LD*)	Percent Change (Count)	Statistical Power (*LD*) Two-Tailed		Statistical Power (*LD*) One-Tailed	
				0.10	*0.20*	*0.10*	*0.20*
ME2	+26.5%	0.0%	-37.5%	**1.0**	**1.0**	**1.0**	**1.0**
ME3	-50.1%	34.6%	-63.7%	0.25	0.47	0.47	0.77
ME4	-47.3	84.5%	150.0%	0.11	0.21	0.21	0.42
UL8	-54.1%	20.2%	-50.0%	0.42	0.72	0.72	0.96
UL10	+213.5%	0.0%	100.0%	**1.0**	**1.0**	**1.0**	**1.0**
UL11	-30.5%	47.1%	30.8%	0.13	0.25	0.25	0.46
UL12	+100.0%[2]	-	100%	-	-	-	-
UL13	0.0%[2]	-	0.0%	-	-	-	-
UL19	-80.4%[2]	-	0.0%	-	-	-	-
RY8	-0.20%	3.3%	100.0%	0.11	0.22	0.22	0.42
RA7	+153.7%	3.7%	350.0%	**1.0**	**1.0**	**1.0**	**1.0**

[1]Based on 2016 data. [2]Only one flight in 2016.

Table 16. *Summary of trends in mountain goat abundance (LD) on individual MGWRs in the Upper Lillooet, 2017 to 2021*

MGWR	Percent Change (*LD*)	CV (%)[1] (*LD*)	Percent Change (Count)	Statistical Power (*LD*) Two-Tailed		Statistical Power (*LD*) One-Tailed	
				0.10	*0.20*	*0.10*	*0.20*
ME2	-40.4%	8.3%	-47.4%	**0.72**	**0.97**	**0.97**	**1.0**
ME3	-28.1%	51.7%	-40.0%	0.11	0.22	0.22	0.42
ME4	-18.2%	91.4%	+264.0%	0.067	0.14	0.14	0.27
UL8	-43.3%	0.0%	-30.4%	**1.0**	**1.0**	**1.0**	**1.0**
UL10	+198.3%	6.7%	+30.0%	**1.0**	**1.0**	**1.0**	**1.0**
UL11	-59.9%	87.0%	+30.8%	0.13	0.26	0.26	0.48
UL12	+89.9%	141.4%	+100%	0.13	0.25	0.25	0.46
UL13	-100.0%	141.4%	0.0%	**1.0**	**1.0**	**1.0**	**1.0**
UL19	-46.6%	52.5%	+100.0%	0.16	0.32	0.32	0.57
RY8	+21.2%	28.3%	+120%	0.14	0.28	0.28	0.51
RA7	-4.7%	24.5%	+95.6%	0.07	0.14	0.14	0.27

[1]Based on 2017 data.

Table 17. *Summary of trends in mountain goat abundance on MGWRs in the Upper Lillooet surveys, 2016 to 2021*

Count Data				*LD*				
MGWR	*r*	λ	Trend	MGWR	*r*	λ	Trend	1-β[1]
ME2	-0.09	0.91	**Declining**	ME2	0.05	1.05	**Increasing**	**High**
ME3	-0.20	0.82	**Declining**	ME3	-0.05	0.95	**Declining**	**Low-High**
ME4	0.18	1.20	Increasing	ME4	0.08	1.08	Increasing	Low-Moderate
UL8	-0.14	0.87	**Declining**	UL8	-0.16	0.86	**Declining**	**Moderate-High**
UL10	2.39	10.92	Increasing	UL10	5.00	0.23	**Increasing**	**High**
UL11	0.05	1.06	Increasing	UL11	-0.07	0.93	Declining	Low-Moderate
UL12	NA	NA	NA	UL12	NA	NA	NA	NA
UL13	NA	NA	NA	UL13	NA	NA	NA	NA
UL19	NA	NA	NA	UL19	NA	NA	NA	NA
RY8	0.14	1.15	Increasing	RY8	0.00	1.00	Stable	Low-Moderate
RA7	0.21	1.24	Increasing	RA7	0.19	1.20	**Increasing**	**High**
Trend	**N**	**%**		**Trend**	**N**	**%**		
Declining	3	37.5%		Declining	3	37.5%		
Increasing	5	62.5%		Increasing	4	50.0%		
Stable	0	0.0%		Stable	1	12.5%		
TOTAL	8	100.0%		**TOTAL**	8	100.0%		

[1]Statistical power; see Table 8 for details.

Table 18. *Summary of trends in mountain goat abundance on MGWRs in the Upper Lillooet surveys, 2017 to 2021*

Count Data				*LD*				
MGWR	*r*	λ	Trend	MGWR	*r*	λ	Trend	1-β[1]
ME2	-0.16	0.85	**Declining**	ME2	-0.13	0.88	**Declining**	High
ME3	-0.13	0.88	**Declining**	ME3	-0.08	0.92	**Declining**	Low-Moderate
ME4	0.32	1.38	Increasing	ME4	-0.05	0.95	**Declining**	Low
UL8	-0.09	0.91	**Declining**	UL8	-0.09	0.91	**Declining**	High
UL10	0.86	2.36	Increasing	UL10	0.27	1.31	Increasing	High
UL11	0.07	1.07	Increasing	UL11	-0.23	0.80	**Declining**	Low-Moderate
UL12	1.90	6.69	Increasing	UL12	0.60	1.82	Increasing	Low-Moderate
UL13	0.00	0.00	Stable	UL13	-1.50	0.22	**Declining**	High
UL19	1.55	4.73	Increasing	UL19	-0.16	0.85	**Declining**	Low-Moderate
RY8	0.20	1.22	Increasing	RY8	-0.05	0.95	**Declining**	Low-Moderate
RA7	0.17	1.18	Increasing	RA7	0.23	1.26	Increasing	Low
Trend	**N**	**%**		**Trend**	**N**	**%**		
Declining	3	33.3%		Declining	8	88.9%		
Increasing	7	77.8%		Increasing	3	33.3%		
Stable	1	11.1%		Stable	0	0.0%		
TOTAL	**11**	**100.0%**		**TOTAL**	**11**	**100.0%**		

[1]Statistical power; see Table 7 for details.

Table 19. *Linear densities (LD) on each of the MGWRs sampled in the Upper Lillooet, 2016, 2017 and 2021*

MGWR	*LD* Feb 2016	*LD* Mar 2016	*LD* Feb 2017	*LD* Mar 2017	*LD* Feb 2021	*LD* Mar 2021
ME 3	9.13	5.54	10.63	4.94	5.07	6.12
ME 2	4.94	4.94	11.11	9.88	3.57	8.93
ME 4	3.85	15.38	28.46	6.15	11.67	16.67
UL10	3.70	3.70	4.07	3.70	8.00	15.20
UL11	3.97	7.94	16.67	3.97	3.45	4.83
UL12	-	0.00	0.00	7.35	3.33	3.81
UL13	-	0.00	0.00	0.81	0.00	0.00
UL8	12.78	9.58	7.35	7.35	4.16	6.10
UL19	-	1.61	0.81	0.37	0.63	0.00
RA7	3.89	4.07	7.96	11.30	10.30	9.90
RY8	7.60	8.01	7.39	4.93	6.38	9.26

Table 20*. Count data (number of goats observed) on each of the MGWRs sampled in the Upper Lillooet, 2016, 2017 and 2021*

MGWR	Count Feb 2016	Count Mar 2016	Count Feb 2017	Count Mar 2017	Count Feb 2021	Count Mar 2021
ME 3	56	35	25	30	13	20
ME 2	8	8	13	6	2	8
ME 4	4	12	9	2	21	19
UL8	34	30	23	23	16	16
UL10	0	0	1	0	18	13
UL11	5	0	8	5	8	9
UL12	-	0	0	0	0	4
UL13	-	0	0	0	0	0
UL19	-	1	0	0	1	0
RA7	21	9	18	51	61	74
RY8	16	17	16	14	29	37
RY2	-	-	-	-	-	7

Kid:Adult Ratios

Trends in the kid:adult ratios indicate that the Upper Lillooet has double the proportion of kids versus the Elaho (Figure 9). Mean observed kid:adult ratios in the Elaho were 0.15 (range 0.12 to 0.18) and 0.17 (range 0.13 to 0.21), while the Upper Lillooet had mean kid:adult ratios of 0.31 (0.24 to 0.36) and 0.35 (0.26 to 0.43). The estimated female survivorship, *S*, based on kid:adult ratios (recruitment, *R*) and the derived λ is 0.70 and 0.75 for the Elaho, and 0.71 and 0.72 for the Upper Lillooet (Table 21). The estimated survivorship, *S*, needed for population stability is 0.85 and 0.83 for the Elaho, and 0.69 and 0.65 for the Upper Lillooet.

A comparison of winter versus summer kid:adult ratios in the Elaho indicates higher kid:adult ratios in winter versus summer in 2016, equivocal ratios in 2017, and lower ratios in winter versus summer in 2017. In the Upper Lillooet, kid:adult ratios were higher in the winter versus summer in 2016 and 2017, and ratios were higher in the summer versus winter in 2021 (Figures 10 and 11).

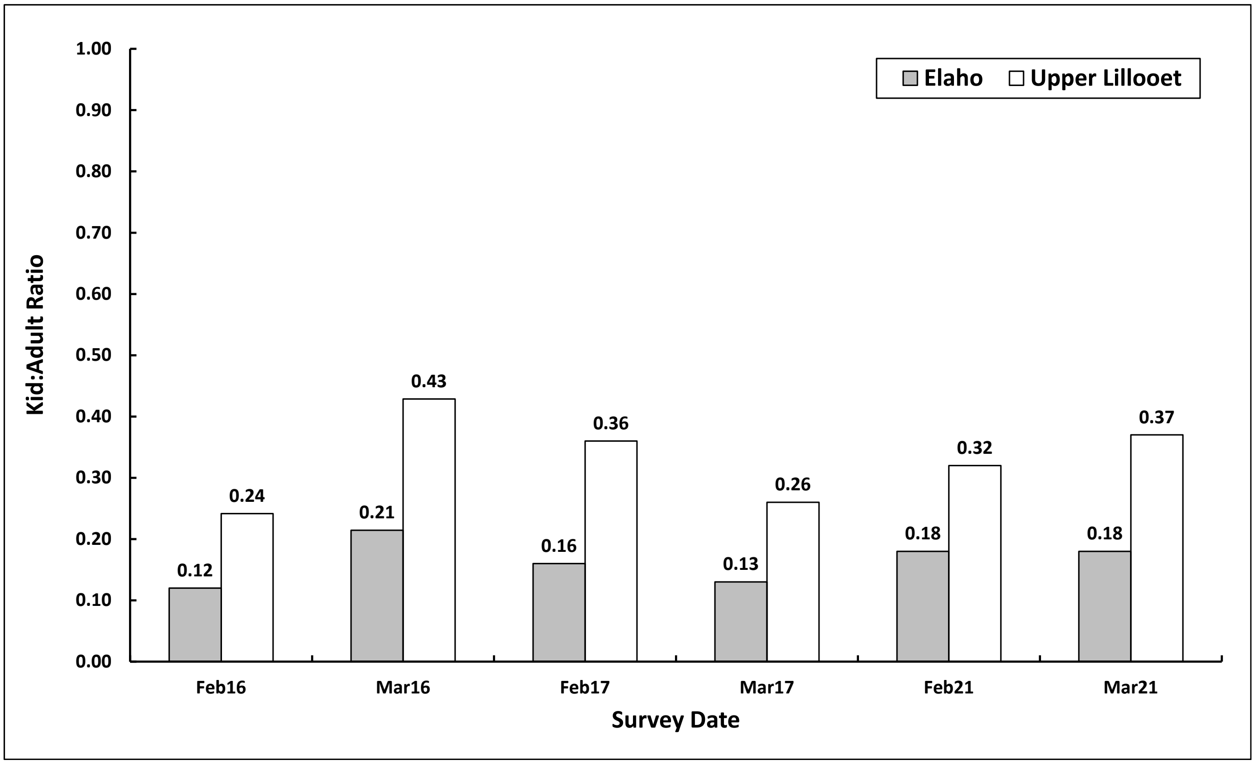

***Figure 9**. Trends in the kid:adult ratios in the Elaho and Upper Lillooet, 2016, 2017 and 2021.*

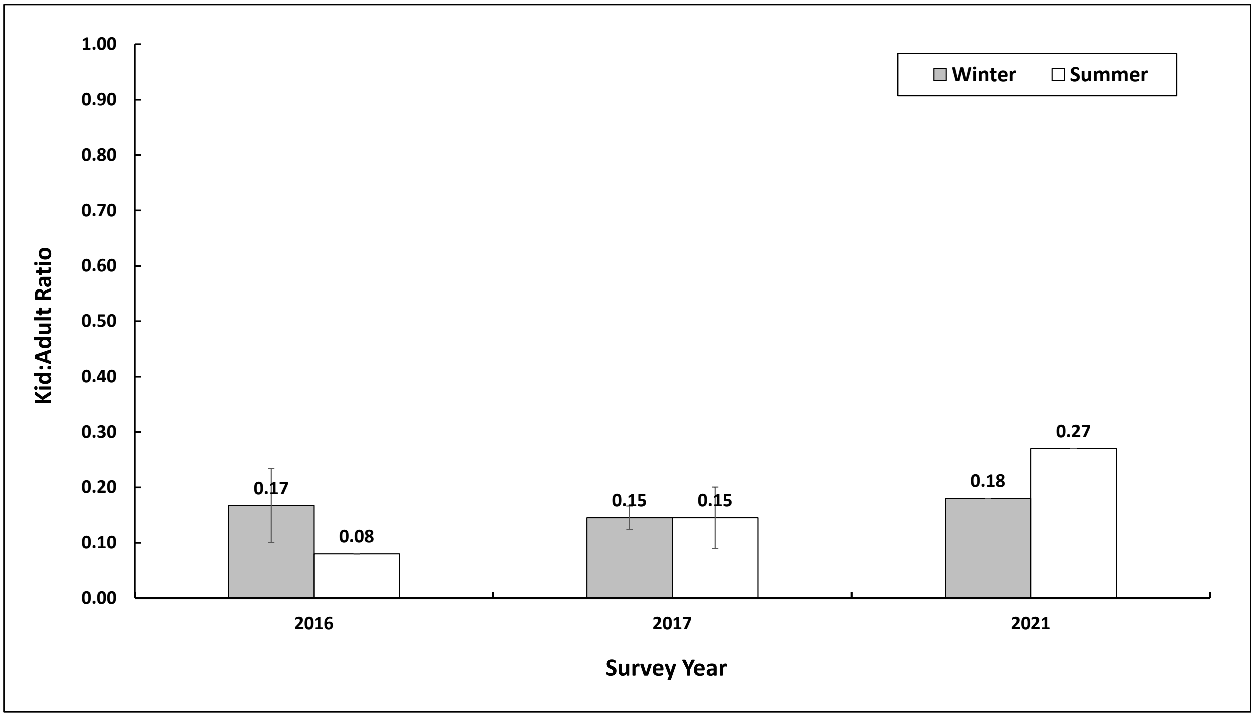

***Figure 10**. Trends in the mean winter and summer kid:adult ratios in population units that contain Elaho MGWRs, 2016, 2017 and 2021.*

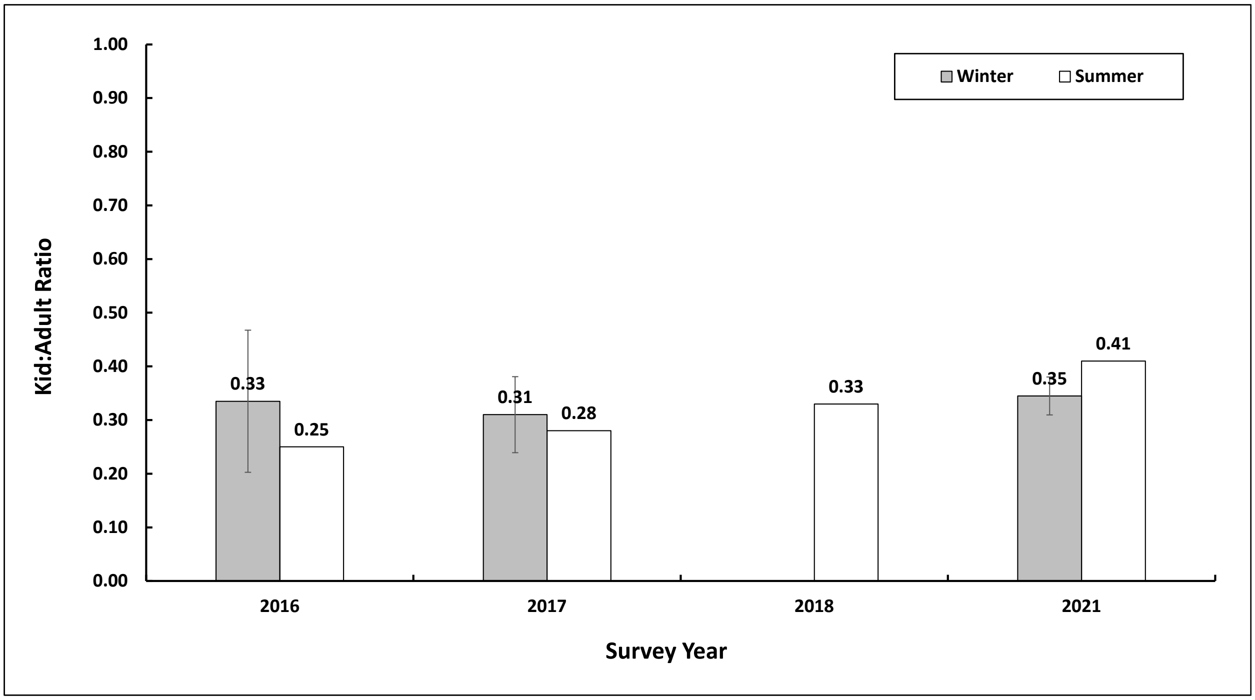

Figure 11. *Trends in the winter and summer kid:adult ratios in population units that contain Upper Lillooet MGWRs, 2016, 2017 and 2021.*

Table 21. *Kid:adult ratios, lambda (λ), estimated adult survivorship (S), and hypothetical survivorship needed for population stability in both study areas*

Survey Month	Kid:Adult (Observed)	Lambda (Count Data)	Adult Survivorship (Estimated)	Adult Survivorship Needed for Population Stability
		Elaho		
Feb	0.15	0.82	0.70	**0.85**
Mar	0.17	0.91	0.75	**0.83**
		Upper Lillooet		
Feb	0.31	1.03	0.71	**0.69**
Mar	0.35	1.11	0.72	**0.65**

Mountain Goat Densities

Mountain goat densities (observed goats per km^2) ranged from 0.12 to 0.76 goats per km^2 in the Elaho, and 2.61 to 5.29 goats per km^2 in the Upper Lillooet (Table 22). These densities included all MGWRs sampled, even if no mountain goat themselves were sighted (tracks may have been observed, but no animals). Densities of mountain goats on MGWRs where goats were observed, ranged from 0.57 to 1.52 goats per km^2 in the Elaho, and 4.10 to 6.35 goats per km^2 in the Upper Lillooet (Table 23).

Table 22. *Mean mountain goat densities (goats per km²), ranges, and variance for all MGWRs sampled in both study areas*

Elaho						
	February			March		
Year	Mean Density (Goats per km²)	Range	CV (%)	Mean Density (Goats per km²)	Range	CV (%)
2016	0.46	0-3.15	200.3%	0.75	0-3.75	161.9%
2017	0.64	0-2.40	143.8%	0.76	0-4.35	176.0%
2021	0.12	0-0.70	216.8%	0.53	0-2.86	161.3%
Upper Lillooet						
	February			March		
Year	Mean Density (Goats per km²)	Range	CV (%)	Mean Density (Goats per km²)	Range	CV (%)
2016	5.21	0-12.26	92.8%	2.61	0-10.59	140.1%
2017	4.71	0-19.62	149.8%	3.26	0-12.26	125.6%
2021	4.50	0-19.62	122.7%	5.29	0-22.1	115.5%

Table 23. *Mean mountain goat densities (goats per km²), ranges, and variance for MGWRs sampled with mountain goats sighted (not just tracks) in both study areas*

Elaho						
	February			March		
Year	Mean Density (Goats per km²)	Range	CV (%)	Mean Density (Goats per km²)	Range	CV (%)
2016	0.85	0.23-3.75	135.8%	1.25	0.23-3.75	110.4%
2017	1.41	0.12-2.40	62.2%	1.52	0.52-4.35	105.7%
2021	0.57	0.45-0.70	30.4%	1.17	0.61-2.86	81.4%
Upper Lillooet						
	February			March		
Year	Mean Density (Goats per km²)	Range	CV (%)	Mean Density (Goats per km²)	Range	CV (%)
2016	5.95	1.12-10.60	79.0%	4.10	0.60-10.59	94.9%
2017	6.47	0.33-19.6	117.6%	5.13	0.56-12.26	80.1%
2021	5.50	0.60-19.6	102.8%	6.35	0.92-22.10	97.3%

Detection Probabilities

Detection probabilities in the Elaho were lower in 2021 in all burn categories (Figure 12). For paired MGWRs that were repeated for all three years, detection probabilities in 2021 were half of previous years for the 50-75% and 75-100% burn categories (Figure 13). In the Upper Lillooet study area, there were no changes in the detection probabilities from 2016 to 2021 (Figure 14).

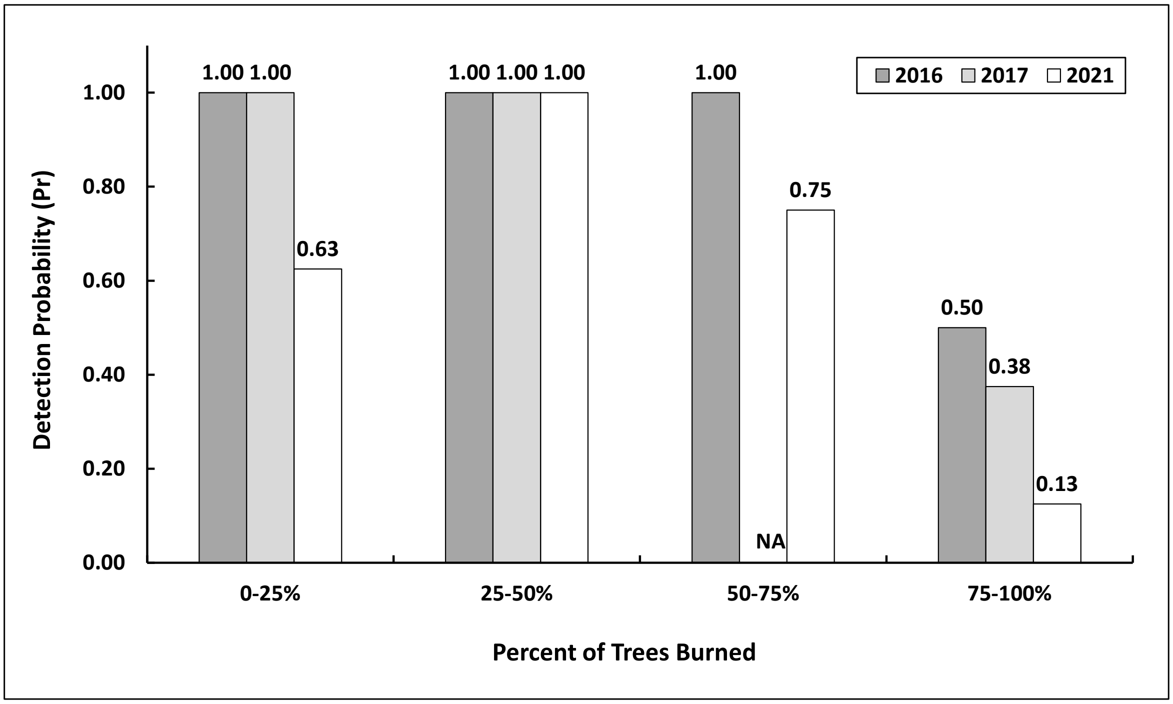

Figure 12. Trends in detection probabilities in the Elaho, all MGWRs sampled, 2016, 2017 and 2021.

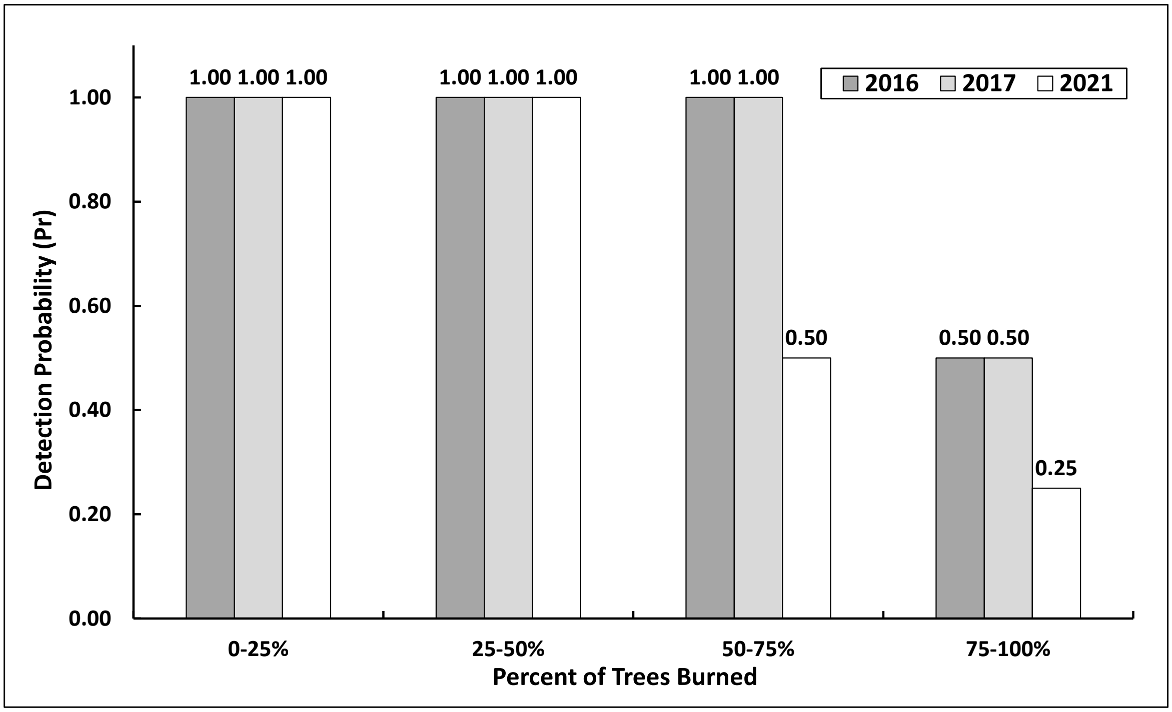

Figure 13. Trends in detection probabilities in the Elaho, paired MGWRs sampled, 2016, 2017 and 2021.

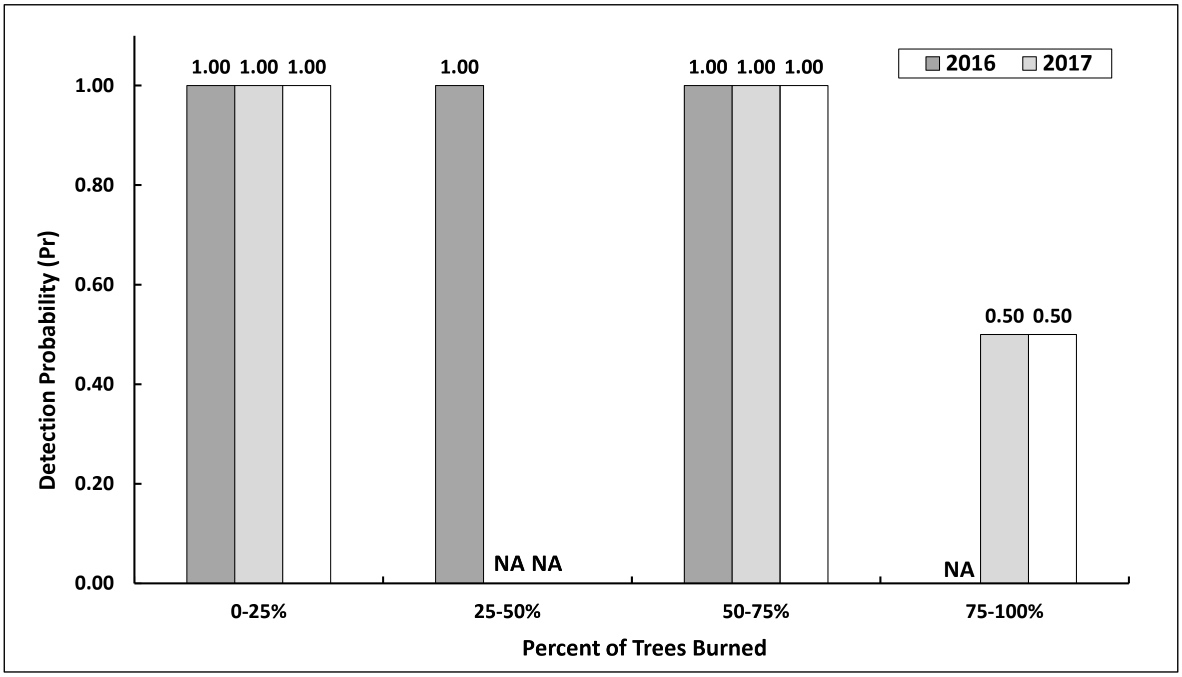

Figure 14. *Trends in detection probabilities in the Upper Lillooet, all MGWRs sampled, 2016, 2017 and 2021.*

Mountain Goat Abundance and Forest Patch Size

There are strong correlations between residual forest size (ha) and the *LD* in both the Elaho and Upper Lillooet (Figures 15 [A to F] and 16 [A to F]). Figure 17 shows the strongest correlations obtained from the March 2017 (Elaho) and February 2016 (Upper Lillooet) surveys. One outlier MGWR was removed from the Upper Lillooet analysis to increase the predictive power. Adding the escape terrain area as a covariate did not increase the predictive capability in the Elaho for the *LD* and count data but did for the Upper Lillooet (Table 24). The predictive equations to estimate the expected *LD* and number of goats (March 2017 data) for the Elaho are:

$$LD = 0.019 \text{ (forest size prior to burn)},$$

and

$$\text{No. goats} = 0.0563 \text{ (forest size prior to burn)},$$

The predictive equations to estimate the expected *LD* and number of goats (February 2016 and March 2017) for the Upper Lillooet are:

$$LD = 0.04575 \text{ (forest size prior to burn)} + 0.02367 \text{ (escape terrain area)}$$

and

$$\text{No. goats} = 0.09298 \text{ (forest size prior to burn)} + 0.04719 \text{ (escape terrain area)}$$

As per Nietvelt et al. (2018) and Nietvelt (2023), the number of mountain goats are generally correlated with residual forest size (ha) in both study areas (Figures 15 [A to F] and 16 [A to F]). The only year where a weaker correlation was observed was in 2021 in the Elaho (Figure 15 [E and F]).

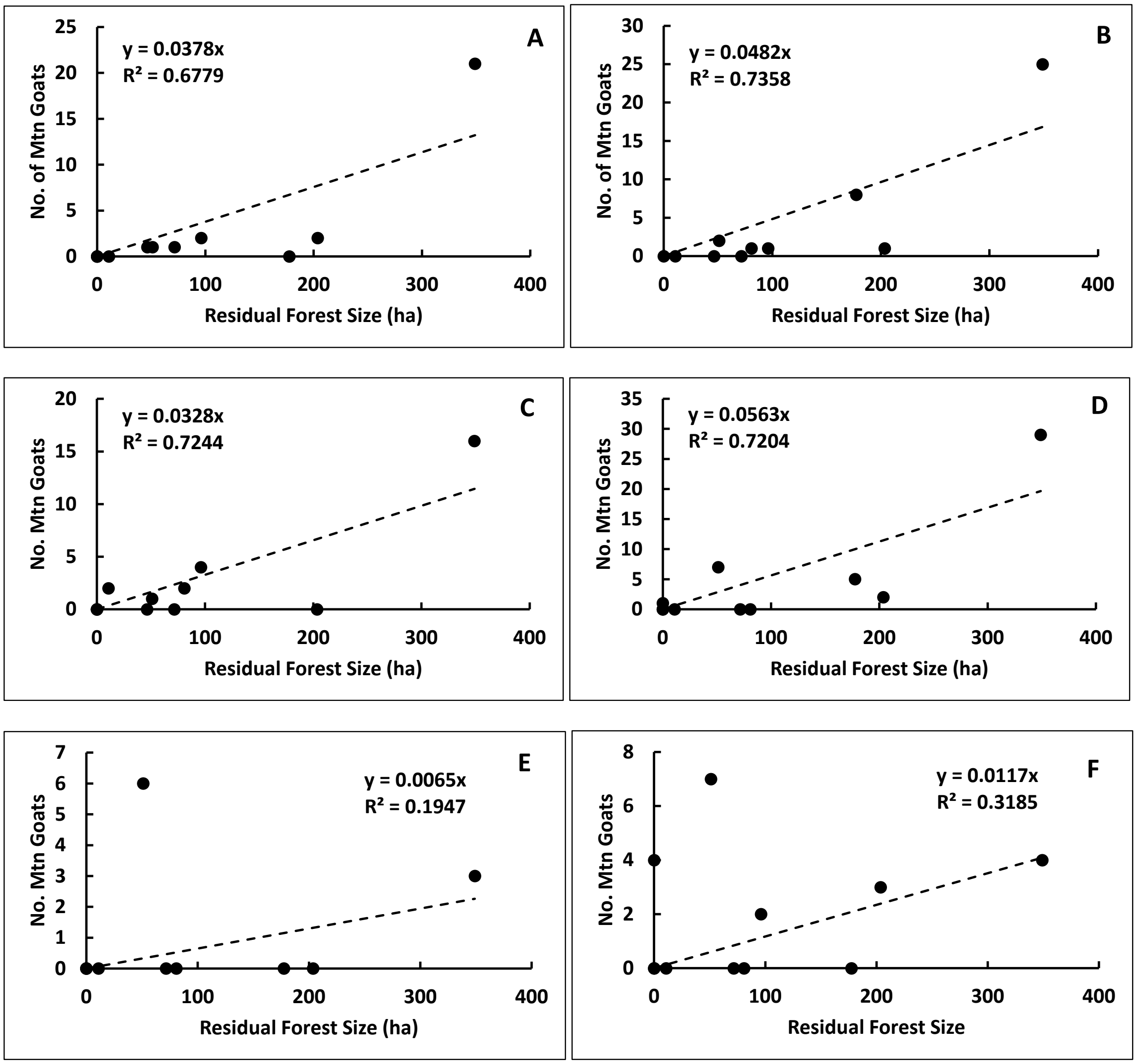

Figure 15. *Relationship between the residual forest patch size and the number of goats in each MGWR, Elaho February (2016 = A, 2017 = C, 2021 = E), and March (2016 = B, 2017 = D, 2021 = F).*

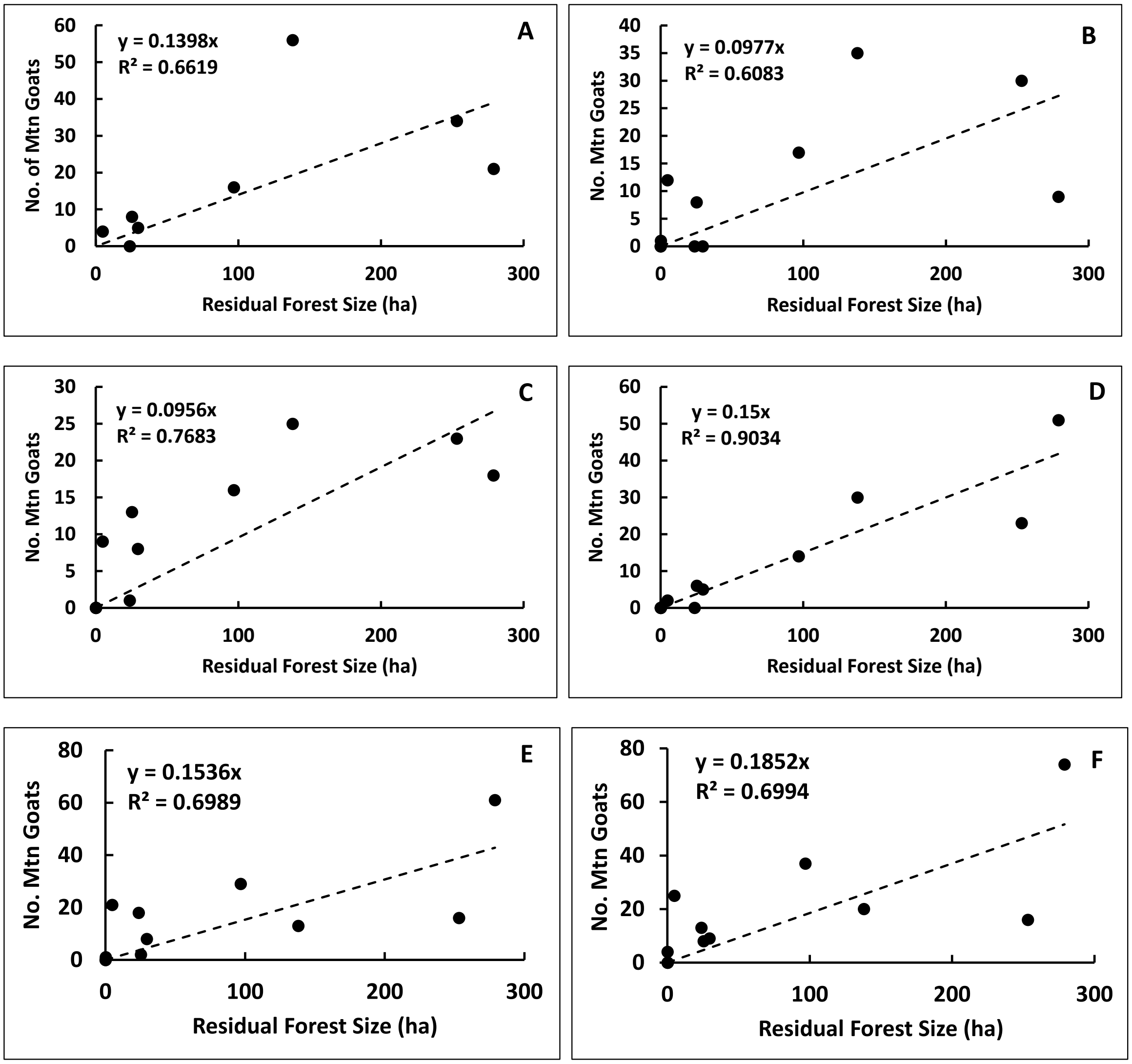

Figure 16. *Relationship between the residual forest patch size and the number of goats in each MGWR, Upper Lillooet February (2016 = A, 2017 = C, 2021 = E), and March (2016 = B, 2017 = D, 2021 = F).*

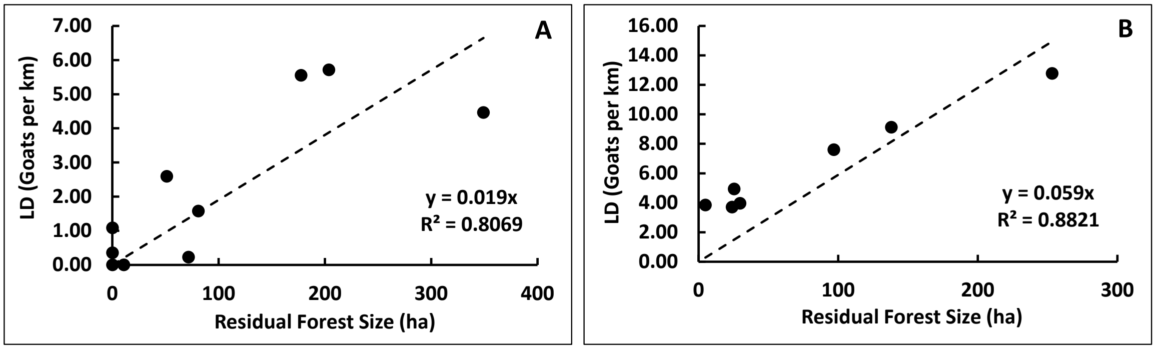

Figure 17. *Relationship between the residual forest patch size and the linear density (LD) of goats and predictive equations for the Elaho (A, March 2017) and Upper Lillooet (B, February 2016) study areas.*

Table 24. *Results from the regression analysis to predict expected mountain goat abundance (count and LD) for an individual MGWRs*

Dependent Variable	Regression Equation	r^2	P Value
Elaho			
No. of Goats	Forest Patch Size Prior to Burn*	0.72	0.001
No. of Goats	Escape Terrain Area	0.01	0.768
No. of Goats	Forest Patch Size Prior to Burn + Escape Terrain Area	0.75	0.004
LD	Forest Patch Size Prior to Burn*	0.81	0.0002
LD	Escape Terrain Area	0.079	0.40
LD	Forest Patch Size Prior to Burn + Escape Terrain Area	0.81	0.001
Upper Lillooet			
No. of Goats	Forest Patch Size Prior to Burn	0.90	0.0001
No. of Goats	Escape Terrain Area	0.85	0.0001
No. of Goats	Forest Patch Size Prior to Burn + Escape Terrain Area*	0.97	0.0001
LD	Forest Patch Size Prior to Burn	0.88	0.001
LD	Escape Terrain Area	0.66	0.01
LD	Forest Patch Size Prior to Burn + Escape Terrain Area*	0.93	0.001

*Equation used to calculate expected.

Using the equations to predict the *LD* in the Elaho, the mean *LD* was much less than predicted in all years except February 2017 (Tables 25 to 27). The largest difference between the predicted and observed was in 2021 (>1,000% and 95.6%; Table 27). Similarly, the mean *LD* in the Upper Lillooet was also below the predicted value for all years except for March 2021, where the observed was higher (Tables 28 to 30).

Table 25. *Predicted and observed mountain goat abundance (LD) for the Elaho study area, 2016*

MGWR	*LD* Predicted	*LD* Observed Feb	Difference	*LD* Predicted	*LD* Observed Mar	Difference
7	6.63	3.23	-105.2%	6.63	3.85	-72.4%
30	3.37	0.56	-506.8%	3.37	4.44	24.1%
26	3.87	4.29	9.8%	3.87	1.90	-103.1%
66	1.54	-	-	1.54	1.05	-46.0%
58	3.40	2.95	-15.0%	3.40	1.59	-113.6%
41	1.85	0.00	NA*	1.85	0.00	NA*
56	0.41	0.00	NA*	-	-	-
39	1.98	0.00	NA*	-	-	-
40	1.03	1.29	20.3%	1.03	1.61	36.2%
25	1.62	4.63	65.0%	1.62	1.67	2.9%
31	1.83	1.84	0.9%	1.83	1.38	-32.2%
57	1.76	0.86	-105.5%	1.76	0.29	-516.5%
Mean	**2.44**	**1.79**	**-36.6%**	**2.69**	**1.78**	**-51.2%**

*Cannot calculate due to a zero denominator, hence the predicted value is undefined.

Table 26. *Predicted and observed mountain goat abundance (LD) for the Elaho study area, 2017*

MGWR	*LD* Predicted	*LD* Observed Feb	Difference	*LD* Predicted	*LD* Observed Mar	Difference
7	6.63	2.46	-169.3%	6.63	4.46	-48.6%
30	-	-	-	3.37	5.56	39.3%
26	3.87	6.67	42.0%	3.87	5.71	32.3%
66	1.54	14.21	89.2%	1.54	1.58	2.7%
58	3.40	0.23	-1394.9%	3.40	0.23	-1,394.9%
41	1.85	0.00	NA*	1.85	1.09	-70.4%
56	0.41	0.00	NA*	0.41	0.00	NA*
39	-	-	-	1.98	0.36	-455.3%
40	1.03	1.61	36.2%	1.03	0.00	NA*
25	1.62	3.33	51.4%	1.62	2.59	37.6%
31	1.83	6.91	73.6%	-	-	-
57	1.76	1.43	-23.3%	-	-	-
Mean	**2.39**	**3.69**	**35.1%**	**2.57**	**2.16**	**-19.1%**

*Cannot calculate due to a zero denominator, hence the predicted value is undefined.

Table 27. Predicted and observed mountain goat abundance (LD) for the Elaho study area, 2021

MGWR	*LD* Predicted	*LD* Observed Feb	Difference	*LD* Predicted	*LD* Observed Mar	Difference
7	6.63	0.22	-2,967.7%	6.63	1.69	-291.8%
30	3.37	0.00	NA*	3.37	1.88	-79.8%
26	3.87	0.77	-402.8%	3.87	2.05	-88.6%
66	1.54	0.00	NA*	1.54	0.00	NA*
58	3.40	0.00	NA*	3.40	0.21	-1,530.7%
41	1.85	0.00	NA*	1.85	3.00	38.3%
56	0.41	0.00	NA*	0.41	0.00	NA*
39	1.98	0.00	NA*	1.98	0.00	NA*
40	1.03	0.00	NA*	1.03	0.00	NA*
25	1.62	0.96	-68.3%	1.62	3.33	51.4%
31	-	-	-	1.83	1.90	4.1%
57	-	-	-	-	-	-
Mean	**2.57**	**0.19**	**-1,219.6%**	**2.50**	**1.28**	**-95.7%**

*Cannot calculate due to a zero denominator, hence the predicted value is undefined.

Table 28. Predicted and observed mountain goat abundance (LD) for the Upper Lillooet study area, 2016

MGWR	*LD* Predicted	*LD* Observed Feb	Difference	*LD* Predicted	*LD* Observed Mar	Difference
ME 3	12.52	9.13	-37.1%	12.52	5.54	-126.0%
ME 2	2.99	4.94	39.4%	2.99	4.94	39.4%
ME 4	2.92	3.85	24.0%	2.92	15.38	81.0%
UL10	1.36	3.70	63.3%	1.36	3.70	63.3%
UL11	1.69	3.97	57.3%	1.69	7.94	78.7%
UL12	-	-	-	4.87	0.00	NA*
UL13	-	-	-	2.89	0.00	NA*
UL8	13.20	12.78	-3.3%	13.20	9.58	-37.8%
UL19	-	-	-	1.71	1.61	-6.3%
RA7	26.06	3.89	-570.2%	26.06	4.07	-539.7%
RY8	6.95	7.60	8.6%	6.95	8.01	13.3%
Mean	**8.46**	**6.23**	**-35.8%**	**7.02**	**5.53**	**-27.0%**

*Cannot calculate due to a zero denominator, hence the predicted value is undefined.

Table 29. *Predicted and observed mountain goat abundance (LD) for the Upper Lillooet study area, 2017*

MGWR	*LD* Predicted	*LD* Observed Feb	Difference (%)	*LD* Predicted	*LD* Observed Mar	Difference (%)
ME 3	12.52	5.07	-146.6%	12.52	4.94	-153.3%
ME 2	2.99	3.57	16.2%	2.99	9.88	69.7%
ME 4	2.92	11.67	75.0%	2.92	6.15	52.5%
UL10	1.36	8.00	83.0%	1.36	3.70	63.3%
UL11	1.69	3.45	50.9%	1.69	3.97	57.3%
UL12	4.87	3.33	-46.1%	4.87	7.35	33.7%
UL13	2.89	0.00	NA*	2.89	0.81	-258.9%
UL8	13.20	4.16	-217.7%	13.20	7.35	-79.7%
UL19	1.71	0.63	-174.3%	1.71	0.37	-362.8%
RA7	26.06	10.30	-153.0%	26.06	11.30	-130.7%
RY8	6.95	6.38	-8.8%	6.95	4.93	-41.0%
Mean	**7.02**	**5.14**	**-36.5%**	**7.02**	**5.52**	**-27.1%**

*Cannot calculate due to a zero denominator, hence the predicted value is undefined.

Table 30. *Predicted and observed mountain goat abundance (LD) for the Upper Lillooet study area, 2021*

MGWR	*LD* Predicted	*LD* Observed Feb	Difference	*LD* Predicted	*LD* Observed Mar	Difference
ME 3	12.52	5.07	-146.6%	12.52	6.12	-104.5%
ME 2	2.99	3.57	16.2%	2.99	8.93	66.5%
ME 4	2.92	11.67	75.0%	2.92	16.67	82.5%
UL10	1.36	8.00	83.0%	1.36	15.20	91.1%
UL11	1.69	3.45	50.9%	1.69	4.83	64.9%
UL12	4.87	3.33	-46.1%	4.87	3.81	-27.9%
UL13	2.89	0.00	NA*	2.89	0.00	NA*
UL8	13.20	4.16	-217.7%	13.20	6.10	-116.3%
UL19	1.71	0.63	-174.3%	1.71	0.00	NA*
RA7	26.06	10.30	-153.0%	26.06	9.90	-163.2%
RY8	6.95	6.38	-8.8%	6.95	9.26	24.9%
Mean	**7.02**	**5.14**	**-36.5%**	**7.02**	**7.35**	**4.5%**

*Cannot calculate due to a zero denominator, hence the predicted value is undefined.

For the count data in the Elaho, predicted values were very similar to observed values in the February 2016 surveys, and much lower in the March 2016 surveys (Table 31). In 2017, observed counts were greater than predicted in both February and March surveys, while observed counts were substantially lower in both 2021 surveys (Tables 32 and 33). In the Upper Lillooet, observed values were greater in all years, with February surveys having higher observed counts in 2016 and 2017 and higher observed counts in March in 2021 (Tables 34 to 36).

Table 31. *Predicted and observed mountain goat abundance (count data) for the Elaho study area, 2016*

MGWR	Count Predicted	Count Observed Feb	Difference	Count Predicted	Count Observed Mar	Difference
7	20	21	6.4%	20	25	21.4%
30	10	1	-898.9%	10	8	-24.9%
26	11	9	-27.3%	5	3	-80.5%
66	-	-	-	11	4	-186.5%
58	10	13	22.6%	10	7	-43.8%
41	5	0	NA*	5	1	-421.9%
56	1	0	NA*	5	0	NA*
39	6	0	NA*	5	9	46.7%
40	3	4	23.8%	3	5	39.0%
25	5	25	80.8%	5	2	-127.6%
31	5	4	-35.4%	20	25	21.4%
57	5	3	-74.0%	10	8	-24.9%
Total	**82**	**80**	**-2.8%**	**80**	**64**	**-24.5%**

*Cannot calculate due to a zero denominator, hence the predicted value is undefined.

Table 32. *Predicted and observed mountain goat abundance (count data) for the Elaho study area, 2017*

MGWR	Count Predicted	Count Observed Feb	Difference	Count Predicted	Count Observed Mar	Difference
7	20	16	-22.8%	20	29	32.3%
31	5	15	63.9%	-	-	-
26	11	14	18.1%	11	12	4.5%
66	5	27	83.1%	5	3	-51.8%
40	3	5	39.0%	3	0	NA*
58	10	1	-906.7%	10	1	-906.7%
41	5	0	NA*	5	1	-448.8%
57	5	5	-4.4%	-	-	-
56	1	0	NA*	1	0	NA*
39	6	0	NA*	6	1	-487.7%
25	5	18	73.4%	5	14	65.7%
Total	**77**	**101**	**24.0%**	**20**	**29**	**32.3%**

*Cannot calculate due to a zero denominator, hence the predicted value is undefined.

Table 33. *Predicted and observed mountain goat abundance (count data) for the Elaho study area, 2021*

MGWR	Count Predicted	Count Observed Feb	Difference	Count Predicted	Count Observed Mar	Difference
7	20	3	-554.9%	20	11	-78.6%
30	10	0	NA*	10	3	-233.0%
31	-	-	-	5	4	-35.4%
26	11	3	-282.0%	11	8	-43.3%
66	5	0	NA*	5	0	NA*
58	10	0	NA*	10	1	-906.7%
41	5	0	NA*	5	6	8.5%
56	1	0	NA*	1	0	NA*
39	6	0	NA*	6	0	NA*
40	3	0	NA*	3	0	NA*
25	5	10	52.0%	5	19	74.8%
Total	**76**	**16**	**-375.8%**	**82**	**52**	**-56.8%**

*Cannot calculate due to a zero denominator, hence the predicted value is undefined.

***Table 34.** Predicted and observed mountain goat abundance (count data) for the Upper Lillooet study area, 2016*

MGWR	Count Predicted	Count Observed Feb	Difference	Count Predicted	Count Observed Mar	Difference
ME 3	25	61	58.6%	25	37	31.7%
ME 2	6	8	24.0%	6	8	24.0%
ME 4	6	5	-16.7%	6	20	70.8%
UL10	3	10	72.5%	3	10	72.5%
UL11	3	5	31.4%	3	10	65.7%
UL12	-	-	-	10	0	NA*
UL13	-	-	-	6	0	NA*
UL8	27	40	33.1%	27	30	10.8%
UL19	-	-	-	3	2	-72.2%
RA7	52	21	-149.8%	52	22	-138.4%
RY8	14	37	62.1%	14	39	64.0%
Total	**137**	**187**	**26.9%**	**156**	**178**	**12.5%**

*Cannot calculate due to a zero denominator, hence the predicted value is undefined.

***Table 35.** Predicted and observed mountain goat abundance (count data) for the Upper Lillooet study area, 2017*

MGWR	Count Predicted	Count Observed Feb	Difference	Count Predicted	Count Observed Mar	Difference
ME 3	25	71	64.4%	25	33	23.4%
ME 2	6	18	66.2%	6	16	62.0%
ME 4	6	37	84.2%	6	8	27.1%
UL10	3	11	75.0%	3	10	72.5%
UL11	3	21	83.7%	3	5	31.4%
UL12	10	0	NA*	11	1	-951.3%
UL13	6	0	NA*	7	0	NA*
UL8	27	23	-16.4%	25	23	-8.3%
UL19	3	1	-234.4%	3	1	-234.4%
RA7	52	43	-22.0%	52	61	14.0%
RY8	14	36	61.1%	14	24	41.6%
Total	**156**	**261**	**40.3%**	**156**	**182**	**14.4%**

*Cannot calculate due to a zero denominator, hence the predicted value is undefined.

Table 36. Predicted and observed mountain goat abundance (count data) for the Upper Lillooet study area, 2021

MGWR	Count Predicted	Count Observed Feb	Difference	Count Predicted	Count Observed Mar	Difference
ME 3	25	34	25.7%	25	41	38.3%
ME 2	6	6	-1.3%	6	15	59.5%
ME 4	6	21	72.2%	6	29	79.9%
UL10	3	20	86.2%	3	38	92.8%
UL11	3	10	65.7%	3	14	75.5%
UL12	10	7	-41.0%	10	8	-23.4%
UL13	6	0	NA*	6	0	NA*
UL8	27	32	16.3%	27	47	43.0%
UL19	3	1	-244.5%	3	0	NA*
RA7	52	103	49.1%	52	99	47.0%
RY8	14	60	76.6%	14	87	83.9%
Total	**156**	**294**	**47.0%**	**156**	**378**	**58.8%**

*Cannot calculate due to a zero denominator, hence the predicted value is undefined.

In MGWRs where ≥80% of the forested area was burned, observed abundances (*LD* and count data) were substantially lower in both study areas (Table 37).

Table 37. Predicted and observed mountain goat abundance for MGWRs with ≥80% of the forested area burned using count and LD data for the Elaho and Upper Lillooet study areas, 2016 to 2021

Elaho	Count Data			*LD* (Mean)		
Year and Month	**Expected**	**Observed**	**Difference**	**Expected**	**Observed**	**Difference**
2016 Feb	16	4	-74.4%	1.32	0.32	-75.5%
2016 Mar	7	5	-31.6%	1.44	0.81	-44.0%
2017 Feb	16	5	-68.0%	1.32	0.40	-69.4%
2017 Mar	16	2	-87.2%	1.32	0.36	-72.6%
2021 Feb	16	0	**NA***	1.32	0.00	**NA***
2021 Mar	16	6	-61.6%	1.26	0.83	-33.8%
Upper Lillooet	**Count Data**			***LD* (Mean)**		
Year and Month	**Expected**	**Observed**	**Difference**	**Expected**	**Observed**	**Difference**
2016 Feb	NA	NA	NA	NA	NA	NA
2016 Mar	19	2	-89.6%	3.16	0.54	-83.0%
2017 Feb	19	1	-96.4%	3.16	0.27	-91.5%
2017 Mar	19	2	-89.6%	3.16	2.84	-10.1%
2021 Feb	19	8	-71.4%	3.16	1.32	-58.2%
2021 Mar	19	8	-71.4%	3.16	1.27	-59.8%

*Cannot calculate due to a zero denominator, hence the predicted value is undefined.

Summarizing the overall functioning and effectiveness ratings for individual MGWRs in each year independently, 36.4%, 41.7% and 45.5% of the MGWRs in the Elaho were considered not effective or non-functioning when using expected abundance data along with the percent of trees burned in the MGWR (Tables 38 to 43). Using trend in abundance data, along with the percentage of trees burned in the MGWR, from 2016 to 2021 and 2017 to 2021, 41.7% and 33.3%, respectively, were considered not effective or non-functioning in the Elaho (Tables 44 to 47).

Table 38. *Summary of the functioning and effectiveness ratings of MGWRs in the Elaho study area, 2016 survey*

MGWR	*LD* in MGWR[1]	Count in MGWR[1]	% of Trees in Winter Range Burned	Functioning & Effectiveness Rating	Rationale
7	At	At/Above	0	Functioning / Effective	• Habitat conditions within the UWR are likely to remain suitable/stable or possibly improve. • Key habitat features will likely be maintained in abundance. • Site continues to be used by species and populations appear stable.
31	At	Below/At	0	Functioning / Effective	• Habitat conditions within the UWR are likely to remain suitable/stable or possibly improve. • Key habitat features will likely be maintained in abundance. • Site continues to be used by species and populations appear stable.
30	Below	Below/Below	0	Functioning But at High Risk	• Conditions are likely to result in a population decline. • Key habitat elements are limiting productivity.
26	Below	Below/Below	0	Functioning But at Risk	• Conditions within the UWR may be stable or result in short-term population declines.
58	Below	Above/Below	60	Functioning But at High Risk	• Conditions are likely to result in a population decline. • Key habitat elements are limiting productivity.
41	Below/ Above	Below/Below	100	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
56	Below	Below	100	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
57	Below	Below	50	Functioning But at High Risk	• Conditions are likely to result in a population decline. • Key habitat elements are limiting productivity.
39	Below	Below	100	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
40	Below	Above	80	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
25	Below/ Above	Above	40	Functioning But at High Risk	• Conditions are likely to result in a population decline. • Key habitat elements are limiting productivity.

[1]At, above, or below expected abundance estimates.

Table 39. *Summary of the functioning and effectiveness ratings of MGWRs in the Elaho study area, 2017 survey*

MGWR	*LD* in MGWR[1]	Count in MGWR[1]	% of Trees in Winter Range Burned	Functioning & Effectiveness Rating	Rationale
7	Below	Below/Above	0	Functioning / Effective	• Habitat conditions within the UWR are likely to remain suitable/stable or possibly improve. • Key habitat features will likely be maintained in abundance. • Site continues to be used by species and populations appear stable.
30	Above	At	0	Functioning / Effective	• Habitat conditions within the UWR are likely to remain suitable/stable or possibly improve. • Key habitat features will likely be maintained in abundance. • Site continues to be used by species and populations appear stable.
26	Above	Above	0	Functioning / Effective	• Habitat conditions within the UWR are likely to remain suitable/stable or possibly improve. • Key habitat features will likely be maintained in abundance. • Site continues to be used by species and populations appear stable.
66	At/Above	Above/Below	0	Functioning / Effective	• Habitat conditions within the UWR are likely to remain suitable/stable or possibly improve. • Key habitat features will likely be maintained in abundance. • Site continues to be used by species and populations appear stable.
58	Below	Below	60	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
41	Below	Below	100	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
56	Below	Below	100	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
39	Below	Below	100	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
40	Above/ Below	Below	80	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
25	Above/At	Above	40	Functioning But at High Risk	• Conditions are likely to result in a population decline. • Key habitat elements are limiting productivity.
31	Above	Above	0	Functioning / Effective	• Site continues to be used by species and populations appear stable.
57	Below	At	50	Functioning But at High Risk	• Conditions are likely to result in a population decline. • Key habitat elements are limiting productivity.

[1]At, above, or below expected abundance estimates.

***Table 40.** Summary of the functioning and effectiveness ratings of MGWRs in the Elaho study area, 2021 survey*

MGWR	*LD* in MGWR[1]	Count in MGWR[1]	% of Trees in Winter Range Burned	Functioning & Effectiveness Rating	Rationale
7	Below	Below	0	Functioning But at High Risk	• Conditions are likely to result in a population decline. • Key habitat elements are limiting productivity.
30	Below	Below	0	Functioning But at High Risk	• Conditions are likely to result in a population decline. • Key habitat elements are limiting productivity.
26	Below	Below	0	Functioning But at Risk	• Conditions within the UWR may be stable or result in short-term population declines.
66	Below	Below	0	Functioning But at High Risk	• Conditions are likely to result in a population decline. • Key habitat elements are limiting productivity.
58	Below	Below	60	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
41	Below / Above	Below / Above	100	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
56	Below	Below	100	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
39	Below	Below	100	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
40	Below	Below	80	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
25	Below/ Above	Above	40	Functioning But at High Risk	• Conditions are likely to result in a population decline. • Key habitat elements are limiting productivity.
31	At	Below	0	Functioning / Effective	• Site continues to be used by species and populations appear stable.

[1]At, above, or below expected abundance estimates.

Table 41. *Summary of functioning and effectiveness ratings for individual MGWRs in the Elaho 2016 survey*

Functioning & Effectiveness Rating	No. MGWRs	Percent (%)
Effective or Functioning	2	18.2%
Functioning But at Risk	1	9.1%
Functioning But at High Risk	4	36.4%
Not Effective or Non-Functioning	4	36.4%
TOTAL	**11**	**100.0%**

Table 42. *Summary of functioning and effectiveness ratings for individual MGWRs in the Elaho 2017 survey*

Functioning & Effectiveness Rating	No. MGWRs	Percent (%)
Effective or Functioning	5	41.7%
Functioning But at Risk	0	0.0%
Functioning But at High Risk	2	16.7%
Not Effective or Non-Functioning	5	41.7%
TOTAL	**12**	**100.0%**

Table 43. *Summary of functioning and effectiveness ratings for individual MGWRs in the Elaho 2021 survey*

Functioning & Effectiveness Rating	No. MGWRs	Percent (%)
Effective or Functioning	1	9.1%
Functioning But at Risk	4	36.4%
Functioning But at High Risk	4	36.4%
Not Effective or Non-Functioning	5	45.5%
TOTAL	**12**	**100.0%**

Table 44. *Summary of the functioning and effectiveness ratings of MGWRs in the Elaho study area 2016 to 2021 (trend)*

MGWR	*LD* Trend	Count Trend	Confidence in *LD* Trend?	*LD* in MGWR[1]	% of Forest in Winter Range Burned	Functioning & Effectiveness Rating	Rationale
7	Declining	Declining	High	Below	0	Functioning But at High Risk	• Conditions are likely to result in a population decline. • Key habitat elements are limiting productivity.
30	Declining	Declining	Low-Moderate	Below	0	Functioning But at High Risk	• Conditions are likely to result in a population decline. • Key habitat elements are limiting productivity.
26	Declining	Stable	Low-Moderate	Below	0	Functioning But at Risk	• Conditions within the UWR may be stable or result in short-term population declines.
66	NA	NA	NA	NA	0	NA	• NA
58	Declining	Stable	Moderate-High	Below	60	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
41	Increasing	Increasing	High	Below/ Above	100	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
56	-	-	-	Below	100	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
39	-	-	-	Below	100	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
40	Increasing	Stable	High	Below	80	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
25	Declining	Increasing	Low-Moderate	Below/ Above	40	Functioning But at High Risk	• Conditions are likely to result in population decline. • Key habitat elements are limiting productivity.

[1]At, above, or below expected abundance estimates.

***Table 45**. Summary of the functioning and effectiveness ratings of MGWRs in the Elaho study area 2017 to 2021 (trend)*

MGWR	*LD* Trend	Count Trend	Confidence in *LD* Trend?	*LD* in MGWR[1]	% of Forest in Winter Range Burned	Functioning & Effectiveness Rating	Rationale
7	Declining	Declining	Moderate to High	Below	0	Functioning But at High Risk	• Conditions are likely to result in a population decline. • Key habitat elements are limiting productivity.
30	Declining	Declining	NA	Below	0	Functioning But at High Risk	• Conditions are likely to result in a population decline. • Key habitat elements are limiting productivity.
26	Declining	Increasing	High	Below	0	Functioning But at High Risk	• Conditions within the UWR may be stable or result in short-term population declines.
66	Declining	Declining	Low-Moderate	Below	0	Functioning But at High Risk	• Conditions are likely to result in a population decline. • Key habitat elements are limiting productivity.
58	Increasing	Stable	High	Below	60	Functioning But at High Risk	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
41	Increasing	Declining	Low-Moderate	Below/ Above	100	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
56	-	-	-	Below	100	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
39	-	-	-	Below	100	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
40	Declining	Declining	Low-Moderate	Below	80	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
25	Declining	Increasing	Moderate to High	Below/ Above	40	Functioning But at High Risk	• Conditions are likely to result in a population decline. • Key habitat elements are limiting productivity.

[1]At, above, or below expected abundance estimates.

Table 46. Summary of functioning and effectiveness ratings for individual MGWRs in the Elaho, 2016 to 2021 (using trend)

Functioning & Effectiveness Rating	No. MGWRs	Percent (%)
Effective or Functioning	1	8.3%
Functioning But at Risk	1	8.3%
Functioning But at High Risk	4	33.3%
Not Effective or Non-Functioning	5	41.7%
NA	1	8.3%
TOTAL	12	100.0%

Table 47. Summary of functioning and effectiveness ratings for individual MGWRs in the Elaho, 2017 to 2021 (using trend)

Functioning & Effectiveness Rating	No. MGWRs	Percent (%)
Effective or Functioning	1	8.3%
Functioning But at Risk	0	0.0%
Functioning But at High Risk	7	58.3%
Not Effective or Non-Functioning	4	33.3%
NA	0	0.0%
TOTAL	12	100.0%

The overall functioning and effectiveness ratings for each year independently in the Upper Lillooet indicate that 27.3% of the MGWRs sampled were considered not effective or non-functioning using expected abundance data and the percentage of trees burned in the MGWRs (Tables 48 to 53). Using trend in abundance data, along with the percentage of trees burned in the MGWR, from 2016 to 2021 and 2017 to 2021, the same percentage (27.3%) of MGWRs were considered not effective or non-functioning (Tables 54 to 57).

Table 48. Summary of the functioning and effectiveness ratings of MGWRs in the Upper Lillooet study area, 2016 survey

MGWR	*LD* in MGWR[1]	Count in MGWR[1]	% of Trees in Winter Range Burned	Functioning & Effectiveness Rating	Rationale
ME 3	Below	Above	25	Functioning But at Risk	• Conditions within the UWR may be stable or result in short-term population declines.
ME 2	Above	Above	60	Functioning But at Risk	• Conditions within the UWR may be stable or result in short-term population declines.
ME 4	Above	Below	5	Functioning / Effective	• Habitat conditions within the UWR are likely to remain suitable/stable or possibly improve. • Key habitat features will likely be maintained in abundance. • Site continues to be used by species and populations appear stable.
UL10	Above	Above	0	Functioning / Effective	• Habitat conditions within the UWR are likely to remain suitable/stable or possibly improve. • Key habitat features will likely be maintained in abundance. • Site continues to be used by species and populations appear stable.
UL11	Above	Above	0	Functioning / Effective	• Habitat conditions within the UWR are likely to remain suitable/stable or possibly improve. • Key habitat features will likely be maintained in abundance. • Site continues to be used by species and populations appear stable.
UL12	Below	Below	100	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
UL13	Below	Below	100	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
UL8	Below	Below	0	Functioning But at Risk	• Conditions within the UWR may be stable or result in short-term population declines.
UL19	Above	Below	99	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
RA7	Below	Below	1	Functioning But at Risk	• Conditions within the UWR may be stable or result in short-term population declines.
RY8	Above	Above	0	Functioning / Effective	• Habitat conditions within the UWR are likely to remain suitable/stable or possibly improve. • Key habitat features will likely be maintained in abundance. • Site continues to be used by species and populations appear stable.

[1]At, above, or below expected abundance estimates.

Table 49. *Summary of the functioning and effectiveness ratings of MGWRs in the Upper Lillooet study area, 2017 survey*

MGWR	*LD* in MGWR[1]	Count in MGWR[1]	% of Trees in Winter Range Burned	Functioning & Effectiveness Rating	Rationale
ME 3	Below	Above/At	25	Functioning But at Risk	• Conditions within the UWR may be stable or result in short-term population declines.
ME 2	Above	Above	60	Functioning But at Risk	• Conditions within the UWR may be stable or result in short-term population declines.
ME 4	Above	Above	5	Functioning / Effective	• Habitat conditions within the UWR are likely to remain suitable/stable or possibly improve. • Key habitat features will likely be maintained in abundance. • Site continues to be used by species and populations appear stable.
UL10	Above	Above	0	Functioning / Effective	• Habitat conditions within the UWR are likely to remain suitable/stable or possibly improve. • Key habitat features will likely be maintained in abundance. • Site continues to be used by species and populations appear stable.
UL11	Above	Above/At	0	Functioning / Effective	• Habitat conditions within the UWR are likely to remain suitable/stable or possibly improve. • Key habitat features will likely be maintained in abundance. • Site continues to be used by species and populations appear stable.
UL12	Below/ Above	Below	100	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
UL13	Below	Below	100	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
UL8	Below	Below	0	Functioning But at Risk	• Conditions within the UWR may be stable or result in short-term population declines.
UL19	Below	Below	99	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
RA7	Below	Below/Above	1	Functioning / Effective	• Conditions within the UWR may be stable or result in short-term population declines.
RY8	Below	Above	0	Functioning / Effective	• Habitat conditions within the UWR are likely to remain suitable/stable or possibly improve. • Key habitat features will likely be maintained in abundance. • Site continues to be used by species and populations appear stable.

[1]At, above, or below expected abundance estimates.

Table 50. *Summary of the functioning and effectiveness ratings of MGWRs in the Upper Lillooet study area, 2021 survey*

MGWR	*LD* in MGWR[1]	Count in MGWR[1]	% of Trees in Winter Range Burned	Functioning & Effectiveness Rating	Rationale
ME 3	Below	At/Above	25	Functioning But at Risk	• Conditions within the UWR may be stable or result in short-term population declines.
ME 2	Above	Below/Above	60	Functioning But at Risk	• Conditions within the UWR may be stable or result in short-term population declines.
ME 4	Above	Above	5	Functioning / Effective	• Habitat conditions within the UWR are likely to remain suitable/stable or possibly improve. • Key habitat features will likely be maintained in abundance. • Site continues to be used by species and populations appear stable.
UL10	Above	Above	0	Functioning / Effective	• Habitat conditions within the UWR are likely to remain suitable/stable or possibly improve. • Key habitat features will likely be maintained in abundance. • Site continues to be used by species and populations appear stable.
UL11	Above	Above	0	Functioning / Effective	• Habitat conditions within the UWR are likely to remain suitable/stable or possibly improve. • Key habitat features will likely be maintained in abundance. • Site continues to be used by species and populations appear stable.
UL12	Below	Below	100	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
UL13	Below	Below	100	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
UL8	Below	Below/At	0	Functioning But at Risk	• Conditions within the UWR may be stable or result in short-term declines.
UL19	Below	Below	99	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
RA7	Below	Above	1	Functioning But at Risk	• Conditions within the UWR may be stable or result in short-term population declines.
RY8	Below/ Above	Above	0	Functioning / Effective	• Habitat conditions within the UWR are likely to remain suitable/stable or possibly improve. • Key habitat features will likely be maintained in abundance. • Site continues to be used by species and populations appear stable.

[1]At, above, or below expected abundance estimates.

Table 51. *Summary of functioning and effectiveness ratings for individual MGWRs in the Upper Lillooet 2016 survey*

Functioning & Effectiveness Rating	No. MGWRs	Percent (%)
Effective or Functioning	4	36.4%
Functioning But at Risk	4	36.4%
Functioning But at High Risk	0	0.0%
Not Effective or Non-Functioning	3	27.3%
TOTAL	**11**	**100.0%**

Table 52. *Summary of functioning and effectiveness ratings for individual MGWRs in the Upper Lillooet 2017 survey*

Functioning & Effectiveness Rating	No. MGWRs	Percent (%)
Effective or Functioning	5	45.5%
Functioning But at Risk	3	27.3%
Functioning But at High Risk	0	0.0%
Not Effective or Non-Functioning	3	27.3%
TOTAL	**11**	**100.0%**

Table 53. *Summary of functioning and effectiveness ratings for individual MGWRs in the Upper Lillooet 2021 survey*

Functioning & Effectiveness Rating	No. MGWRs	Percent (%)
Effective or Functioning	4	36.4%
Functioning But at Risk	4	36.4%
Functioning But at High Risk	0	0.0%
Not Effective or Non-Functioning	3	27.3%
TOTAL	**11**	**100.0%**

Table 54. *Summary of the functioning and effectiveness ratings of MGWRs in the Upper Lillooet study area 2016 to 2021 (trend)*

MGWR	*LD* Trend	Count Trend	Confidence in *LD* Trend	*LD* in MGWR[1]	% of Forest in Winter Range Burned	Functioning & Effectiveness Rating	Rationale
ME2	Increasing	Declining	High	At/Above	60	Functioning But at High Risk	• Conditions are likely to result in a population decline. • Key habitat elements are limiting productivity.
ME3	Declining	Declining	Moderate	Below	25	Functioning But at High Risk	• Conditions are likely to result in a population decline. • Key habitat elements are limiting productivity.
ME4	Increasing	Increasing	Low-Moderate	Above	5	Functioning / Effective	• Conditions within the UWR may be stable or result in short-term declines.
UL8	Declining	Declining	Moderate-High	Below	0	Functioning But at Risk	• Conditions are likely to result in a population decline. • Key habitat elements are limiting productivity.
UL10	Increasing	Increasing	High	Above	0	Functioning / Effective	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
UL11	Declining	Increasing	Low-Moderate	Above	0	Functioning But at Risk	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
UL12	-	-	-	Below	100	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
UL13	-	-	-	Below	100	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
UL19	-	-	-	Below	99	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR

MGWR	*LD* Trend	Count Trend	Confidence in *LD* Trend	*LD* in MGWR[1]	% of Forest in Winter Range Burned	Functioning & Effectiveness Rating	Rationale
RY8	Declining	Increasing	Low-Moderate	Above	0	Functioning / Effective	• Habitat conditions within the UWR are likely to remain suitable/stable or possibly improve. • Key habitat features will likely be maintained in abundance. • Site continues to be used by species and populations appear stable.
RA7	Increasing	Increasing	High	Above	1	Functioning / Effective	• Habitat conditions within the UWR are likely to remain suitable/stable or possibly improve. • Key habitat features will likely be maintained in abundance. • Site continues to be used by species and populations appear stable.

[1]At, above, or below expected abundance estimates in Feb/Mar 2021 surveys.

Table 55. *Summary of the functioning and effectiveness ratings of MGWRs in the Upper Lillooet study area 2017 to 2021 (trend)*

MGWR	*LD* Trend	Count Trend	Confidence in *LD* Trend	*LD* in MGWR[1]	% of Forest in Winter Range Burned	Functioning & Effectiveness Rating	Rationale
ME2	Declining	Declining	High	Above/At	60	Functioning But at High Risk	• Conditions are likely to result in a population decline. • Key habitat elements are limiting productivity
ME3	Declining	Declining	Low-Moderate	At/Below	25	Functioning But at High Risk	• Conditions are likely to result in a population decline. • Key habitat elements are limiting productivity.
ME4	Declining	Increasing	Low	Above	5	Functioning / Effective	• Conditions within the UWR may be stable or result in short-term population declines.
UL8	Declining	Declining	High	Below	0	Functioning But at Risk	• Conditions are likely to result in a population decline. • Key habitat elements are limiting productivity.
UL10	Increasing	Increasing	High	Above	0	Functioning / Effective	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
UL11	Declining	Increasing	Low-Moderate	Above	0	Functioning But at Risk	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
UL12	Increasing	Increasing	Low-Moderate	Below	100	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
UL13	-	-	-	Below	100	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.
UL19	-	-	-	Below	99	Not Effective or Non-Functioning	• Conditions are likely resulting in significant population declines. • The species will likely be extirpated from the UWR.

MGWR	*LD* Trend	Count Trend	Confidence in *LD* Trend	*LD* in MGWR[1]	% of Forest in Winter Range Burned	Functioning & Effectiveness Rating	Rationale
RY8	Declining	Increasing	Low-Moderate	Below/ Above	0	Functioning / Effective	• Habitat conditions within the UWR are likely to remain suitable/stable or possibly improve. • Key habitat features will likely be maintained in abundance. • Site continues to be used by species and populations appear stable.
RA7	Increasing	Increasing	Low	Below	1	Functioning / Effective	• Habitat conditions within the UWR are likely to remain suitable/stable or possibly improve. • Key habitat features will likely be maintained in abundance. • Site continues to be used by species and populations appear stable.

[1]At, above, or below expected abundance estimates.

Table 56. *Summary of functioning and effectiveness ratings for individual MGWRs in the Upper Lillooet, 2016 to 2021 (using trend)*

Functioning & Effectiveness Rating	No. MGWRs	Percent (%)
Effective or Functioning	4	36.4%
Functioning But at Risk	2	18.2%
Functioning But at High Risk	2	18.2%
Not Effective or Non-Functioning	3	27.3%
TOTAL	**11**	**100.0%**

Table 57. *Summary of functioning and effectiveness ratings for individual MGWRs in the Upper Lillooet, 2017 to 2021 (using trend)*

Functioning & Effectiveness Rating	Count	Percent (%)
Effective or Functioning	4	36.4%
Functioning But at Risk	2	18.2%
Functioning But at High Risk	2	18.2%
Not Effective or Non-Functioning	3	27.3%
TOTAL	**11**	**100.0%**

When considering each study area overall (combing all individual MGWRs) from 2016 to 2021, the Elaho has a "Functioning But at High Risk" ranking based on declining abundance trends (*LD* and count data), a low kid:adult ratio, and only 8.3% of the MGWRs being effective or functioning. Conversely the Upper Lillooet has a "Functioning But at Risk" ranking based on an increasing trend in abundance (*LD* and count data), a high kid:adult ratio, and 36.4% of the MGWRs being effective or functioning (Table 58).

Table 58. *Overall summary of functioning and effectiveness ratings at a study area scale, Elaho and Upper Lillooet, 2016 to 2021 (using trend)*

LD Trend	Count Trend	Mean Kid: Adult Ratio	Percent Effective & Functioning	Overall Functioning & Effectiveness Rating
Elaho				
Declining	Declining	0.16	8.3%	Functioning But at High Risk
Upper Lillooet				
Increasing	Increasing	0.34	36.4%	Functioning But at Risk

DISCUSSION

The 2015 wildfires in the Elaho and Upper Lillooet study areas had a substantial effect on MGWR habitat condition and mountain goat abundance. The functioning and effectiveness of the MGWRs impacted by the fires varied considerably. As per Nietvelt et al. (2018) and Nietvelt (2023), the abundance of mountain goats correlates strongly with residual forest patch size, meaning that as forested area within the MGWR decreases (i.e., due to wildfire impacts), so does the abundance of mountain goats. Monitoring methods for coastal mountain goats used by Nietvelt (2023) to quantify changes in abundance proved to be a robust way of examining these relationships, and in this case, habitat changes due to wildfire.

In the Elaho study area, approximately 33% or more of the MGWRs were considered not effective or functioning following wildfires, while approximately 27% of the MGWRs in the Upper Lillooet were considered not effective or functioning. This is primarily due to the elimination of >80% of the forested area within the MGWRs. In the Elaho study area, populations of mountain goats on winter ranges that were not burned by wildfire (controls) also experienced a decline between 2016 and 2021, suggesting that there might be additional factors contributing to observed declines across the study area and these MGWRs.

Trends in Abundance

Trends in mountain goat abundance (*LD* and count data) indicated that the Elaho experienced a decline from 2016 to 2021. Moreover, MGWRs that were selected as controls (unburned) also demonstrated a decline in goat abundance, and it is not clear what the cause might be. The decline in abundance in the Elaho is also reflected in the detection probabilities, where these probabilities were lower in 2021 in all burn categories as compared to 2016 and 2017.

In contrast, trends in the abundance of mountain goats the Upper Lillooet showed a general increase in abundance, although power analysis indicates this is not significant. Moreover, the detection probabilities in the Upper Lillooet, remained the same. None of the severely burned (≥80% of the forested area burned) showed signs of mountain goat population recovery for either area.

Overall declines in abundance (*LD*) of mountain goats in the Elaho study area had adequate statistical power to detect this downward trend. Even though coefficients of variation (CV) were relatively high at approximately 96% and 72%, these declines were substantial enough (55% to 82%) to be statistically significant. Some individual MGWRs in the Elaho and the Upper Lillooet also demonstrated adequate statistical power to detect a decline (Elaho) or an increase (Upper Lillooet). Therefore, the analyses indicating that population declines occurred in the Elaho between 2016 and 2021 were real and not due to type II error (i.e., a false decline; Gerrodette 1987).

Based on calculated lambda (λ) values and kid:adult ratios (recruitment, *R*), estimated female survivorship (*S)* in the Elaho was approximately 0.70 to 0.75. To reach population stability a survivorship of approximately 0.84 would be required. Nietvelt et al. (2022) and Nietvelt (2023) found that the survivorship of a collared sample of mountain goats (male and females combined) in the Mount Meager winter range complex in the Upper Lillooet had a much lower cumulative survivorship value of 0.60 than was estimated from the broader surveys in the Upper Lillooet (0.71-0.72.)

Kid:Adult Ratios

One striking difference between the two study areas were the kid:adult ratios (see Figure 18 for an example of a nursery group). The Elaho had approximately half the proportion of kid to adults as observed in the Upper Lillooet. This analysis indicates that declines in the Elaho might be connected to poor kid recruitment and/or possibly a decline in adult female survivorship or a combination of the two (see Nietvelt 2023), in addition to the observed habitat perturbations. Summer kid:adult ratios, while more limited, indicated that kid productivity is also lower in the Elaho study area than the Upper Lillooet. While it is unclear why the kid:adult ratios are low in the Elaho, some studies have found low ratios to be negatively correlated with winter severity during pregnancy (Adams and Bailey 1982; Swenson 1985), April-May snowfall and snow depth (Thompson 1980; Hopkins et al. 1992), predation and even as a response to predation risk and stress (Dulude-de Broin et al. 2020). Blanchong et al. (2018) found low kid:adult ratios were a result of respiratory disease in an area where mountain goats were sympatric with bighorn sheep (*Ovis canadensis*) in Nevada. In another study, Pendergast and Bindernagel (1977) suspected that coal exploration correlated with a decline in mountain goat populations. Joslin (1986) found that an increase in energy exploration activity (e.g., seismic lines) coincided with a decline in adult female numbers, kid numbers, and productivity, with the productivity of females declining significantly ($r = 0.906$) in association with a cumulative increase in seismic activity.

Other potential causes for declines in the Elaho population could relate to animal health or exposure to parasites or pathogens such as the giant liver fluke (*Fascioloides magna*), *Toxoplasma gondii*, and contagious ecthyma. To date, however, none of these have been confirmed to occur in mountain goat populations in the Elaho or Upper Lillooet. The giant liver fluke is an internal parasitic flatworm in the family Trematode, and their natural hosts are members of the deer family, such as elk (*Cervus canadensis*; Pybus 2001), which overlap the range of mountain goats in the Elaho. While mountain goats and bighorn sheep (*Ovis canadensis*) are not natural hosts, giant liver flukes have been documented as a source of mortality in bighorn sheep near Radium Hot Springs, B.C. (Mathieu et al. 2022). Giant liver flukes have also been confirmed in sampled Roosevelt elk that were translocated to the Elaho (Helen Schwantje pers. comm.).

Figure 18. *A nursery group of nannies and kids in the Upper Lillooet study area.*

Coastal Versus Coastal-Transitional

While the Elaho is a coastal ecosystem, the Upper Lillooet is considered coastal-transitional (Figures 19 and 20). This means the habitat and mountain goat habitat selection display aspects of both coastal and interior ecotypes (Nietvelt et al. 2022). Kid:adult ratios as high as 25:100 to 31:100 have been observed by Smith (1984) in southeast Alaska (coastal ecosystem), which is higher than observed in the Elaho (15:100) but lower than observed in the Upper Lillooet (31:100 to 41:100). Similarly, Hebert and Turnball (1977) found a lower (<20:100) kid:adult ratio in coastal British Columbia populations versus interior populations where the ratio was >25:100. Some have suggested that coastal ecosystems are more productive than interior types where coastal mountain goats have a lower age of primiparity as evidenced by greater horn volume (Rice et al. 2021). However, Rice et al. (2021) assumed that greater horn growth means rapid body growth and hence earlier primiparity due to higher habitat productivity, although horn growth can also be related to genetics and is not related to habitat productivity (White et al. 2021; Martchenko et al. 2022). Another factor to consider is the greater winter snow depths that might limit the carrying capacity and productivity of mountain goats in purely coastal ecosystems, particularly in years with severe snow accumulations or prolonged periods of unseasonably cold and wet spring conditions. Hebert and Turnball (1977) hypothesized that the lower productivity and smaller group sizes of mountain goats observed in coastal versus interior ecosystems could be directly related to the deeper and moister snow conditions in coastal ecosystems. The Elaho study area is more of coastal ecosystem than the Upper Lillooet, and this is evidenced by the snowpack having a much higher snow water equivalent (>1,000mm versus 550mm), and a deeper snowpack. Therefore, high severity wildfires as observed in the Elaho could have a disproportionate impact on mountain goat populations due to a greater reliance on old trees for snow interception cover.

There are marked differences in mountain goat densities and *LD*s between the two study areas. In the Elaho, mountain goat densities on winter ranges where animals were observed (not just tracks), densities ranged from 0.57 to 1.52 goats per km^2, whereas the Upper Lillooet had densities ranging from 4.10 to 6.47 goats per km^2. This also reflects the *LD* in both study areas, and mountain goat density correlates strongly with the *LD* (Nietvelt 2023). These densities compare to those found in other areas, where Fox (1984) found that mountain goat densities ranged from 0.03 to 14 goats per km^2 in southeast Alaska. What also needs to be considered is that these densities were calculated in winter, and mountain goats in some instances use ≤ 14% of their total annual home range size, and female home range sizes can average only 1.0 km^2 (Poole et al. 2009; Nietvelt et at. 2022). In southeast Alaska, female mountain goats home ranges are approximately 69% less in winter than in summer (Shakeri et al. 2021).

Figure 19. *Example of a goat winter range (58) in the Elaho with a high burn intensity.*

Figure 20. *The Mount Meager goat winter range (ME 3) in the Upper Lillooet study area. After heavy snow events, goats use the trees for snow interception and security cover because the snow is shallower under the coniferous forest canopy.*

Figure 21 illustrates the impacts of fire and potential pathogens and disturbance on the Elaho mountain goat populations. While wildfire might be the primary perturbation, other factors such pathogens might be contributing factors as well.

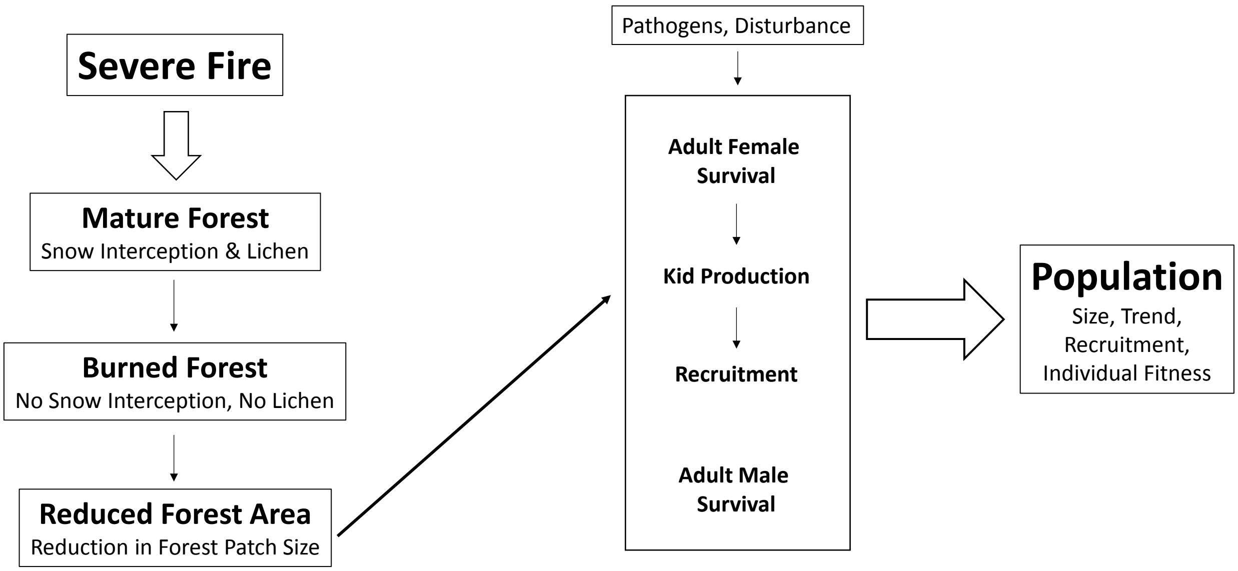

Figure 21. *A conceptual model illustrating the impacts of fire and potential pathogens and disturbance on Elaho mountain goat populations.*

Functioning and Effectiveness

This is the first attempt at applying functioning and effectiveness rankings for ungulate winter ranges. Given the impacts of wildfires on these MGWRs, in terms of forest cover loss and reduced mountain goat abundance, this evaluation can serve as an example on how to conduct other effectiveness evaluations. Two key components need to be in place for an effectiveness evaluation of this nature: measures of habitat condition and measures of animal use and abundance. As mountain goats are habitat specialists and spatially limited to the proximity of escape terrain, assessments of functioning and effectiveness are slightly more straight forward than with wider ranging species such as grizzly bears (*Ursus arctos horribilis*). However, if the seasonal habitats of the species are known and well studied and use and abundance can be calculated with a high degree of confidence to approximate trends, then assessments of functioning and effectiveness can be more easily determined.

Limitations and Caveats

There are some limitations and caveats to this analysis and data that need to be considered:

1. When the study MGWRs were first mapped, they were subsequently validated to confirm mountain goat presence. While some baseline data exists, the primary goals were not to conduct a total animal count or to count tracks but to confirm that the habitat was in fact used by mountain goats. Therefore, reliable winter baseline data pre-fire are sparse and unreliable.
2. Predicted mountain goat abundance estimates (*LD* and count data) were derived from regression equations using abundance of mountain goats post-fire. These populations were already compromised from fire, not just in abundance, but also distribution as some unburned winter ranges may have had more goats post-fire than pre-fire due to mountain goats moving away from burned to unburned winter ranges. Caution must be used when assessing whether a winter range is below, above or at an expected abundance level, except where winter ranges are burned ≥80%.
3. Some winter ranges had a single mountain goat or set of tracks, primarily winter ranges where ≥80% of the forest was completely burned. If only one animal was detected, it did not mean the winter range was occupied as it had no functioning herd or population.
4. This evaluation is on mountain goat winter range only and not summer range. Once snow clears, these burned winter ranges could serve as valuable summer range as snow is not limiting, and elevation and summer attributes are adequately met. Escape terrain is still present and grass and herbaceous vegetation can provide forage for mountain goats during this critical time (i.e., kidding, growing season).

Post-Fire Reforestation

Efforts are underway to reforest some of the burned areas adjacent to these MGWRs by planting (Codie Johnston pers. comm., RESULTS database[9]). However, the upper elevations of the MGWRs are not currently slated for active planting and these forests will have to regenerate naturally. Natural regeneration of burned forests within the MGWRs should be monitored to determine whether planting should be considered.

9 https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/silviculture/silviculture-reporting-results

SUMMARY

The 2015 wildfires had a substantial impact on the effectiveness and functioning of MGWRs in a coastal and coastal-transitional ecosystem. The wildfires did not impact the MGWRs evenly and winter ranges with ≥80% of the trees burned were no longer effective or functional. This is the first post-fire evaluation of MGWRs, and monitoring methods presented by Nietvelt (2023) provided a robust way to examine the effectiveness and functioning of MGWRs. This is also the first attempt at using a modified effectiveness and functioning framework as presented by Erikson et al. (2009) and presents a useful approach for examining whether a WHA or UWR is functional or not. Once an evaluation is complete, key habitat elements and disturbances can then be recovered or mitigated to make the WHA or UWR more effective and functional. As mountain goats are highly specialized in their habitat requirements, particularly by proximity to escape terrain, even MGWRs that have experienced ≥80% of the trees burned should be retained as mountain goat habitat. While habitat use by mountain goats has shown to be greatly reduced in the winter months in these burned winter ranges, mountain goats might continue to use these areas during the summer as escape terrain is a limiting habitat feature on the land base.

Post-fire forest regeneration within the burned MGWRs needs to be evaluated over the long-term to determine whether planting is required.

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