FIRE AND BIGHORN SHEEP IN THE SAN GABRIEL MOUNTAINS:

FORTY YEARS OF LESSONS LEARNED

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The year 2020 has been unlike most. Among issues constantly in the news, have been the prevalence and extent of devastating wildfires across the western United States and, in particular, in California. Fire plays an integral role in many ecosystems, but especially in the fire-adapted chaparral ecosystems of southern California. Chaparral is widespread in the transverse ranges, which extend from Santa Barbara County eastward nearly 400 km to the Little San Bernardino Mountains in central San Bernardino County. Chaparral comprises the dominant vegetation type at elevations below about 1,800 m on the coastal slope of several of the transverse mountain ranges, including the San Rafael, San Gabriel and San Bernardino mountains, all of which support populations of bighorn sheep.

The critically important role of fire in chaparral ecosystems is well known, and its role in producing and maintaining abundant, high-quality forage for mule deer and other ruminants has long been recognized. Not only are bighorn sheep occupying the chaparral of Southern California the recipients of nutritional benefits associated with fires, but they also benefit from the openness of vegetation created by fires. Although the advantages of periodic fire are not restricted to bighorn sheep occupying chaparral-dominated systems, they likely benefit disproportionately more when compared to bighorn sheep occupying other ecosystems.

Fire is an important ecological process, but the USFS had emphasized a policy of fire suppression for many decades. In 1970, that policy was modified from one of fire suppression to that of fire management. Nevertheless, fire suppression has remained a dominant factor affecting the chaparral ecosystem and its wildlife. In the early 1970s, Dick Weaver—who for three decades was my mentor in the California Department of Fish and Game—recommended a let-burn policy for fires affecting bighorn sheep habitat in the San Gabriel and San Bernardino mountains. Since then, others have advocated strongly for such a policy. In 1981, about three years into our intensive investigation of bighorn sheep occupying the San Gabriel Mountains, the late Steve Holl and I developed a number of univariate models depicting the hypothetical value of various habitat components to mule deer and bighorn sheep, and presented that information at an international symposium addressing the management and dynamics of vegetation in Mediterranean-type ecosystems—as represented by chaparral in Southern California—and also emphasized the constraints on habitat management options. One of our models (Figure 1) emphasized the inverse relationship between availability of cover and forage, and the relative benefit of the cover to forage ratio for those two species. Two years later, in 1983, after completing our in-depth work in the San Gabriel Mountains, Steve and I concluded that management actions should be directed specifically at vegetation manipulation in chaparral and oak vegetation types to enhance habitat quality for bighorn sheep, and the recommendation to use prescribed fire for that purpose has been a recurring theme in our work since then.

Following a steep decline in the bighorn sheep population (Figure 2), we conducted an exhaustive review of fire histories and population dynamics of bighorn sheep in the San Gabriel

Mountains. As a result, we concluded that bighorn sheep respond positively in numbers following fires of adequate scope, and that the combined benefits to forage and habitat openness lasted for about 12 years. As post-fire vegetation succession (i.e., increase in vegetation density) occurred, habitat quality for bighorn sheep declined, and their distribution became increasingly restricted as a result of increased canopy cover. Increased cover resulted in a decline in habitat availability, a concomitant decline in forage quality for both mule deer and bighorn sheep, and a decline in openness (i.e., visibility) that likely led to an increase in susceptibility of bighorn sheep to predation. Collectively, these contributed to the decreasing population. We also identified prescribed fire as the only practical method of enhancing habitat quality for bighorn sheep in the chaparral ecosystems occupied by bighorn sheep, and concluded that the Angeles and San Bernardino national forests, which share administrative responsibilities for that part of the San Gabriel Mountains currently occupied by bighorn sheep, must implement prescribed ignitions to enhance habitat quality. Any such action would also lead to an increase in mule deer numbers, and probably also in mountain lions, but we hypothesized that predation pressure on bighorn sheep would decline. Ecosystems are complex entities!

In 2008, we published a habitat-selection model based on the springtime distribution of bighorn sheep from 1979 to 2002, during which time we recorded locations of 1,171 social groups. The model included multiple variables that generally are associated with bighorn sheep, among which are elevation, slope, hillshade, terrain ruggedness, distance to roads, distance to trails, aspect of slope and others. That work was the first to consider fire history (i.e., time since the last fire at a specific location) as a potential explanatory variable. Although we identified highly significant relationships between the distribution of bighorn sheep and a number of variables, our results indicated that fire history had an overwhelming influence on distribution of bighorn sheep on springtime ranges relative to the other variables. In our final model, fire history was the factor most apt to influence openness, enhance forage quality, and increase forage availability, each of which is extremely important to bighorn sheep, and can be manipulated through management. Further, we determined that the benefits associated with fire lasted only 15 years, a period after which burned areas were no longer selected by bighorn sheep. The initial step in exploring that question involved establishing a baseline of bighorn sheep distribution that resulted from our long-term investigation. To do that, we plotted the observations of bighorn sheep on winter-spring ranges that we recorded during aerial surveys from 1979–2002 (Figure 3).

We next used the results of our model to develop an estimate of how much bighorn sheep habitat existed during three specific years of disparate population levels, and that were relative indicators of the amount of bighorn sheep habitat existing each of those years. In 1980, at which time the population of bighorn sheep was near its maximum, we identified a total of 486 km^2 of likely suitable habitat across the mountain range (Figure 4). In 2002, following the dramatic decline in bighorn sheep numbers described previously and after 85% of the winter-spring ranges had not burned for 18 years and the population was near its low point, we identified a total of only 390 km^2 of suitable bighorn sheep habitat in areas occupied by bighorn sheep (Figure 5). In 2004, following a series of major wildfires that burned extensively in the San Gabriel Mountains, we identified 422 km^2 of bighorn sheep habitat in areas occupied by bighorn sheep (Figure 6). Finally, we modeled the amount of suitable bighorn sheep habitat that would be created if the entire San Gabriel Mountains were to burn simultaneously, and predicted 615 km^2 of bighorn

sheep habitat, as defined by our model, would be created in areas currently occupied by bighorn sheep (Figure 7).

Over the next several years, Steve and I further explored relationships among habitat quality, fire histories or fire-return intervals, indices to the mule deer population, indices to the mountain lion population, estimates of the bighorn sheep population, and the amount of high suitability habitat resulting from fire (HSF) made available on a yearly basis. In 2010, we published our analyses describing the complex relationships among the variables considered in those analyses. All evidence pointed to the importance of fire in driving the bighorn sheep population, and the strong relationship between amount of habitat burned and the estimated number of bighorn sheep occupying the mountain range following those fires (Figure 8).

For the previous 50 years, management of bighorn sheep habitat in the San Gabriel Mountains had been limited to suppressing all wildfires in the fire-adapted ecosystem occupied by those specialized ungulates, and population management had been limited to the removal of 66 bighorn sheep for translocation to the San Rafael Mountains on the Los Padres National Forest, Ventura County. The value of fire to bighorn sheep occupying the transverse ranges has been recognized since 1970, implementation of prescribed fire to benefit bighorn sheep has been encouraged consistently since 1983, and the bighorn sheep restoration plan identified prescribed ignitions as the most effective way to enhance habitat suitability and increase the number of bighorn sheep. With one exception that treated an area of 1 km^2 on the South Fork Lytle Creek Winter-Spring Range, however, I am aware of no such ignitions that have been implemented. Steve and I concluded that local perceptions and official policies or legislation—including how the Wilderness Act is interpreted—that constrain the use of prescribed fire, or even use of natural ignitions to improve habitat suitability for bighorn sheep, must be modified before population objectives for bighorn sheep in the San Gabriel Mountains, and elsewhere in the transverse range, can be achieved.

Following publication of the results described above in what we dubbed the "Fire and Rain" paper, we concentrated our efforts on exploring the effects of season and size of fires, and the anticipated responses of bighorn sheep to variation in those variables. We suggested in 2012, that the 'natural' fire regime likely had included smaller, variable-intensity fires that burned primarily during summer and, in many cases, probably were ignited by indigenous peoples prior to European settlement. These fires would have influenced availability and distribution of high suitability habitat created by fires (HSF). We hypothesized that smaller summer fires during contemporary times also would increase the amount of HSF while simultaneously reducing variability in available HSF on an annual basis; the outcomes of our modeling exercises were consistent with those predictions. We concluded that small fires implemented by prescription can help stabilize and maintain a self-sustaining population of bighorn sheep in the San Gabriel Mountains. Nevertheless, the size of even small fires continues to be constrained by policies that dictate exclusion and suppression, or by legislation in the form of the Wilderness Act, that precludes vegetation manipulation designed to benefit a single species.

We also concluded that the application of prescribed fire across small areas resulting from summer ignitions were preferable to the large fires that typically are associated with fall ignitions and strong Santa Ana winds and that result in massive conflagrations. We arrived at

this conclusion because a mosaic of areas that spanned a range of time since the most recent ignition yields a variety of habitat patches of differing quality as a result of post-fire succession when compared to a huge conflagration. After large fires, vegetation over vast areas simultaneously increases in density and becomes less nutritious, and continues to do so largely unabated until a climax stage is reached, or the next conflagration occurs.

Following the capture of bighorn sheep in the San Gabriel Mountains and their release in the San Rafael Mountains in 1985 and 1987, we monitored the distribution of those animals for nearly five years. Using those data, we examined habitat selection by the translocated animals and the results of that investigation were published in 2019. Working with several talented colleagues, we used sophisticated techniques that had become available since 2008 when our initial work in the San Gabriel Mountains was published. We developed several models explaining habitat selection by those translocated animals and, not surprisingly, we found a similar relationship between habitat selection by bighorn sheep and time elapsed since the most recent fire (Figure 9). In the San Rafael Mountains, bighorn sheep selected areas that had burned more recently than were available across the landscape, and there was a strong seasonal effect of time-since-fire during winter, spring and fall. These results were consistent with expectations about habitat use by large herbivores dependent on the best available forage and widely open terrain to detect predators.

In September and October of 2020, the Bobcat fire burned nearly 485 km^2, including much of the San Gabriel Wilderness, an area of dense, decadent brush that had not experienced fire in many years (Figure 10). Eleven years ago, the Station Fire burned about 650 km^2 in the central portion of the San Gabriel Mountains (Figure 11), but did not burn occupied bighorn sheep habitat. As a result of the Bobcat Fire, however, the area burned in the Station Fire is now contiguous with habitat occupied by bighorn sheep occupying the San Gabriel Wilderness Winter-Spring Range (SGW). Thus, the Bobcat Fire may provide an opportunity for bighorn sheep to establish themselves in additional areas northwest and southwest of the area occupied by bighorn sheep on the SGW (Figure 3). Moreover, an even larger amount of bighorn sheep habitat would be predicted to be HSF winter-spring range if the entire mountain range were to burn (Figure 7). While I am unaware of records of bighorn sheep occupying areas west of the current SGW on a permanent basis, there is the potential for bighorn sheep to establish themselves in areas burned by the Bobcat Fire and possibly even further west in the area burned by the Station Fire in 2009 (Figures 10 and 11). Such an event would be positive for bighorn sheep, mule deer and mountain lions, and could create further interest in management options for chaparral habitat and bighorn sheep in the San Gabriel Mountains.

Dr. Vern Bleich worked for the California Department of Fish and Game for 34 years, during which time he worked extensively with large mammals occupying the Great Basin, Mojave, and Sonoran deserts of California, and with bighorn sheep occupying the San Gabriel Mountains. He currently is Research Professor at the University of Nevada Reno, and remains actively involved in conservation and research activities. In 2019 he was appointed to the National Wild Horse and Burro Advisory Board, on which he represents wildlife conservation interests. Persons interested in the papers referenced in this article can request copies by contacting Vern directly (vcbleich@gmail.com).

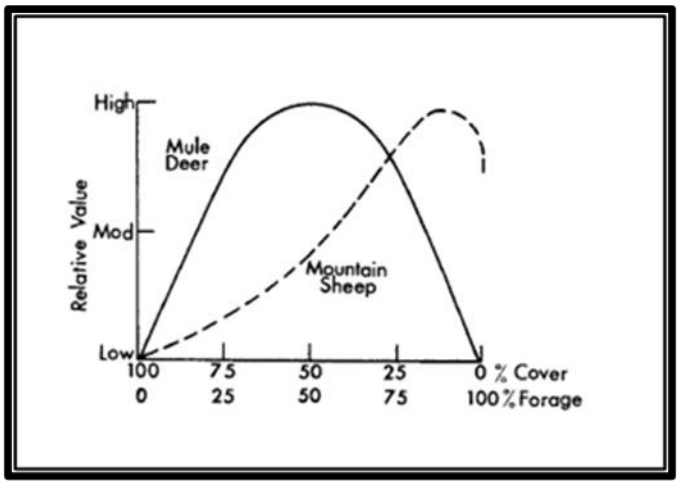

Figure 1. The cover to forage ratio and its hypothetical relative value to mule deer and bighorn sheep in chaparral ecosystems of southern California. Adapted from Bleich and Holl (1982).

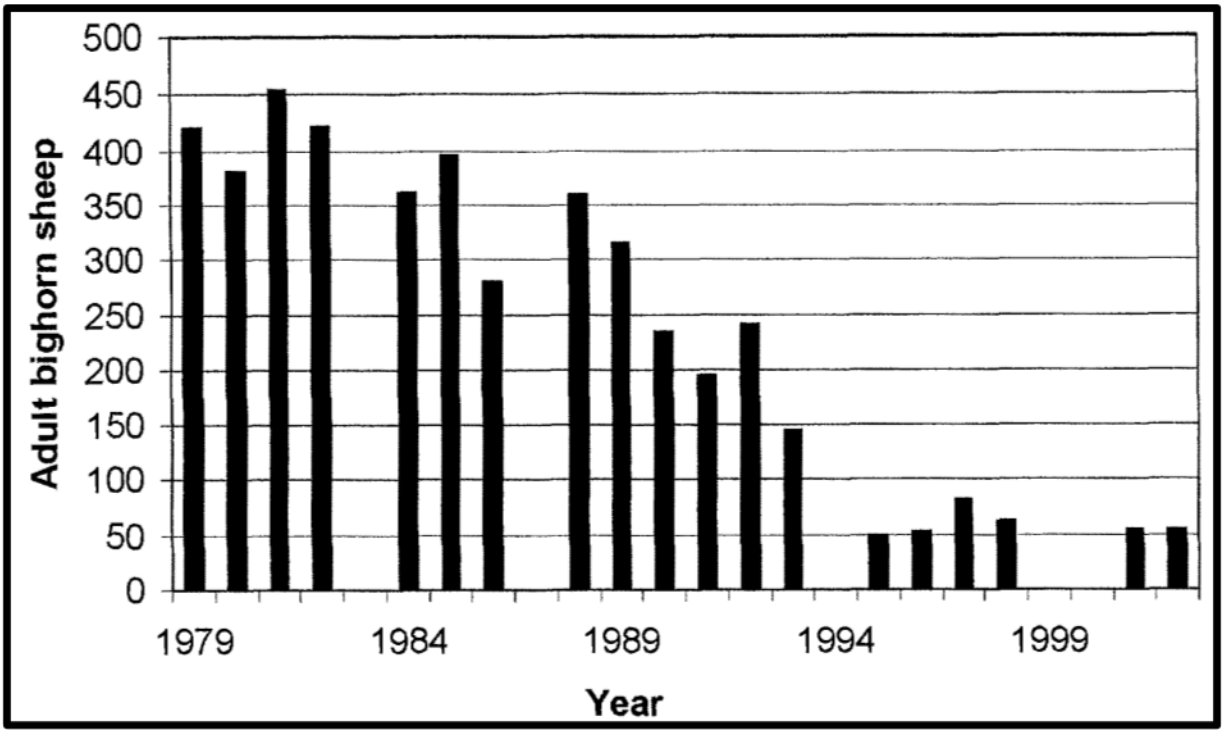

Figure 2. Total number of bighorn sheep counted during aerial surveys of the San Gabriel Mountains from 1979 to 2002. Adapted from Holl et al. (2004).

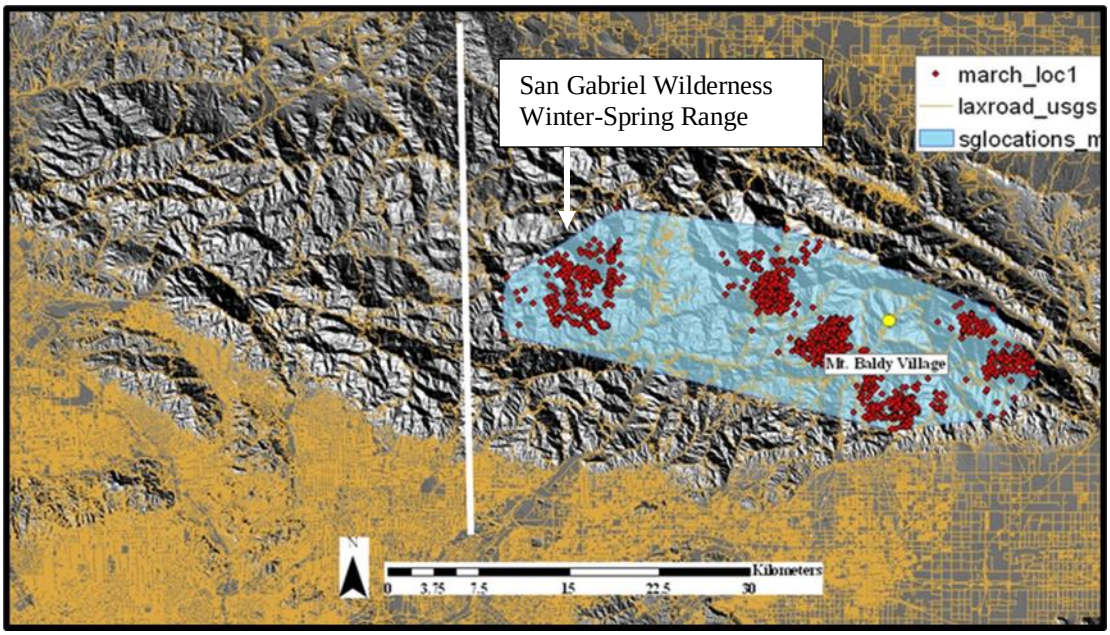

Figure 3. Locations at which bighorn sheep were observed during aerial surveys 1979 to 2002. The white vertical line approximates the westernmost distribution of bighorn sheep in the San Gabriel Mountains, and is included for reference. Also shown for reference is Mt. Baldy Village. The blue area is what is referred to as the minimum convex polygon, and includes all observations of bighorn sheep groups included in our analyses. Note that scales differ between this map and the following maps. Adapted from Bleich et al. (2008).

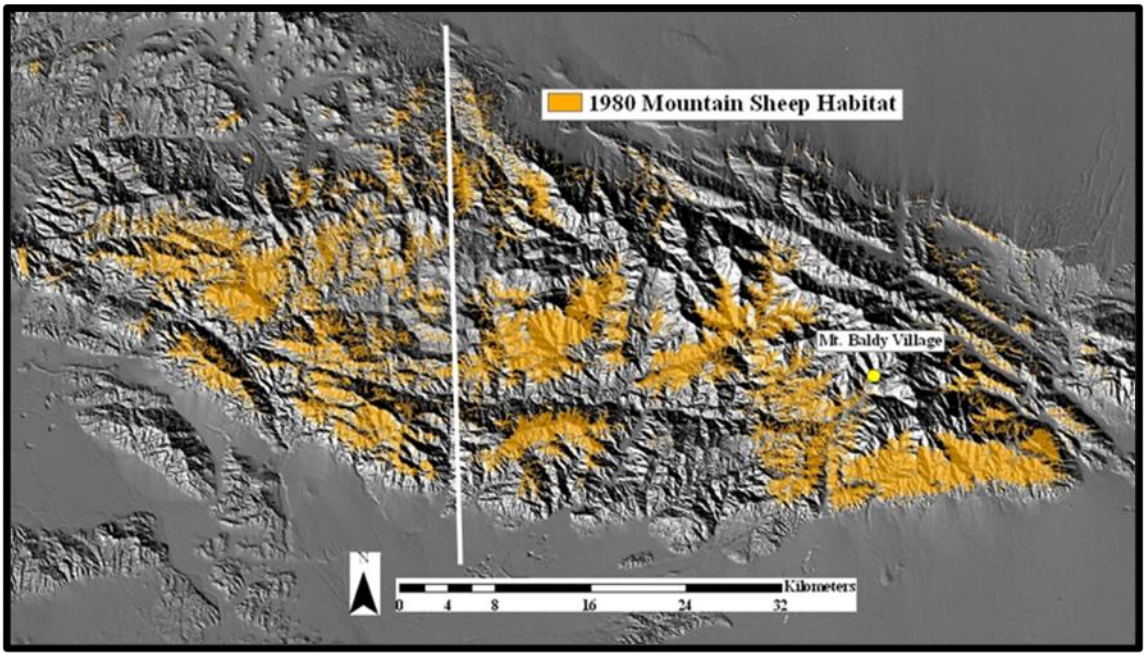

Figure 4. The amount of habitat that that would be selected by bighorn sheep in 1980, at which time the population of bighorn sheep was near its maximum. Bighorn sheep occur only east of the vertical line, and available habitat does not imply occupancy, in part because of the insular nature of suitable habitat, the distribution of burns no more than 15 years old, and the reticence of bighorn sheep to pioneer new areas. Adapted from Bleich et al. (2008).

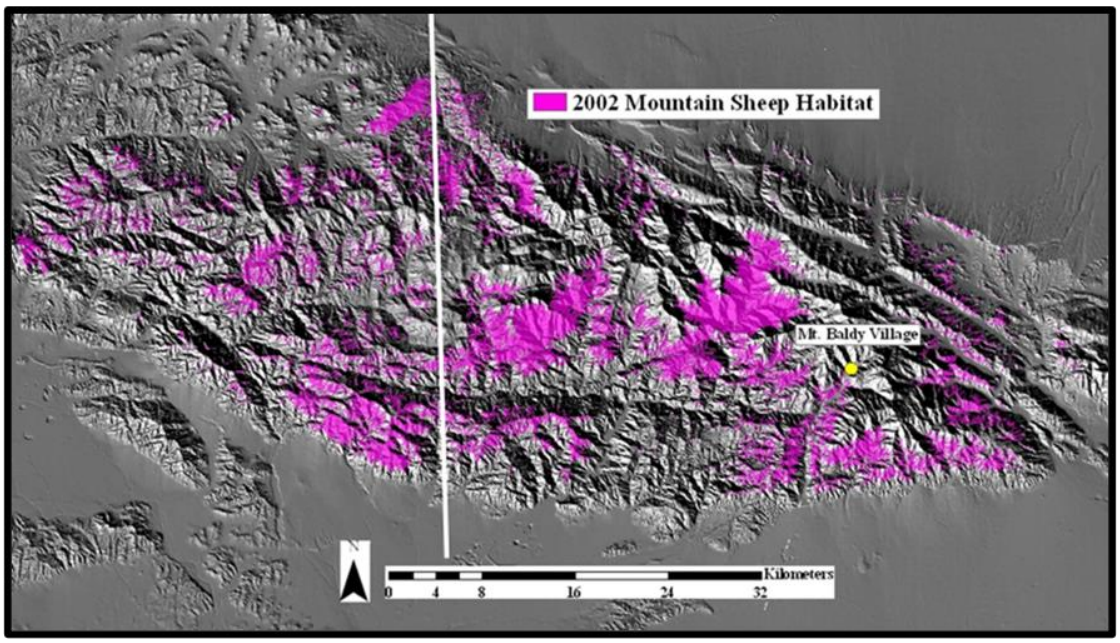

Figure 5. The amount of habitat that would be selected by bighorn sheep in 2002, at which time the population of bighorn sheep was near its minimum; the caveats listed in Figure 4 apply. Adapted from Bleich et al. (2008).

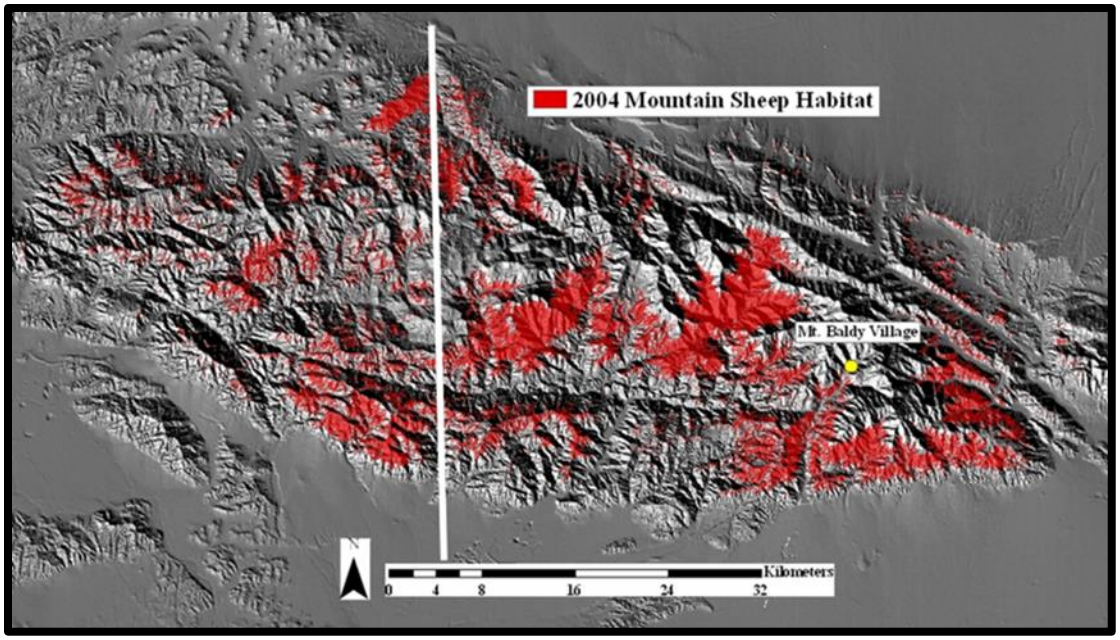

Figure 6. The amount of habitat that would be selected by bighorn sheep in 2004, after a series of wildfires that occurred during the previous several years, and at which time the bighorn sheep population began to increase; the caveats listed in Figure 4 apply. Adapted from Bleich et al. (2008).

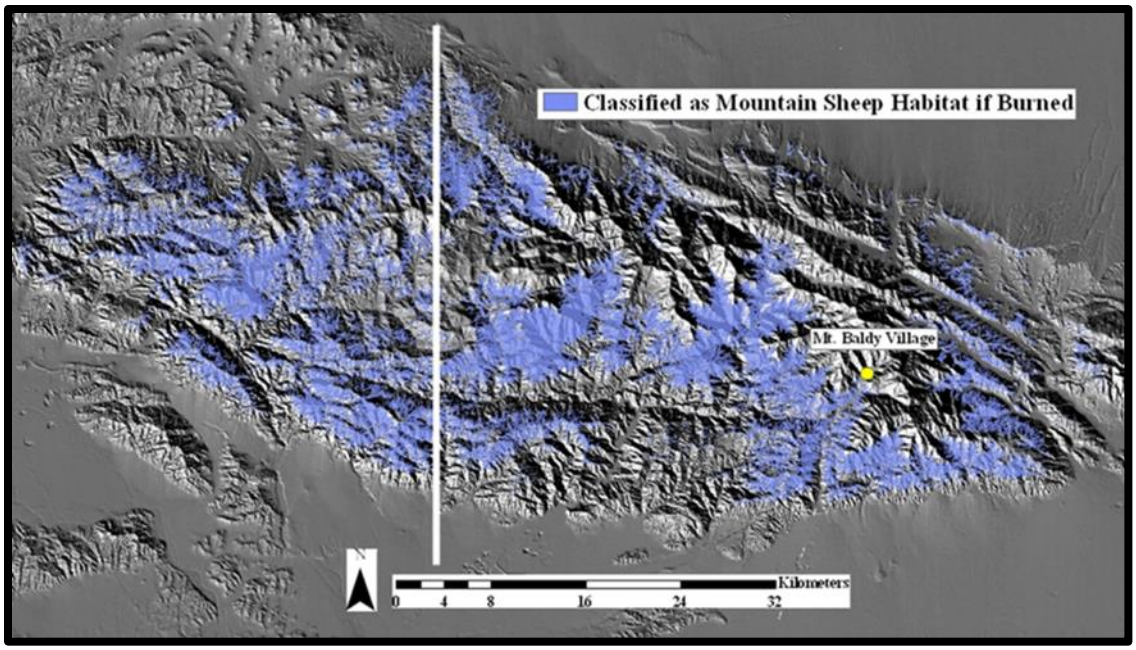

Figure 7. The amount of habitat that would be selected by bighorn sheep in the San Gabriel Mountains if the entire mountain range were to burn simultaneously. It can be inferred from this and the other figures, that translocations of bighorn sheep, if combined with appropriate management strategies, have the potential to yield a far wider distribution and many more bighorn sheep than currently exist in that mountain range. Recall that, at this time, bighorn sheep are not known to occupy areas west of the vertical white line on a permanent basis. Adapted from Bleich et al. (2008).

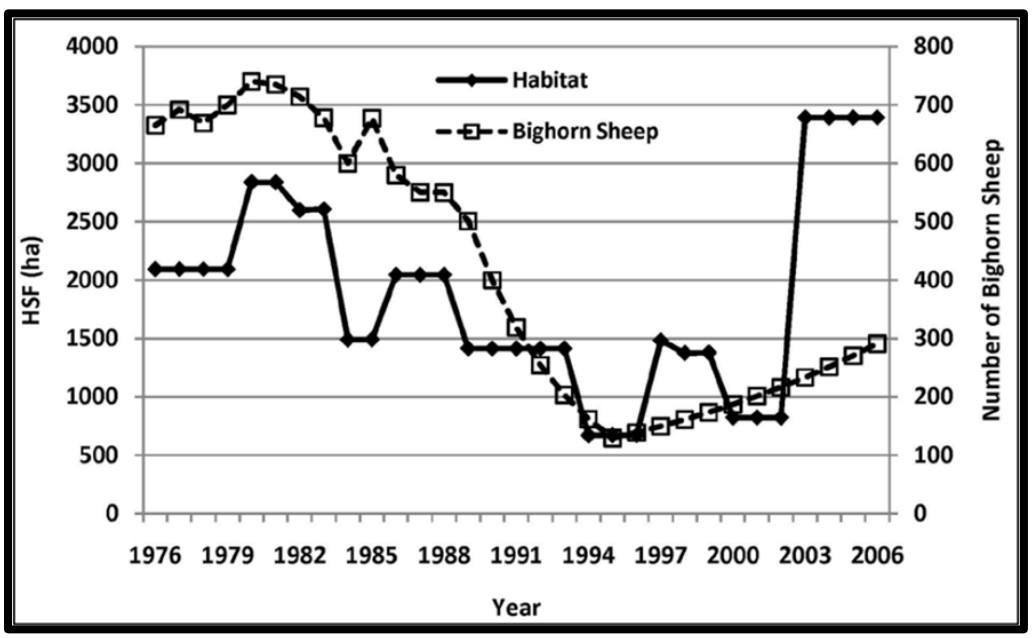

Figure 8. Relationship between the amount of high suitability habitat resulting from fire (HSF) and number of bighorn sheep estimated to occupy the San Gabriel Mountains from 1976 to 2006. Adapted from Holl and Bleich (2010).

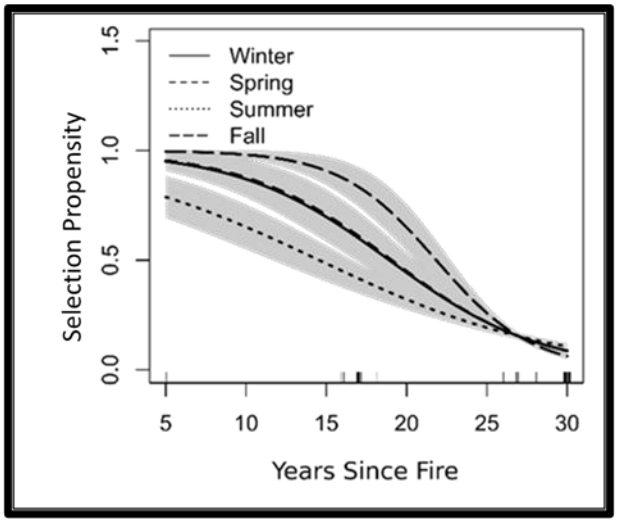

Figure 9. Propensity of bighorn sheep in the San Rafael Mountains, Ventura County, to select areas burned during Winter, Spring, Summer, and Fall, with all other model covariates (e.g., slope, aspect, elevation, etc.) held at their mean values, as a function of years since fire. The gray shading represents the 95% confidence interval associated with each of the propensity curves. Adapted from Bleich et al. (2020).

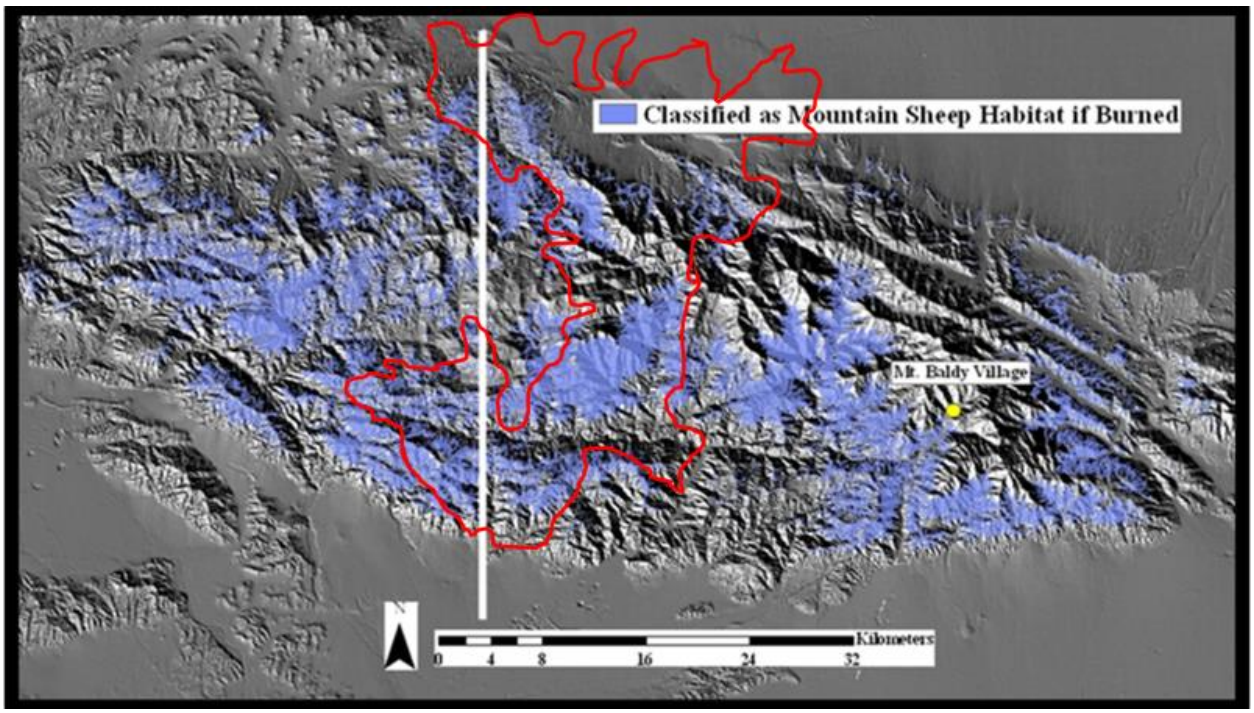

Figure 10. Approximate boundary (red polygon; 460 km^2) of the Bobcat Fire in the central San Gabriel Mountains. Much of the area in the center of the polygon is wilderness, and had not burned for many years. Bighorn sheep inhabit this area, and the Bobcat fire will enhance habitat for those bighorn sheep, mule deer, and mountain lions for the next 15 or so years. The fire may provide an opportunity for bighorn sheep to expand their distribution to the northwest and southwest of the area in which they currently are concentrated, as shown in Figure 3, and potentially into the area burned by the Station Fire in 2009, as illustrated in Figure 11.

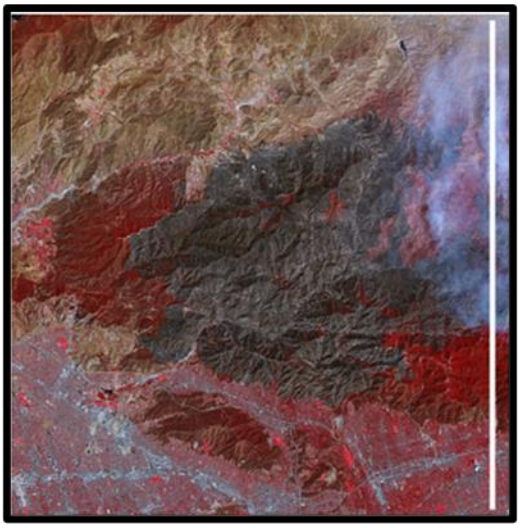

Figure 11. The Station Fire of 2009 burned approximately 650 km^2 in the central portion of the San Gabriel Mountains, but west of that part of the mountain range occupied by bighorn sheep utilizing the San Gabriel Wilderness Winter-Spring Range. This image illustrates the area burned in that conflagration, and is at about the same scale as other figures in this article. For reference, the vertical line approximating the western edge of the Bobcat Fire is shown, and proximity of the area burned in the Station Fire to the western edge of the current distribution of bighorn in the San Gabriel Mountains can be visualized by comparing figures 10 and 11.