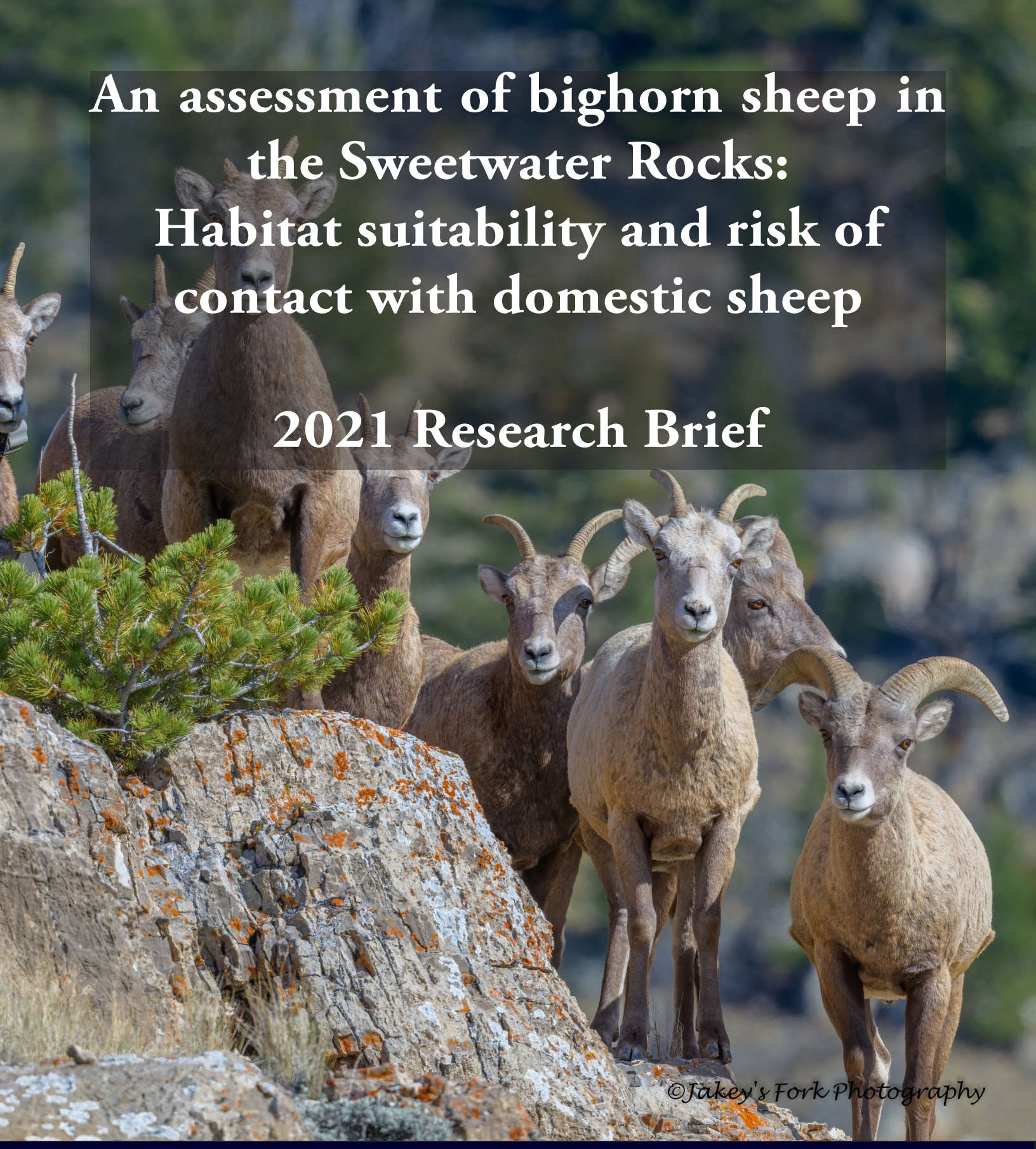
An assessment of bighorn sheep in the Sweetwater Rocks: Habitat suitability and risk of contact with domestic sheep

2021 Research Brief



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PROJECT BACKGROUND

Mountain sheep were extirpated from much of their historical range by the early 1900s largely due to overharvest, habitat loss and fragmentation, and diseases originally transmitted from domestic animals (Buechner 1960, Foreyt and Jessup 1982, Krausman 2000). However, with the rising of the conservation movement in the 20th century, restoration of wild sheep has been successful (Hurley et al. 2015). Translocations became one of the most valuable and successful tools in restoring mountain sheep to previously occupied ranges (Singer et al. 2000a, Singer et al. 2000c).

Though successful as a whole, not every translocation effort resulted in establishment of a viable population. In a review of 100 translocations between 1923 and 1997, 41% were successful (Singer et al. 2000b). Indeed, animals are uniquely adapted to the environment in which they reside, from their movement tactics (Aikens et al. 2017), to their nutritional dynamics (Monteith et al. 2013), and to their reproductive timing (Whiting et al. 2011). Therefore, as biologists came to appreciate, the source population of sheep and the habitat of the translocation site played a crucial role in the success of translocation efforts (Whiting et al. 2011, Lula et al. 2020).

Contact between domestic and wild sheep poses significant risk to wild sheep (Onderka and Wishart 1988, Foreyt et al. 1994, George et al. 2008) via transmission of pneumonia-causing pathogens. Spatial and temporal separation between the two species, therefore, is a commonly suggested or required mitigation tactic (Western Association of Fish and Wildlife Agencies Wild Sheep Working Group 2012) and managers are beginning to use risk of contact analyses to further assess the risk of disease transfer under various separation strategies (Clifford et al. 2009, Cahn et al. 2011, Carpenter et al. 2014, O'Brien et al. 2014). In Wyoming, conducting a domestic sheep risk assessment is required by Wyoming State Law (Wyo. Stat. § 11-19-604) and Wyoming Game and Fish Commission regulation (Chapter 66) prior to any new bighorn sheep translocations.

The Sweetwater Rocks area of central Wyoming has been a point of consideration for bighorn sheep reintroduction since the 1970s. Although a small population was established from 2 small transplants in the 1940s, the population failed to persist and has been considered nonexistent since the early 1980s. Given recent interest amongst local landowners and others in the region, the question of restoring bighorn sheep to the Sweetwater Rocks area has been reinvigorated. Since the time of the early discussions to restore sheep to the area in the 1980s, analytical techniques and animal movement data have undergone massive advances which yields greater opportunity for predicting viable sheep ranges (Pérez et al. 2012, Clapp et al. 2014, Lula et al. 2020) and greater power in leveraging existing data to make better informed decisions about the likelihood of successful restoration.

Herein, we evaluated the viability of a reintroduction of Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) to the Sweetwater Rocks. First, we predicted seasonal probability of use by male and female bighorn sheep in the Sweetwater Rocks area using GPS data from a nearby bighorn sheep population. Second, we estimated the potential risk of contact of bighorn sheep translocated to the Sweetwater Rocks and nearby grazing allotments for domestic sheep.

STUDY AREA

The bighorn sheep population that occurs in the Ferris and Seminoe mountain ranges of south-central Wyoming have been augmented by translocations in the early 2000s. Following a history of translocations and habitat enhancements (Clapp et al. 2014) there are ~300 bighorn sheep in the population, currently. The Sweetwater Rocks is adjacent to the Ferris-Seminoe (Fig. 1) and both areas consist of high-desert habitat dominated by rocky outcrops and sagebrush-grasslands. Given the spatial proximity and similarities of habitat in the Ferris-Seminoe and Sweetwater Rocks, we anticipate resource use patterns of bighorn sheep to be similar in both areas. For the analyses herein, we used GPS locations from 22 male and 89 female bighorn sheep that were translocated to the Ferris-Seminoe starting in 2009 (Fig. 1).

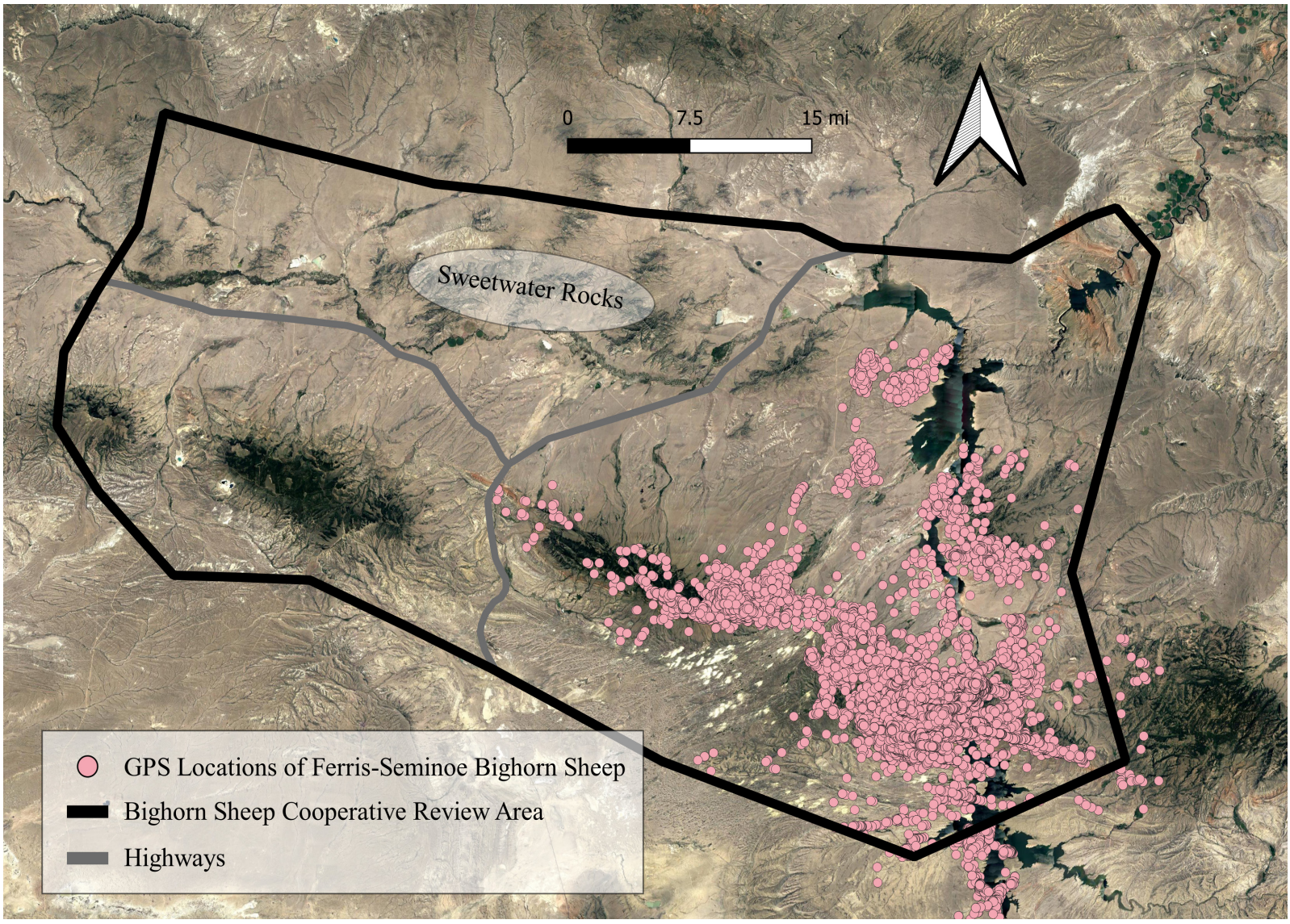

Figure 1. GPS locations of bighorn sheep that were translocated into the Ferris-Seminoe herd unit of south-central Wyoming, 2009–2018. The black polygon is an outline of the Cooperative Review Area outlined in the State-wide Bighorn/Domestic Sheep Interaction Plan which encompasses both the Ferris-Seminoe and the Sweetwater Rocks.

PREDICTED SPACE USE

We used random forest models to predict areas that translocated bighorn sheep would use relative to the available resources of known importance to bighorn sheep, including distance to escape terrain, habitat type, and topographic ruggedness (see Table 1 for all variables used for modeling). Random forest models are a form of machine learning that use a series of decision trees to classify spatial areas into used or unused. The models are trained by comparing all input variables between used points (GPS locations) and available points (randomly selected points). Random forest models tend to have greater predictive accuracy than traditional modeling approaches (Shoemaker et al. 2018). We created separate models for male and female bighorn sheep during summer and winter seasons, and then used the models to predict space use within the Sweetwater Rocks area. We defined summer and winter seasons by the mean date of migration derived from the few animals that migrated in the Ferris-Seminoe population (summer = 23 May–24 Oct; winter = 25 Oct–22 May).

Table 1. List of Variables used in predicting space use of bighorn sheep.

Variable	Type	Source/Reference
Elevation (m)	Topography	Digital Elevation Model (DEM); National Elevation Data; U.S. Geological Survey 2009
Distance to terrain with > 30-degree slopes (m)	Topography	Extracted from DEM using Raster package in R; DeCesare et al. 2006
Distance to terrain with > 60-degree slopes (m)	Topography	Extracted from DEM using Raster package in R
Distance to terrain ruggedness index > 5 (m)	Topography	Extracted from DEM using Raster package in R; Wilson et al. 2007
Slope (degrees)	Topography	Extracted from DEM using Raster Package in R
Slope > 30 degrees	Topography	Extracted from DEM using Raster package in R; DeCesare et al. 2006
Topographic radiation aspect index	Topography	Extracted from DEM using Raster package in R
Topographic ruggedness index	Topography	Extracted from DEM using Raster package in R; Wilson et al. 2007
Percent cover of annual forb-grass	Land Cover	Rangeland Analysis Platform; Jones et al. 2017, Allred et al. 2021
Percent cover of bare ground	Land Cover	Rangeland Analysis Platform; Jones et al. 2017, Allred et al. 2021
Percent cover of litter	Land Cover	Rangeland Analysis Platform; Jones et al. 2017, Allred et al. 2021
Percent cover of perennial forb-grass	Land Cover	Rangeland Analysis Platform ; Jones et al. 2017, Allred et al. 2021
Percent cover of tree	Land Cover	Rangeland Analysis Platform ; Jones et al. 2017, Allred et al. 2021
Integrated normalized difference vegetation index	Vegetation	Landsat NDVI; Robinson et al. 2007, Bischof et al. 2012
Distance to release location (m)	Other	Wyoming Game and Fish Department

All models had high predictive power and low error rates (3.29–5.83% out-of-bag error rates; Fig 1–8). Out-of-bag error is the mean prediction error of the random forest training samples. Among all models, the most important variable in predicting space use of bighorn sheep was distance to the location from which translocated bighorn sheep were released. Considering the low dispersal observed in the Ferris-Seminoe sheep (25%) and the relatively short distance animals moved when they did disperse (< 19 miles), distance to release location is an important driver of the space translocated bighorn sheep are likely to use (Dwinnell et al. 2019). Often there is unoccupied habitat following a translocation because of the reluctance of bighorn sheep to disperse (Singer et al. 2000b).

To assess space use of bighorn sheep in the absence of the influence of release location and thus, predict viable sheep habitat without it being constrained by release location, we implemented each model with and without distance to release location as a variable (Fig. 1–8). Other variables of importance among models were distance to escape terrain, topographic ruggedness, and bare rocky land cover. Whether or not release location was included in the model structure, model predictions identified high-quality habitat for bighorn sheep in the Sweetwater Rocks. When accounting for release location, areas of high probability of use were constrained to the area near the possible release locations. When distance to release location was removed from the model, additional areas of high-quality habitat become evident within Sweetwater Rocks area. Overall, Sweetwater Rocks contains suitable bighorn sheep habitat for both males and females during winter and summer (Fig. 1–8).

Predicted Use by Females in Summer

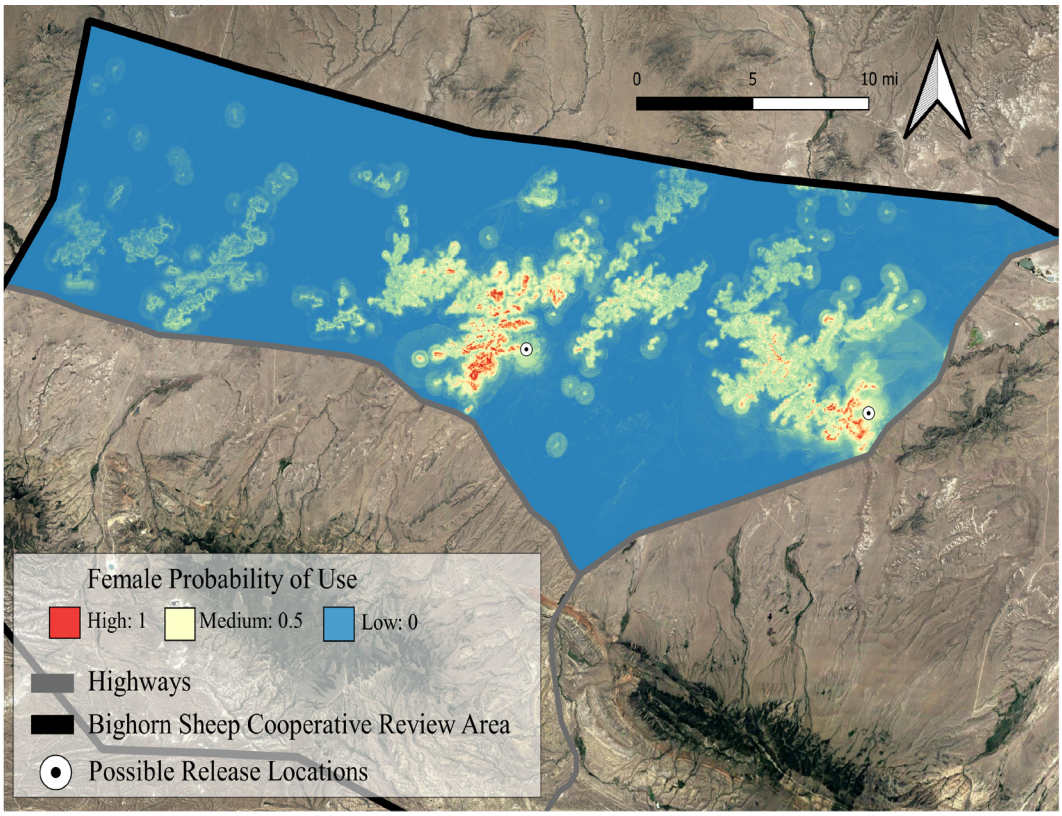

Figure 2. Probability of use by female bighorn sheep during summer in the cooperative review area, accounting for distance to possible release locations. Out of bag error rate for the model was 3.65%

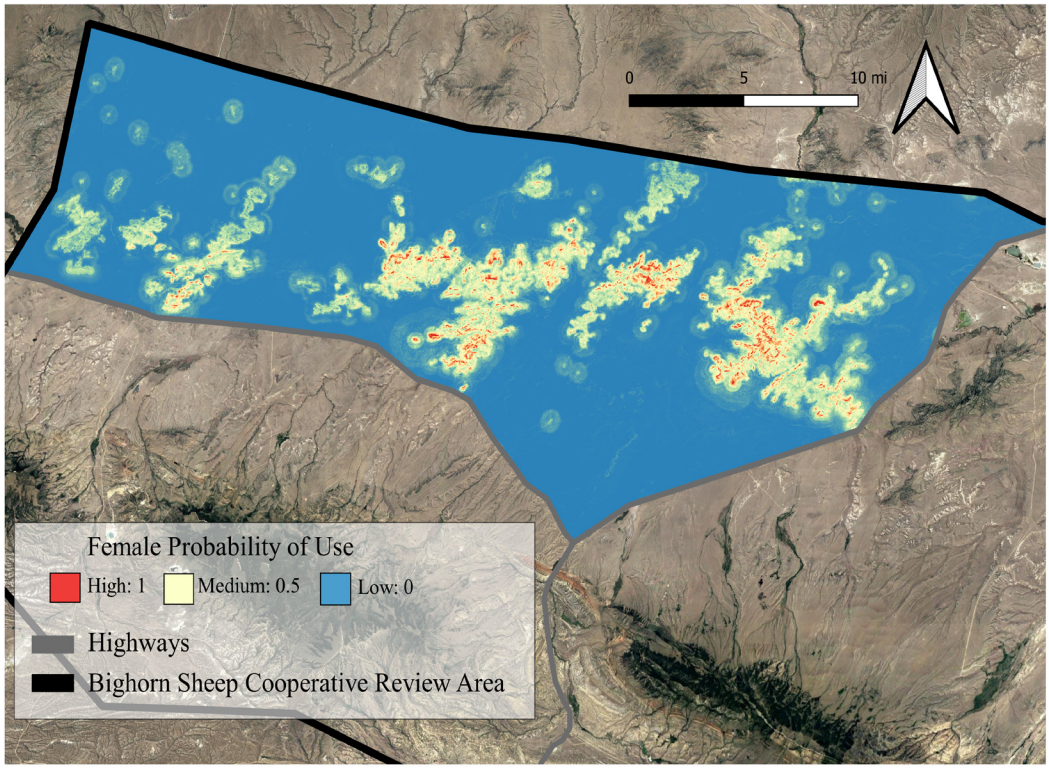

Figure 3. Probability of use by female bighorn sheep during summer in the cooperative review area, not accounting for distance to release location. Out of bag error rate for the model was 4.13%.

Predicted Use by Females in Winter

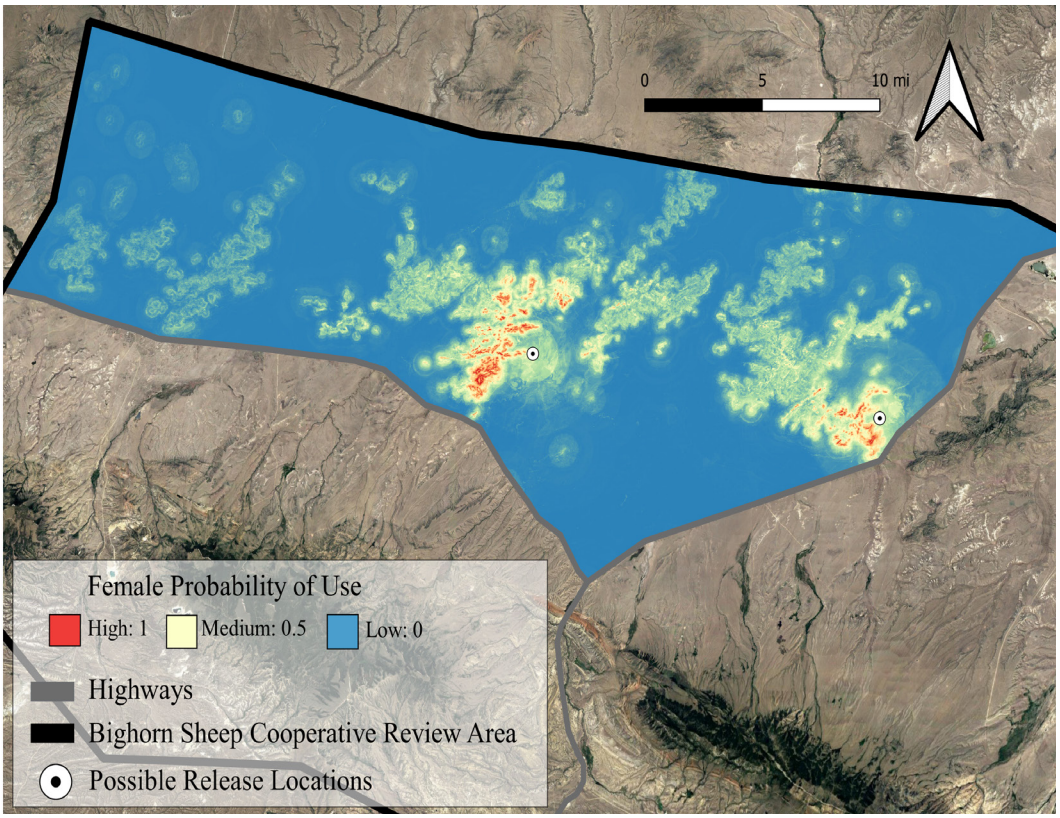

Figure 4. Probability of use by female bighorn sheep during winter in the cooperative review area, accounting for distance to possible release locations. Out of bag error rate for the model was 3.29%.

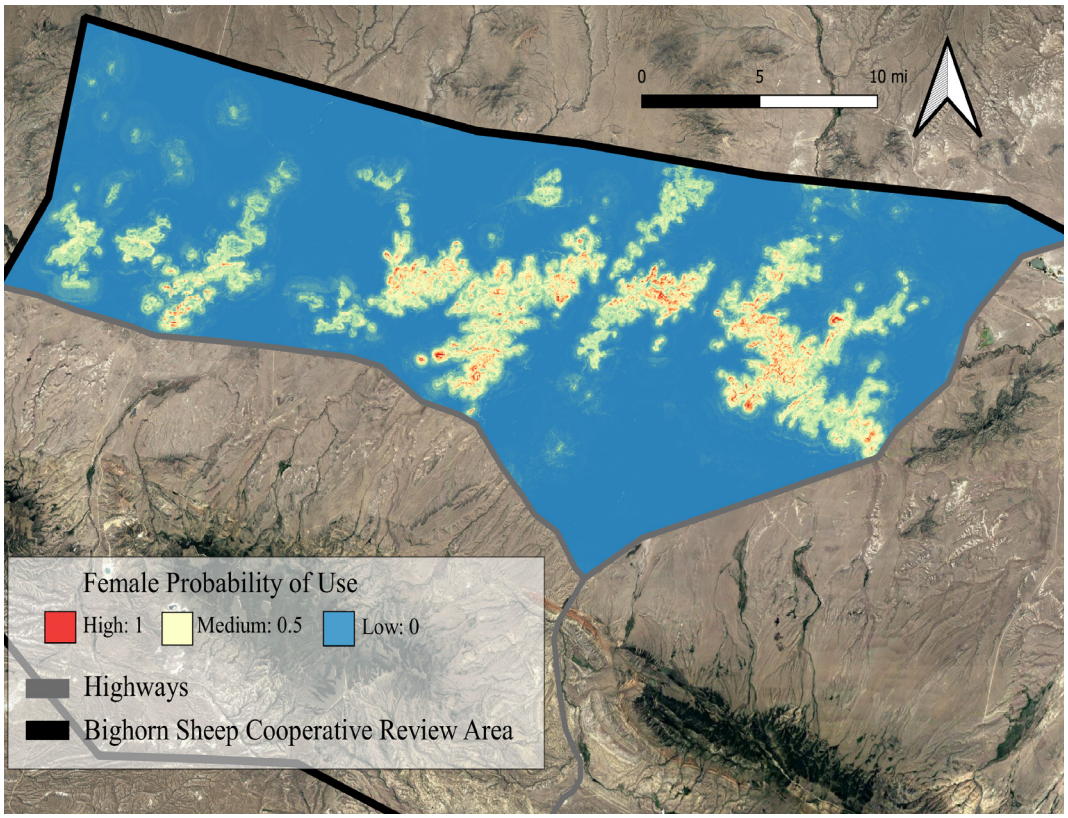

Figure 5. Probability of use by female bighorn sheep during winter in the cooperative review area, not accounting for distance to release location. Out of bag error for the model was 3.61%.

Predicted Use by Males in Summmer

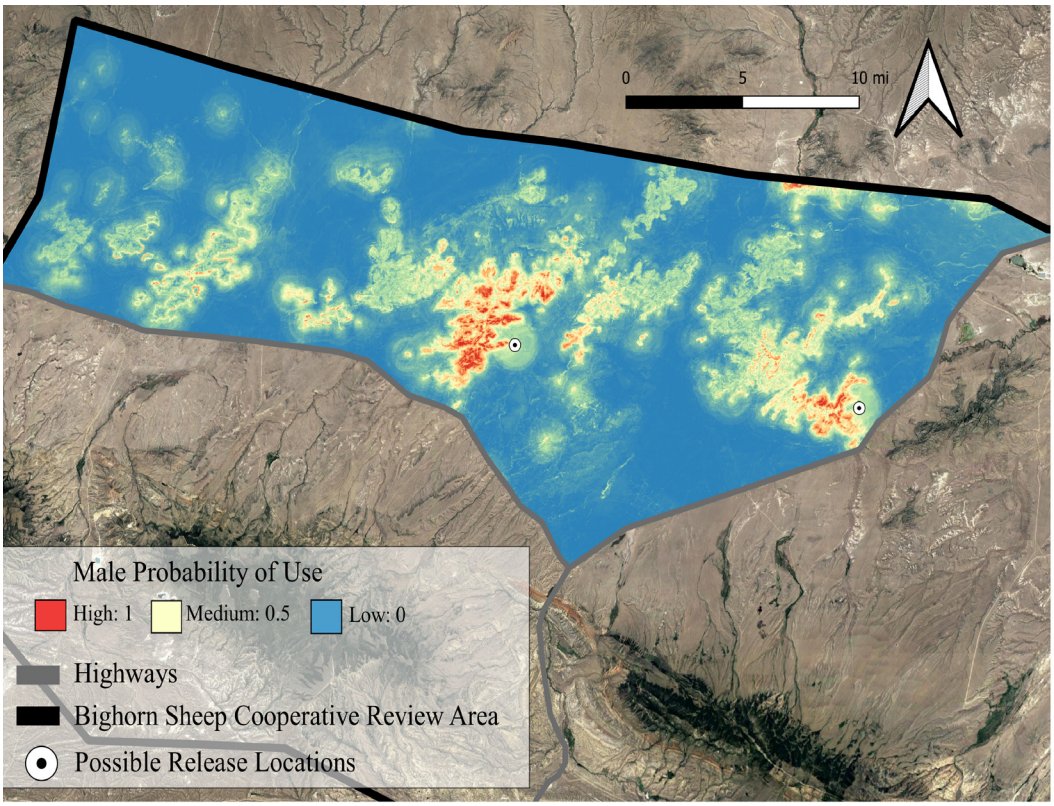

Figure 6. Probability of use by male bighorn sheep during summer in the cooperative review area during summer, accounting for possible release locations. Out of bag error rate for the model was 5.0%.

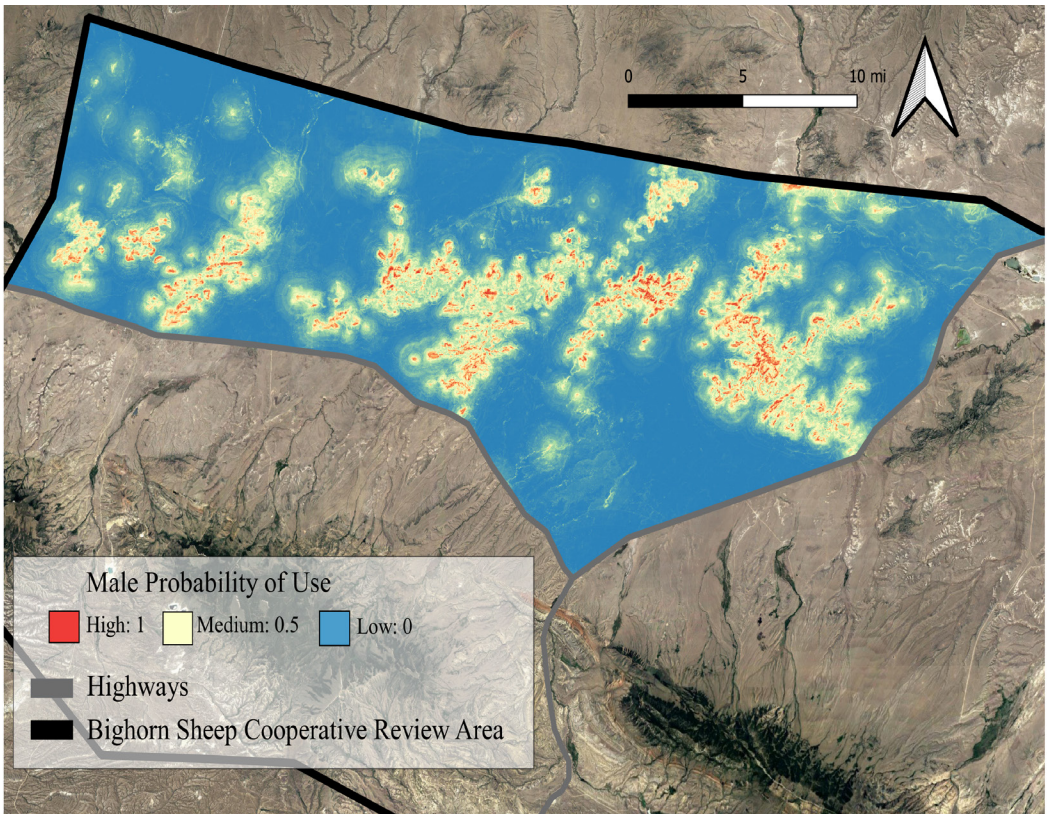

Figure 7. Probability of use by male bighorn sheep during summer in the cooperative review are, not accounting for distance to release location. Out of bag error for the model was 5.83%.

Predicted Use by Males in Winter

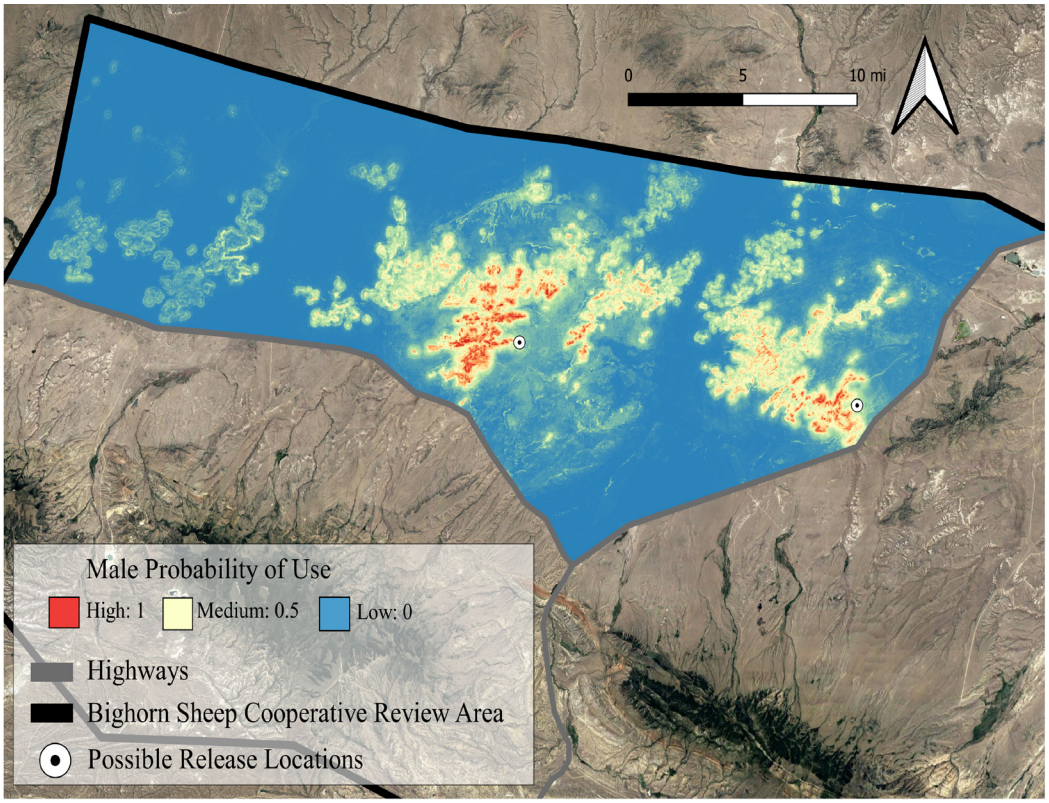

Figure 8. Probability of use by male bighorn sheep during winter in the cooperative review area, accounting for distance to possible release locations. Out of bag error for the model was 3.85%.

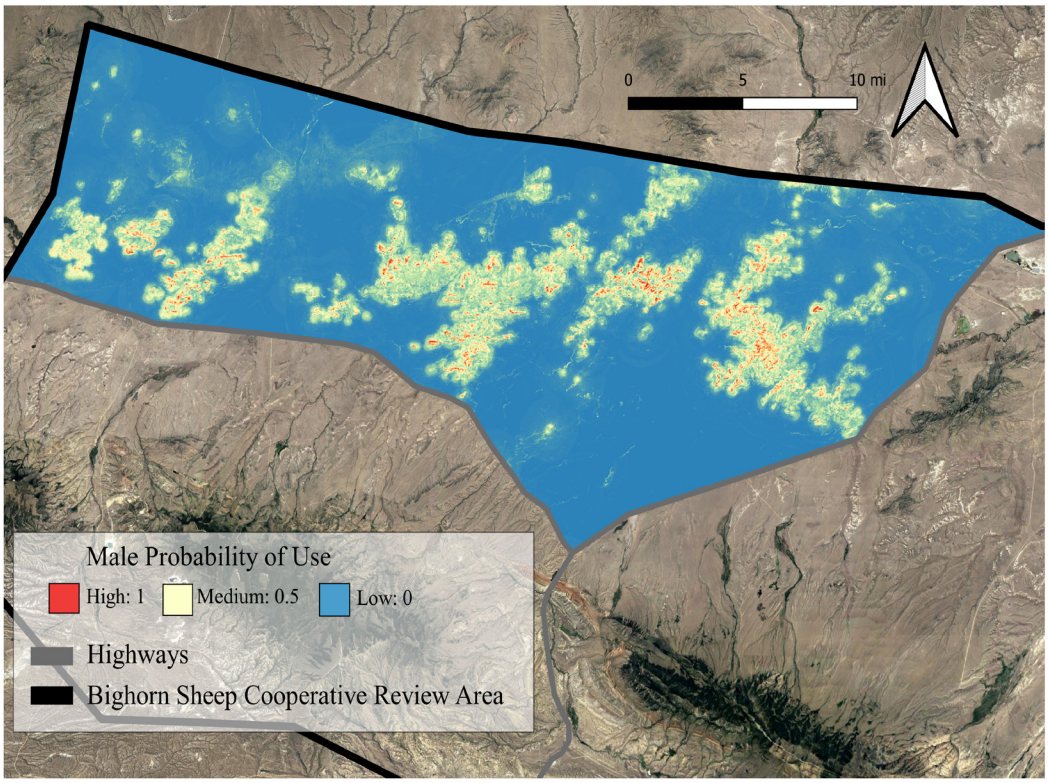

Figure 9. Probability of use by male bighorn sheep during winter in the cooperative review area, not accounting for distance to release location. Out of bag error for the model was 4.45%.

BIGHORN SHEEP RISK OF CONTACT WITH DOMESTIC SHEEP GRAZING ALLOTMENTS

Pneumonia, a directly transmitted respiratory disease, has been a conservation issue for over a century. It has caused massive population declines across the west and has hindered recovery efforts of wild sheep (Buechner 1960, Foreyt and Jessup 1982, Cassirer and Sinclair 2007, Cassirer et al. 2018). The disease is caused by bacterial pathogens that originally spilled into wild sheep populations from domestic sheep (Besser et al. 2013)—domestic sheep are largely immune to these pathogens from years of coevolution, while wild sheep were naive to these pathogens prior to European settlement (Dassanayake et al. 2009). Pneumonia epizootics can cause 10–90% mortality in adults followed by years or decades of suppressed lamb recruitment (Cassirer and Sinclair 2007).

The consequences of contact between domestic sheep and wild sheep is well documented with experimental trials (Wehausen et al. 2011), field observations (Foreyt and Jessup 1982, George et al. 2008), and large-scale population analyses (Singer et al. 2001). Therefore, spatial and temporal separation of domestic and wild sheep has been a widely suggested or required mitigation tactic (Western Association of Fish and Wildlife Agencies Wild Sheep Working Group 2012). Wild sheep, however, sometimes make exploratory long-distance movements away from their core home range (forays; Singer et al. 2001). These foray behaviors can put the herd at risk to pneumonia, especially if a foraying animal contacts domestic sheep (Foreyt and Jessup 1982, O'Brien et al. 2014).

We used the risk of contact tool to assess the potential risk of contact between bighorn sheep translocated to the Sweetwater Rocks and domestic sheep grazing allotments (O'Brien et al. 2014, O'Brien et al. 2021). The tool uses foray behavior of bighorn sheep, core herd home range, identified bighorn sheep habitat, and a map of domestic sheep grazing allotments to estimate the sex-specific probability of a foray movement of a wild sheep to contact a grazing area for domestic sheep for both summer and winter. We used default values for bighorn sheep foray probability and distances that were calculated from over a decade of bighorn sheep GPS locations (O'Brien et al. 2014). The maximum default foray distance is 23 miles and there is a 0.78% chance a male will make the maximum foray movement and a 0.12% chance for females. There is a 54.80% (males) or 10.69% (females) chance that a bighorn sheep will foray 6 miles. The maximum dispersal movement for bighorn sheep in the Ferris-Seminoe was < 19 miles indicating that the default foray values likely represent the movement behavior for bighorn sheep in the Sweetwater Rocks. We used the predicted space use from the random forest models to estimate the core herd home range for bighorn sheep translocated into Sweetwater Rocks (Fig. 10). We used the random forest predictions to create a map of bighorn sheep habitat preferences to serve as a predictive layer of habitat use into the tool. We used the random forest model that does not include distance to release location because it more accurately identifies bighorn sheep habitat for an animal that has decided to make a foray movement and therefore is already moving away from the location it was released at. The Lander and Casper BLM field offices provided locations of authorized grazing allotments for domestic sheep as well as which allotments were currently running sheep and what days the allotments are open (Fig. 10). We adjusted the risk of contact results to reflect the number of days each allotment is open for grazing of domestic sheep.

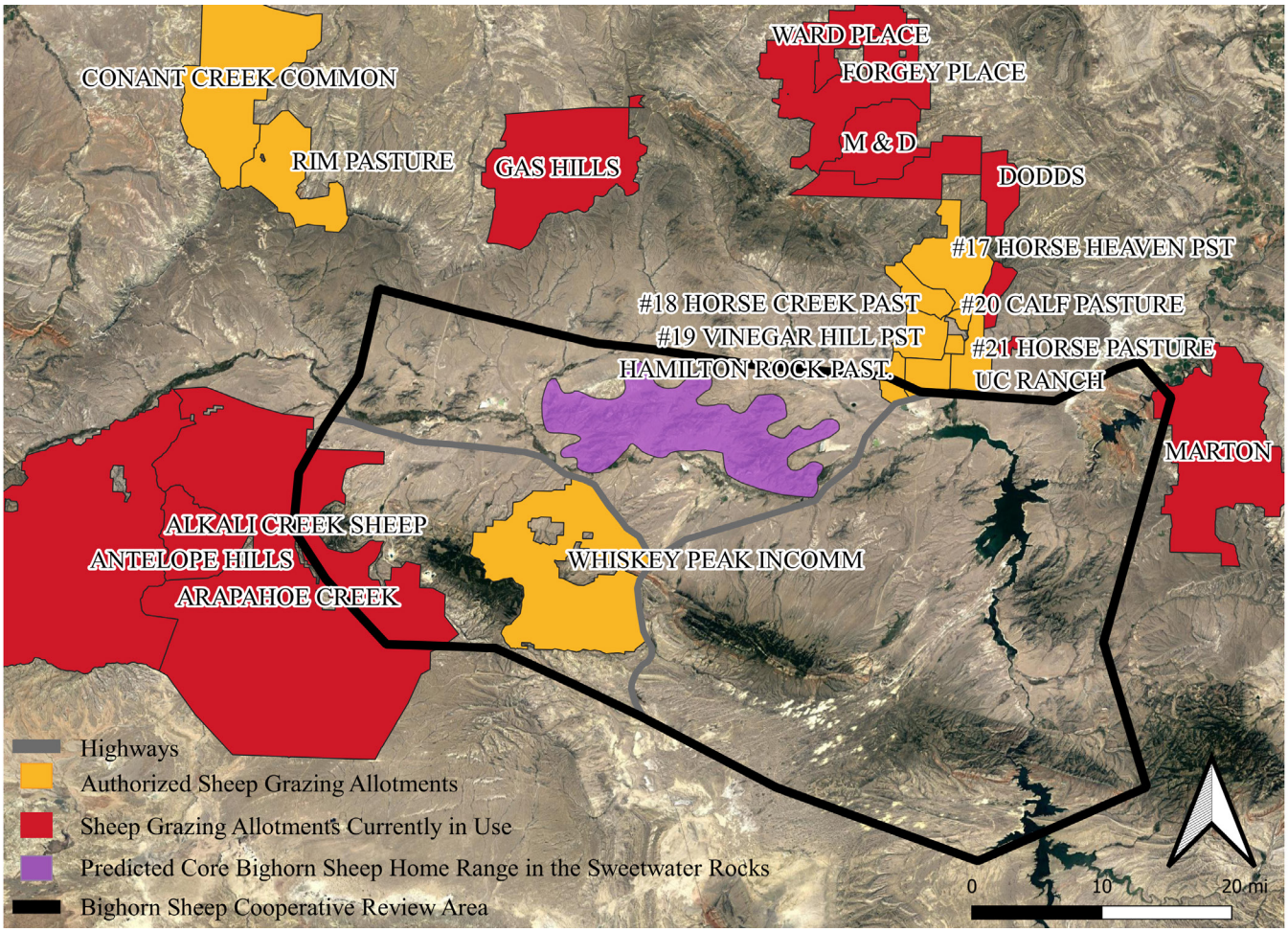

Figure 10. Domestic sheep grazing allotments with potential risk of contact to translocated bighorn sheep in Sweetwater Rocks. The predicted core herd home range for translocated bighorn sheep is indicated in purple. Allotments that are currently running domestic sheep are in red.

The predicted yearly contact rate between active domestic sheep grazing allotments and a population of 40 female and 10 male bighorn sheep translocated to Sweetwater Rocks was 0.03 contacts per year, assuming normal foray behaviors of bighorn sheep (Table 3). As the size of the bighorn sheep population increases, the risk of contact increases because there are more animals that can potentially foray into an allotment (Table 3). If all authorized domestic sheep grazing allotments started running sheep the predicted contact rate would increase from 0.03 to 0.12 contacts per year for the same population size (10 males and 40 females). Specifically, running domestic sheep in the Whiskey Peak Incomm allotment would significantly raise the risk of contact.

Table 3. Number of contacts per year between bighorn sheep translocated to Sweetwater Rocks and domestic sheep grazing allotments, assuming a male to female ratio of 1:4. Allotments that are currently running sheep are indicated with an asterisk (*).

	Contacts per Year for Various Population Sizes				
Allotment	**50**	**100**	**200**	**300**	**400**
#16 PHILLIPS PAST.	0.00	0.00	0.00	0.01	0.01
#17 HORSE HEAVEN PST	0.00	0.01	0.02	0.02	0.03
#18 HORSE CREEK PAST	0.01	0.01	0.02	0.03	0.04
#19 VINEGAR HILL PST	0.01	0.03	0.06	0.08	0.11
#20 CALF PASTURE	0.00	0.00	0.00	0.00	0.00
#21 HORSE PASTURE	0.00	0.00	0.00	0.00	0.00
#22 BULL PASTURE	0.00	0.00	0.00	0.00	0.00
ALKALI CREEK SHEEP*	0.00	0.00	0.00	0.00	0.00
ANTELOPE HILLS*	0.00	0.00	0.00	0.00	0.00
ARAPAHOE CREEK*	0.00	0.01	0.02	0.03	0.04
CONANT CREEK COMMON	0.00	0.00	0.00	0.00	0.00
DODDS*	0.00	0.00	0.00	0.00	0.01
FORGEY PLACE*	0.00	0.00	0.00	0.00	0.00
GAS HILLS*	0.01	0.03	0.06	0.09	0.11
HAMILTON ROCK PAST.	0.01	0.01	0.02	0.03	0.04
M & D*	0.00	0.00	0.00	0.01	0.01
MARTON*	0.00	0.00	0.00	0.00	0.00
RIM PASTURE	0.00	0.00	0.00	0.00	0.00
UC RANCH*	0.00	0.01	0.01	0.02	0.03
UPPER POISON SPIDER CREEK*	0.00	0.01	0.01	0.02	0.03
WARD PLACE*	0.00	0.00	0.00	0.00	0.00
WHISKEY PEAK INCOMM	0.06	0.13	0.26	0.39	0.52
All allotments currently running sheep	0.03	0.06	0.11	0.17	0.23

A contact of a bighorn sheep to a grazing allotment for domestic sheep does not necessarily mean that a disease event will occur. For an individual bighorn sheep to put the rest of the population at risk for pneumonia it must 1) make a foray movement to a domestic sheep grazing allotment, 2) directly contact a domestic sheep on the allotment, 3) contract a pathogen from the domestic sheep, and 4) transmit the pathogen to other bighorn sheep. The risk of contact tool is only able to model the first step of this process. To attempt to include steps 2–4 of the process of putting a bighorn sheep herd at risk for pneumonia, we assessed how frequently disease outbreaks might occur in Sweetwater Rocks under different assumptions of disease transmission assuming that bighorn sheep are only at risk from grazing allotments currently running domestic sheep (Table 4). For example, if 25% of foray movements that contact an active allotment result in pathogen transmission, then there would be an outbreak every 141 years for a population of 50 bighorn sheep.

Table 3. Number of contacts per year between bighorn sheep translocated to Sweetwater Rocks and domestic sheep grazing allotments, assuming a male to female ratio of 1:4. Allotments that are currently running sheep are indicated with an asterisk (*).

	Years between outbreaks for various herd sizes				
Disease transmission assumption	**50**	**100**	**200**	**300**	**400**
If every contact = outbreak	35.13	17.56	8.78	5.85	4.32
If 75% of contacts = outbreak	46.84	23.42	11.71	7.81	5.76
If 50% of contacts = outbreak	70.26	35.13	17.56	11.71	8.64
If 25% of contacts = outbreak	140.51	70.26	35.13	23.42	17.29
If 10% of contacts = outbreak	351.28	175.64	87.82	58.55	43.22
If 5% of contacts = outbreak	702.56	351.28	175.64	117.09	86.44

The risk of contact tool is primarily used for assessing the relative level of risk between different domestic sheep grazing strategies (USDA-FS, 2010). We applied the risk of contact tool in a novel way to assess the potential risk of contact for a translocated population of bighorn sheep. To provide some context to what these levels of risk might mean in a real bighorn sheep population, we compared the results of the risk of contact tool between the Sweetwater Rocks and Ferris-Seminoe. The predicted yearly contact rate for a population of 300 is 0.17 for Sweetwater Rocks and 0.37 for the Ferris-Seminoe (currently ~300 bighorn sheep). Under current grazing activity and regulations, the Sweetwater Rocks bighorn sheep would face lower risk of contact than the Ferris-Semionoe bighorn sheep currently face.

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While the risk of contact tool is a helpful model to assess the relative risk of contact between bighorn sheep and domestic sheep, there are shortcomings. The risk of contact tool does not account for attraction between domestic sheep and bighorn sheep (Heinse et al. 2016) nor for habitat types between the core herd home range and the grazing allotments (i.e., animals have an equal probability of traveling through a flat open corridor as a rocky, rugged corridor). Nonetheless, these predictions are based on explicit foray movements of bighorn sheep relative to habitat preferences and show relatively low contact rates between bighorn sheep translocated to Sweetwater Rocks and domestic sheep grazing allotments.

MANAGEMENT IMPLICATIONS

Overall, there is high quality and continuous habitat for male and female bighorn sheep for both summer and winter within the Sweetwater Rocks. The Sweetwater Rocks is surrounded mostly by flat shrublands, which have low probability of use by bighorn sheep, and is bounded on some sides by major highways. When considering the high-quality habitat offered by the Sweetwater Rocks, and the surrounding poor-quality habitat and potential barriers to movement, it is likely that sheep will establish their home ranges within the target area within Sweetwater Rocks and have a relatively low probability of foraying far beyond those boundaries. This is largely what translocated bighorn sheep in the Ferris Semoinoe have done (Dwinnell et al. 2019). The models herein indicate that release location will be an important factor for the space use of bighorn sheep translocated into the Sweetwater Rocks. Release locations should therefore be carefully taken into consideration. Multiple release locations should be considered for bighorn sheep if the objective is to maximize the space use of the Sweetwater Rocks area (Dwinnell et al. 2019).

Under current grazing activity and regulations, we predict 0.03 contacts per year between bighorn sheep and active domestic sheep grazing allotments for a population of 10 males and 40 females. This is lower than the risk of contact predicted between the Ferris-Seminoe bighorn sheep and domestic sheep grazing allotments (0.06 contacts per year for a herd of 50 bighorn sheep). To date, the pathogens commonly associated with respiratory disease in bighorn sheep have not been documented in the Ferris-Seminoe population (Wyoming Game and Fish Department, unpublished data), which indicates that the predicted risk of contact for the Sweetwater Rocks bighorn sheep is likely within that already accepted in the adjacent Ferris-Seminoe population. As the population of bighorn sheep increases, the risk of contact to domestic sheep grazing allotments increases and long-term population objectives should be considered when assessing risk of contact.

Notably, all predictive models are flawed but some are useful. We acknowledge the uncertainty embedded within our models and that no model is perfect. Nevertheless, we are basing our assessment upon a wealth of GPS data from an adjacent population in similar habitat, we employed robust modeling approaches known to yield high predictive power, and used the standard tool to predict potential risk of contact with domestic sheep grazing allotments. Based on these efforts, model predictions consistently point to Sweetwater Rocks as offering viable habitat for bighorn sheep during summer and winter.

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