FINAL REPORT

HABITAT DISTRIBUTION MODELING FOR THE SOOTY GROUSE

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The stated objectives of this project were to: 1) sample locations of territorial male Sooty Grouse (SOGR) in Mendocino, Glenn, Lake, and Sonoma counties; and 2) create a habitat distribution model that predicts locations of additional breeding sites throughout the region.

STUDY AREA

The survey area encompassed all of Mendocino County, northwestern Sonoma County, northwestern Lake County, and northwestern Glenn County (Fig. 1). Surveys were conducted on large public or otherwise conserved lands (sustainably managed by private owners), where historic breeding-season SOGR observations had been documented. The larger public/conserved parcels surveyed included Austin Creek State Park, Fort Ross State Park, Salty Point State Park, Covelo and Upper Lake Ranger Districts (Mendocino National Forest), Buckeye and Garcia Forests (The Conservation Fund), and several parcels belonging to Mendocino Redwood Company. Eight relatively small private parcels were also surveyed on an opportunistic basis.

METHODS

Data collection

Surveys were conducted between March 18th and May 30th, 2016, during the presumed peak SOGR "hooting" season (Zwickel and Bendell 2004). Surveys generally progressed from south to north. Sites were accessed with a compact 4-wheel-drive vehicle, or on foot where roads were impassable or lacking. Intensive surveys were conducted in accessible forest and coastal mosaic habitats surrounding historic observation locations (eBird and CDFW records). Surveys were conducted by driving or walking along a more or less linear transect, stopping every 300–500 m at prominent spurs or vantage points to listen for hooting males, broadcasting recorded female "cackle" calls, and listening again for hooting males to respond to the recorded calls (see Bland 2013 for a detailed description). Less-intensive surveys were conducted along roads used to travel between intensive survey sites. Methods were similar to those for intensive surveys, but individual listening sites were sited opportunistically where patches of appropriate habitat were encountered. When hooting grouse were detected, the locations of their songpost trees ware recorded with a hand-held GPS unit (Garmin Ltd., Olathe, OK, model 60C). Coordinate locations for 6 hooting males detected by the principle investigator at Cliff Ridge, Mendocino Co., on May 4th, 2005, were also included in the data set.

Data on the presence of large conifers (canopy $\geq$15 m diameter) were collected for

selected sites by analyzing high-resolution satellite images from Google Earth (www.google.com/earth).

Analysis

Geographic analysis was conducted with ArcGIS (Esri Corp., Redlands, CA) and Maxent computer software (Phillips et al. 2006). The environmental layers used to model habitat distribution were previously proven effective for modeling SOGR habitat in the Sierra Nevada Mountains (Bland and Gardner 2013), and included elevation, slope, aspect, solar radiation, CAWHR (California Wildlife Habitat Relationships, U.S. Forest Service) cover type and overstory tree diameter. Maxent response axes are displayed in logistic scale.

The abundance of large conifers (canopy diameter ≥15 m) at occupied versus unoccupied sites was compared with Mann-Whitney *U* tests using Statistica computer software (StatSoft Inc., Tulsa, OK). A set of unoccupied sample sites was identified by first creating a provisional Maxent habitat suitability model based on elevations and forest cover types (California Wildlife Habitat Relations cover types) at occupied sites. Sample sites were randomly-selected from portions of survey routes that transected suitable cover (Maxent suitability >0.50) but where no singing males were detected. This ensured comparisons would not include entirely unsuitable habitat (e.g., chaparral or redwood forest). A random number generator was then used to designate: 1) distance along a transect, 2) right-angle direction from the transect, and 3) right-angle distance from the transect. A 2-ha circular plot was superimposed over the selected point (songpost location for occupied sites, random location for unoccupied sites), and the diameter of all conifer canopies ≥15 m were measured (Fig. 2). Conifers were distinguished from broadleaf species by shape, texture and color, using supervised image classification (Fig. 2). The predominant conifer in the survey area is Douglas fir (*Pseudotsuga menziesii),* although coast redwood *(Sequoia sempervirens)* and white fir *(Abies concolor)* also occur at some sites. The number of large conifers was compared in five canopy-diameter categories: ≥15 m, ≥16 m, ≥18 m, ≥20 m, ≥22 m.

RESULTS

Forty-eight singing males were detected along approximately 382 km of survey transects (Fig. 1). Many of the detections were at sites not previously documented as Sooty Grouse breeding areas. Dates and general locations of surveys are given in Table 1. Coordinate locations of hooting grouse have been provided separately to CDFW, and should only be made available for valid research or conservation purposes.

Singing males were detected only in the southern half of the survey area (Fig. 1). In Sonoma County, they occurred throughout historic SOGR range. Our detections at Jenner Headlands are slightly south of known SOGR range, and mark the southernmost breeding site for SOGR on the Pacific Coast. In Mendocino County, singing males were detected only in the southern and central regions (south of Willits), and no grouse were detected in historic range in either Lake or Glenn counties.

Where we found singing grouse in northern Sonoma and southern Mendocino counties, the number of males comprising each hooting group (or "lek", see Bland 2013), was relatively small (Table 2). Our single-visit survey method did not allow accurate estimates of total males/group, but using Bland's (2013) estimate of 80 % detection during single censuses, we estimate an average group size of 3.0 males (range, 1.25-6.25; actual detections, 1-5, avg., 2.4,

Table 2), 28 % smaller than the 4.2 male average in the central Sierra Nevada Mountains (Bland 2013a; note that Bland's detection ratio is for persistently territorial males and excludes transient males (e.g., yearlings)).

We limited habitat distribution modeling to southern Mendocino County and northern Sonoma County, the region where we detected hooting grouse. The model is depicted in Figure 3. Environmental variables that contributed importantly to the Maxent suitability model are listed in Table 3. The most informative variable we modeled is elevation. Suitable breeding habitat ranged from about 200-1000 m elevation, with a peak at about 650 m (Fig. 4). The second most informative environmental variable is tree size-class (Fig. 5). In suitable habitat, trees <2.5 cm d.b.h. were disproportionately abundant, suggesting the forest is rapidly-regenerating. Trees ≥61 cm d.b.h. occurred in multi-layered canopies (CAWHR size-class 6) more so than even-aged stands (CAWHR size-class 5). The suitability of aspect (Fig. 6) was strongly correlated with degrees azimuth; highest just west of north then declining linearly, or counterclockwise, with azimuth. Douglas fir forest (CAWHR cover type) was more frequent at occupied sites (Fig. 7), and slope suitability peaked at 50% (Fig. 8). Overstory tree diameter mirrored tree size-class with regard to disproportionately abundant seedlings in suitable areas. Overstory trees 51-76 cm d.b.h. were disproportionately rare, whereas overstory trees >76 cm d.b.h. were disproportionately abundant (Fig. 9).

Hooting males were only rarely detected along the mesic coastline or in xeric inner valleys (Fig. 3). The extensive secondary forests that dominate coastal areas appear to have low habitat value for breeding SOGR. North of the modeled region (northern Mendocino, Lake and Glenn counties), SOGR is associated with higher-elevation conifer forest, so a habitat model for that region would differ with regard to vegetation.

Conifers with canopies ≥15 m diameter were significantly more abundant at occupied sites than at unoccupied sites, across all canopy-diameter categories (Table 4).

CONCLUSIONS

Coastal populations of Sooty Grouse are strongly associated with "coastal mosaic" habitats that lie between mesic coastal forests and dry inner valleys. They are closely associated with large fir trees, which males use as territorial songposts in breeding season. The association with large trees (i.e., mature forest) is contrary to the common conception of Sooty Grouse habitat associations (Zwickel and Bendell 1985, Zeiner et al. 1990), but conforms with recent research in the central Sierra Nevada Mountains (Bland and Gardner 2013). SOGR appears to be associated with mature forest canopy throughout California, whether the forest canopy is more or less contiguous, as in the Sierra Nevada, or occurs in small patches as in coastal mosaic habitat. This finding is significant for conservation and management of Sooty Grouse because the species is thought to have declined in northern Sonoma and southern Mendocino Counties as a result of commercial-scale logging over the past century.

We encountered relatively few grouse on public lands, presumably because of a paucity of large fir trees. The state parks we surveyed had all been subjected to intense commercial timber harvest prior to acquisition by the state. Forest Service lands in the region have also been subjected to intense commercial logging. Large areas owned by The Conservation Fund and Mendocino Redwood Company are primarily comprised of dense second-growth forest. The more open landscapes preferred by SOGR tend to be owned primarily by livestock producers. The stronghold for Sooty Grouse in the region appears to be mid-sized private lands (100-1000

acres) which have historically been used for livestock production and are often managed these days as hunting preserves. Private land owners we encountered were interested in Sooty Grouse and keen to know how many occurred on their land. We believe it would be feasible to follow the current survey with a survey on private lands. The habitat suitability model presented here should greatly increase the efficiency of future surveys.

We were unable to detect grouse in the northern half of Mendocino County or the northwestern corners of Glenn or Lake Counties. This finding is significant, insomuch as Mendocino Pass Road, which bisects the northern boundaries of Mendocino and Glenn Counties, was formerly the site of an annual Forest Service Sooty Grouse census (Bauer 1967). Between 1964 and 1976, an average of 12.6 hooting grouse was detected along this transect (Bland 1993). On May 30th, 1993, Bland (1993) detected 18 hooting grouse along the transect. It is remarkable that 13 years later, almost to the day, the same observer detected no singing grouse along the transect. This should be of concern to both the state Department of Fish and Wildlife and the U. S. Forest Service, and we urge these agencies to conduct additional SOGR surveys in this area soon. Along the Mendocino County portion of Mendocino Pass Road, meadows where Sooty Grouse were formerly detected are presently being converted to pine plantations, on both private and public land (Fig. 10).

In Glenn and Lake Counties, SOGR has been uncommon throughout modern times. In areas we searched - sites reported by birdwatchers over recent decades - nearly all primary-growth firs had been harvested. We hypothesize that most of the grouse observed in these areas over the past decade (very few, e.g., at Pine Mtn) are not breeding birds but birds occupying post-breeding or winter range. Suitable breeding habitat - steep meadows surrounded by large firs - has largely been eliminated. SOGR reported from these areas probably breed on private grazing lands nearby, where some large firs have been retained.

There are alternate explanations for why we detected no grouse across the northern third of the survey area, besides or in addition to habitat degradation. We surveyed the area relatively late in the hooting season, but we had no problem locating grouse during the same time period at more southerly, lower-elevation, sites that were more phenologically advanced. Our survey at Mendocino Pass occurred 2 days earlier than a 1993 survey when 18 singing grouse were detected (Bland 1993). If SOGR has become rare in this area, they likely hoot as solitary individuals or in small groups comprised of 2-3 males. Under these circumstances, there is less "social facilitation" or stimulation to hoot, and males hoot less frequently and for shorter periods (Bland 2013a). In any case, we believe SOGR is significantly less abundant across the northern portion of our survey area than is currently recognized, and urge that additional survey work be conducted.

Future research should be directed at determining whether coastal hooting groups have become so small and isolated, as a result of habitat degradation, that they are at risk of genetic isolation and gradual extirpation. Peninsular populations have been extirpated elsewhere in California (Bland 2013b). The winter and post-breeding habitat associations of coastal SOGR populations also need to be documented. Seasonal habitats might differ substantially, as they do in the Sierra Nevada Mountains (Bland and Gardner 2013), or they might be essentially the same year-round. In order to properly conserve and manage coastal SOGR populations, the year-round habitat associations, seasonal movements, and annual home range of both sexes must be better understood. Finally, we urge government agencies and/or conservation organizations to develop SOGR habitat management guidelines which include strategies for retaining large fir

trees at densities and topographic settings preferred by breeding SOGR. Insomuch as SOGR is neither a listed species (endangered, threatened, of conservation concern) or important game species in the north coast region, government funding for SOGR research is limited, given current funding priorities. Perhaps conservation organizations operating in the region (e.g., land trusts, sustainable timber companies) will consider developing SOGR as a flagship or indicator species for the coastal mosaic ecological community.

ACKNOWLEDGMENTS

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Table 1. Dates and general locations of Sooty Grouse surveys.

March 18th	Stewarts Point Road, Sonoma Co.
April 2nd	Meyers Grade, Sonoma Co.
April 2nd	Oak Ridge Road, The Conservation Fund, Sonoma Co.
April 3rd	Buckeye Forest, The Conservation Fund, Sonoma Co.
May 4th	Fort Ross State Park, Sonoma Co.
May 5th	Salt Point State Park, Sonoma Co.
May 5th	School Ridge, The Conservation Fund, Sonoma Co.
May 6th	Bear Creek, The Conservation Fund, Mendocino Co.
May 6th-7th	Fish Rock Road, Mendocino Co.
May 7th	Phelps Ridge, The Conservation Fund, Mendocino Co.
May 12th	Austin Creek State Park, Sonoma Co.
May 16th	Orr Springs Road, Mendocino Co.
May 16th	Low Gap Road, Mendocino Co.
May 17th	Elk Mountain Road, Mendocino National Forest, Lake Co.
May 17th	Middle Mountain, Mendocino Co.
May 22nd	Pine Mountain, Mendocino National Forest, Lake Co.
May 23rd	Mountain View Road, Mendocino Co.
May 23rd	Eel River Road, Mendocino National Forest, Mendocino Co.
May 24th	Buehler Ranch, Mendocino Redwood Company, Mendocino Co.
May 24th	Peachland Road, Mendocino Co.
May 25th	Bradford Ranch (Hopland), Mendocino Co.
May 25th	Mouse Pass, Mendocino Redwood Company, Mendocino Co.
May 26th	Bradford Ranch (Boonville), Mendocino Co.
May 26th	Bell Springs Road, Mendocino Co.
May 27th-28th	Mendocino Pass Road, Mendocino National Forest, Mendocino Co.
May 28th	Mann Ranch, Mendocino Co.
May 29th	Koch Ranch, Mendocino Co.

Table 2. Number of males in hooting groups.

Group/location name	Males actually detected	Estimated total*
Jenner	3	3.75
Fort Ross	1	1.25
Austin Creek	2	2.5
Kings Ridge	4	5
Oak Ridge	4	5
Kelly Road	4	5
Rockpile Road	2	2.5
Bear Creek	1	1.25
Squaw Rock	1	1.25
Phelps Ridge	1	1.25
Maillard Reserve	3	3.75
Buehler Ranch	4	5
Jumping Frog Rock	1	1.25
Alder Creek	3	3.75
Cliff Ridge east	5	6.25
Cliff Ridge west	1	1.25
Low Gap	2	2.5
Orr Springs west	3	3.75
Orr Springs east	2	2.5
West Willits	1	1.25
Average	2.4	3.0
Range	1-5	1.25-6.25

* based on Bland's (2013) finding that single censuses detect approximately 80 % of persistently territorial males.

Table 3. Relative contributions of environmental variables to the habitat distribution model.

Variable	Source	Percent contribution
Elevation	10-m digital elevation model	50.1
Tree size-class	CAWHR	29.8
Aspect	10-m digital elevation model	12.2
Douglas fir cover	CAWHR	2.8
Slope	10-m digital elevation model	2.8
Overstory tree diameter	CAWHR	1.4
Tree density	CAWHR	0.7
Montane Hardwood cover	CAWHR	0.1

Table 4. Number of large conifers at sites occupied versus unoccupied by breeding male grouse.

Diameter class	Occupied mean	Unoccupied mean	Adjusted Z (M-W *U*)	*P*
≥22 m	0.57	0.13	3.39	0.000691
≥20 m	1.15	0.26	4.57	0.000005
≥18 m	2.53	0.89	4.29	0.000018
≥16 m	5.47	2.55	4.13	0.000036
≥15 m	7.45	4.19	3.54	0.000395

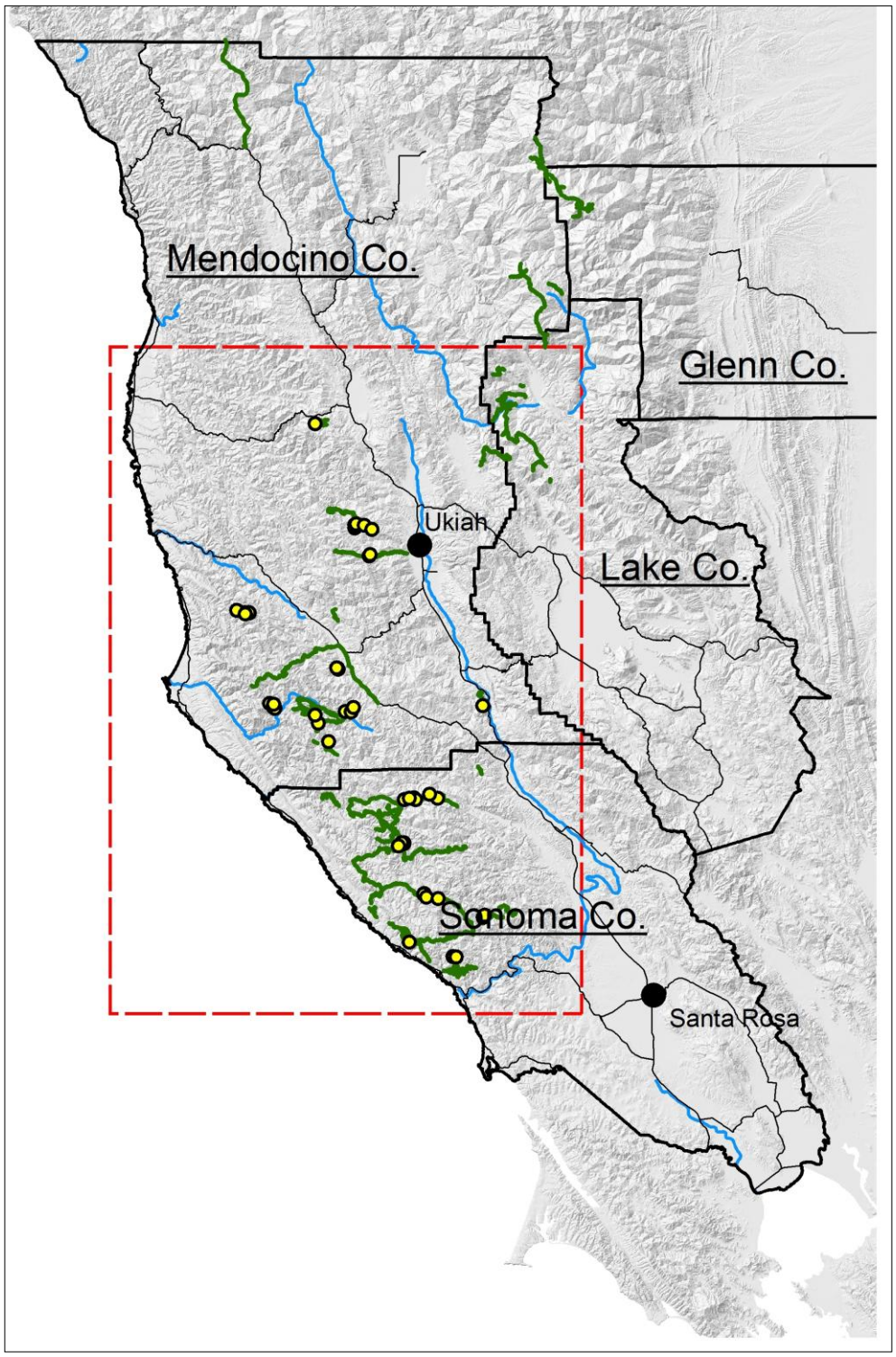

Figure 1. Overall Survey Area. Bold black lines are county boundaries; thin black lines, major roads; blue lines, major rivers; green lines, survey routes; yellow dots, detected grouse; dashed red line, area coverage of habitat suitability model.

A.

B.

Figure 2. Identification and measurement of conifer canopies from satellite images. A: true color image from Google Earth, in which branching patterns (texture) and conical shadows distinguish conifer species (primarily *Pseudotsuga menziesii*). B: the same image, color-classified such that conifers are pink, broadleaved species green, and dry grass tan.

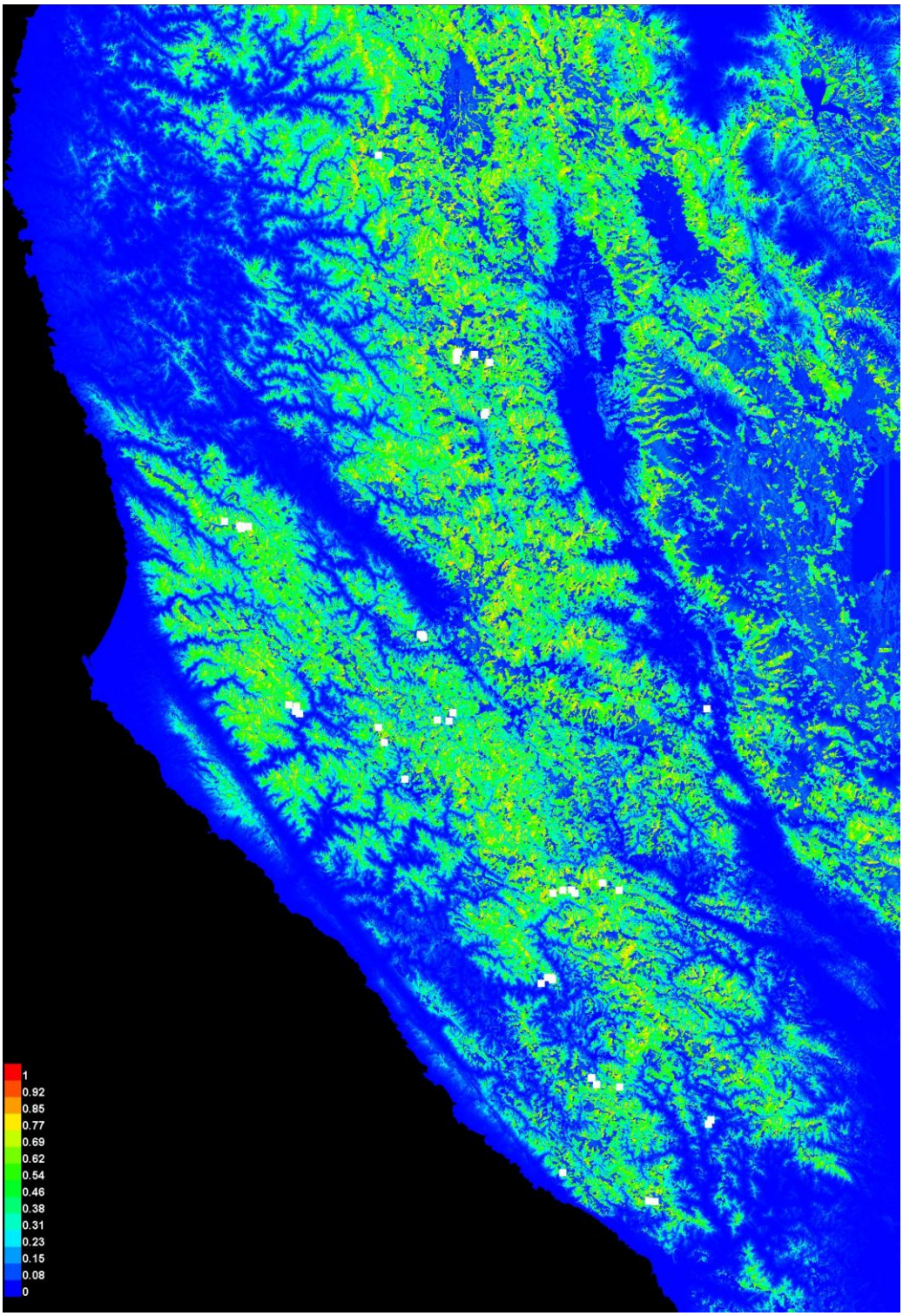

Figure 3. Regional breeding habitat suitability model for Sooty Grouse, based on 48 locations of territorial male grouse (white dots). Warmer colors show areas with better predicted habitat conditions.

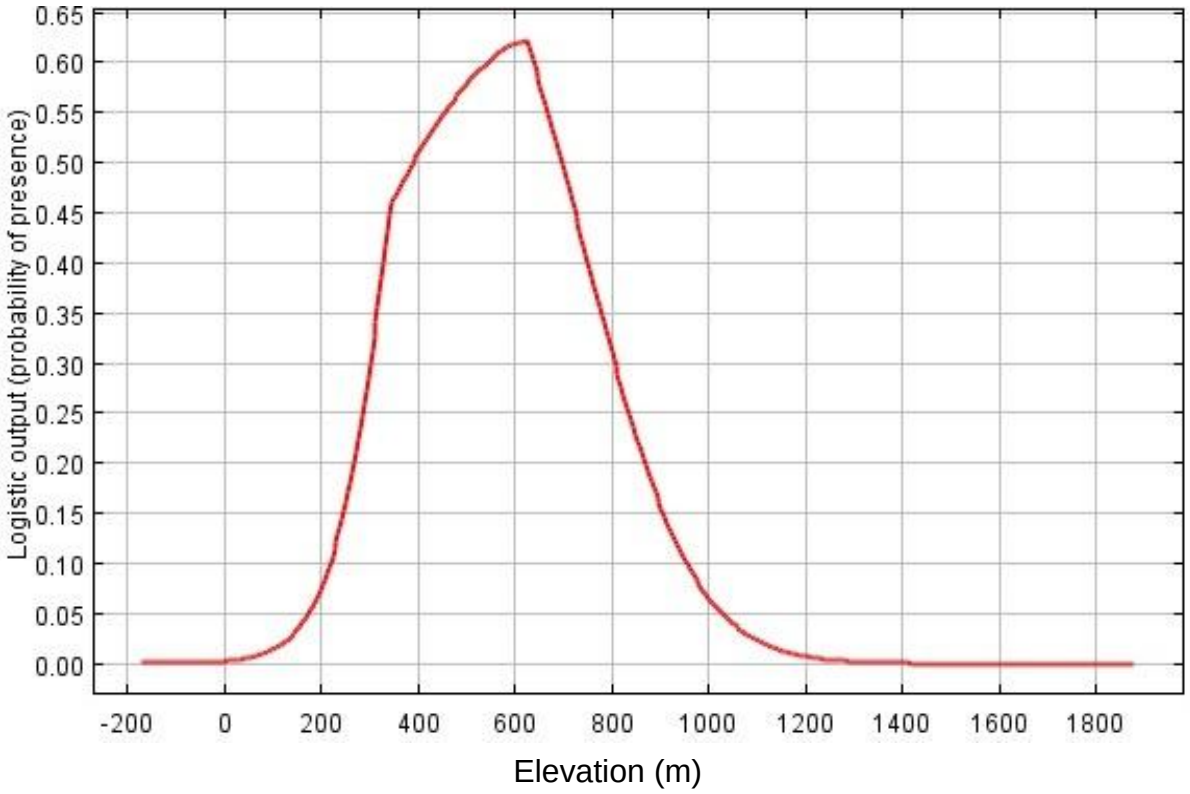

Figure 4. Relationship of the probability of grouse presence to elevation.

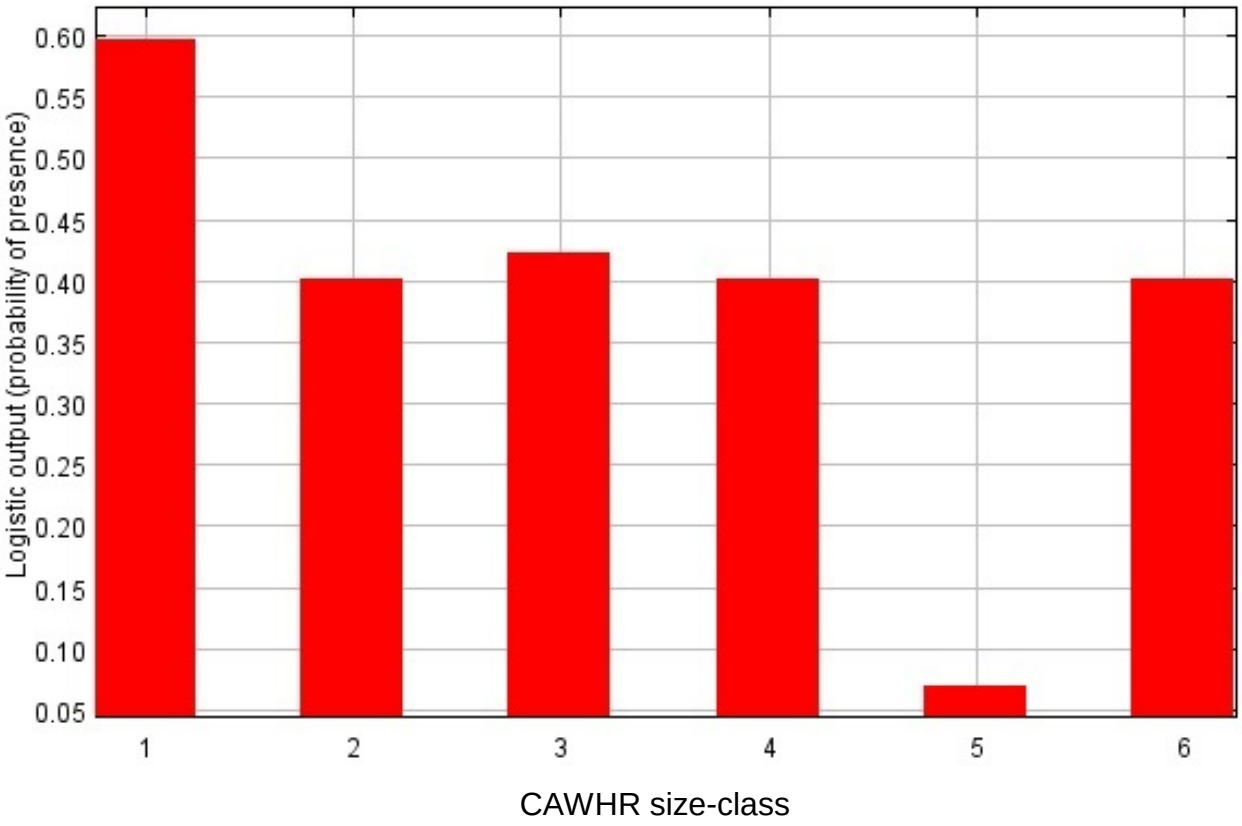

Figure 5. Relationship of the probability of grouse presence to tree size-class. Class 1 diameter at breast height is <2.5 cm; 2, 2.5-15.0 cm; 3, 15.0-28.0 cm; 4, 28.0-61.0 cm; 5, >61.0 cm; 6, class 5 with multi-layered canopy.

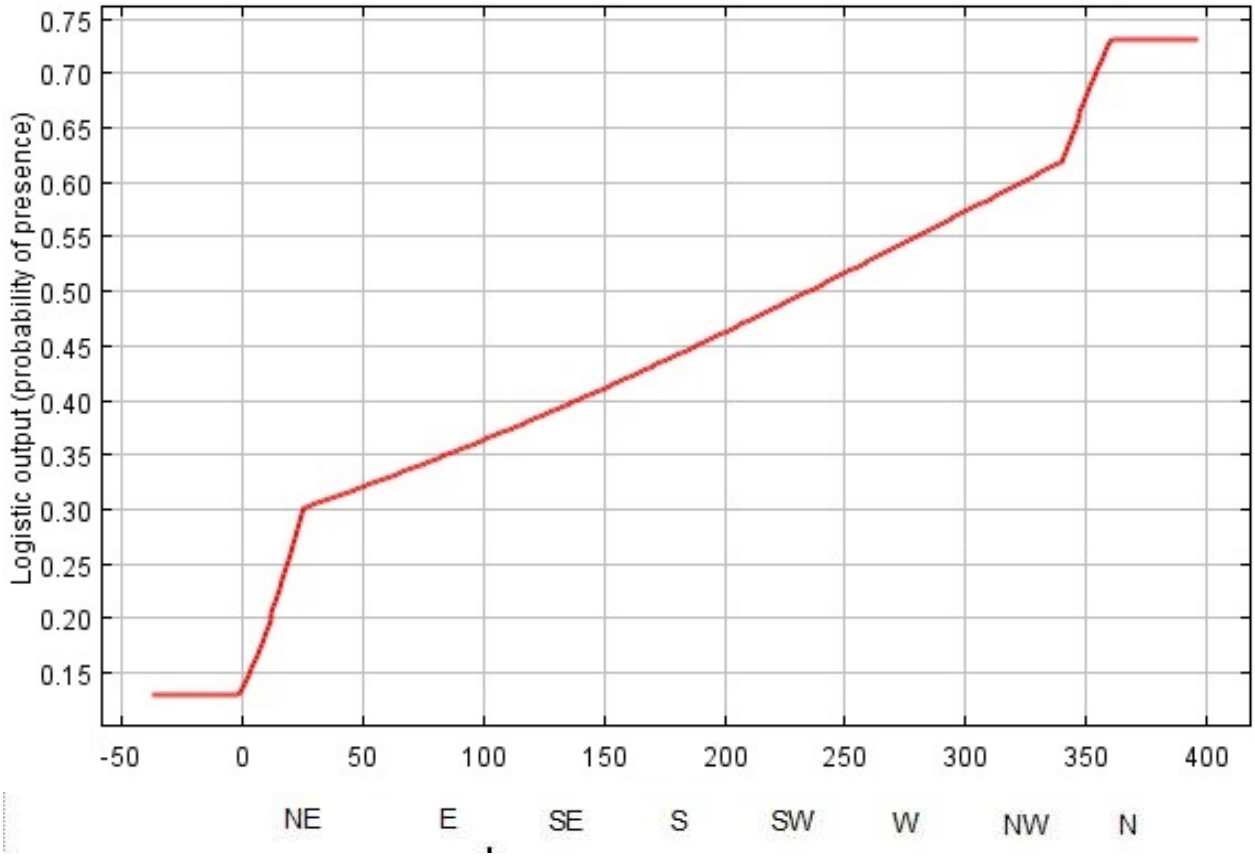

Figure 6. Relationship of the probability of grouse presence to aspect.

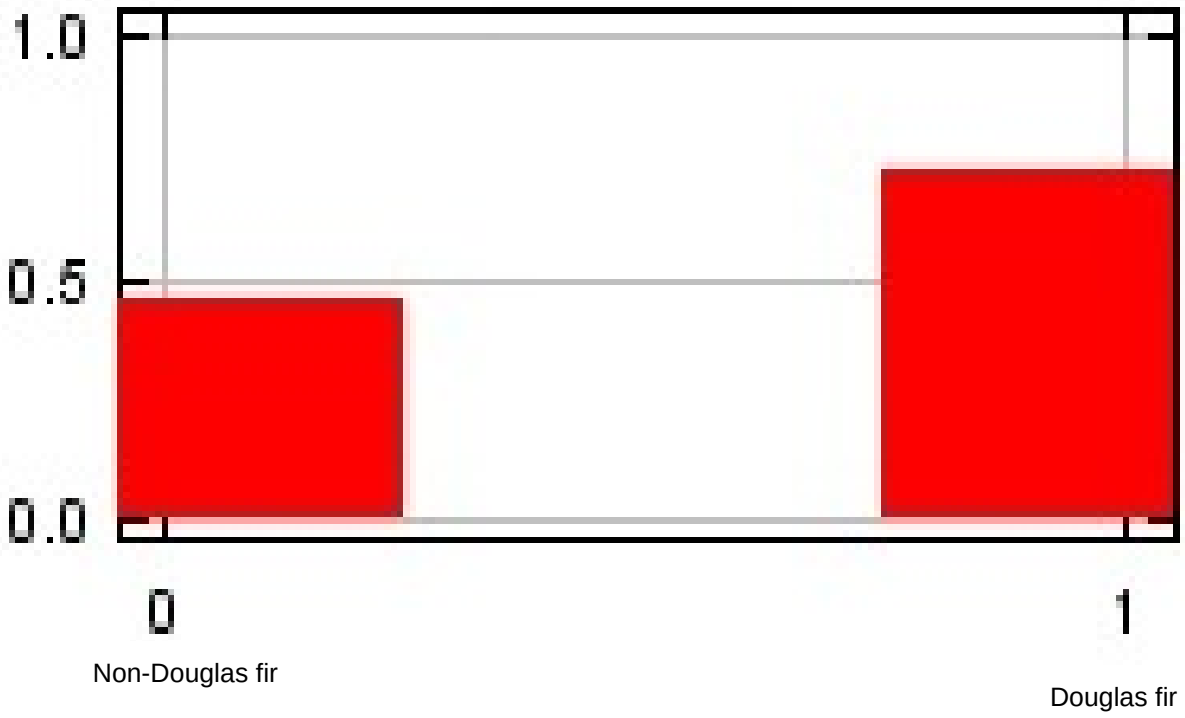

Figure 7. Relationship of the probability of grouse presence to the presence of Douglas fir forest cover.

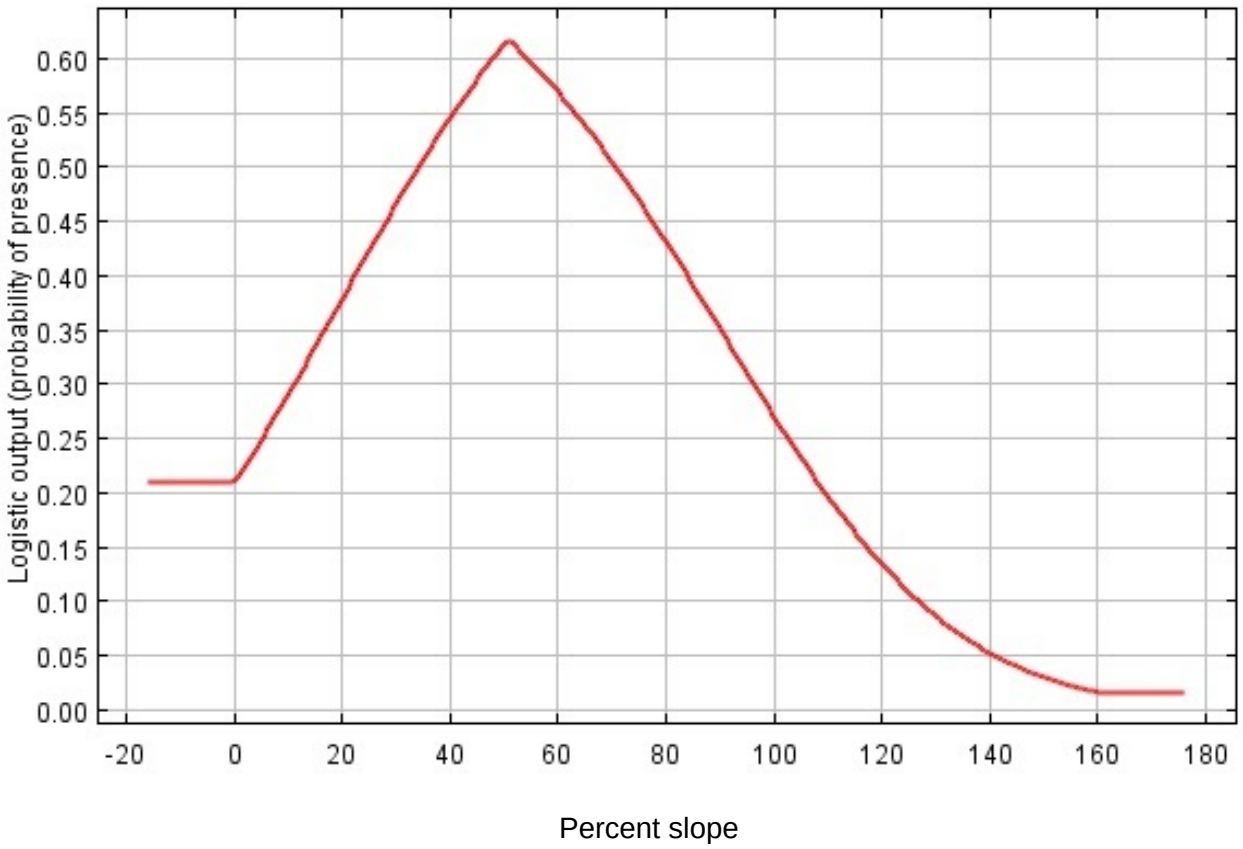

Figure 8. Relationship of the probability of grouse presence to percent slope.

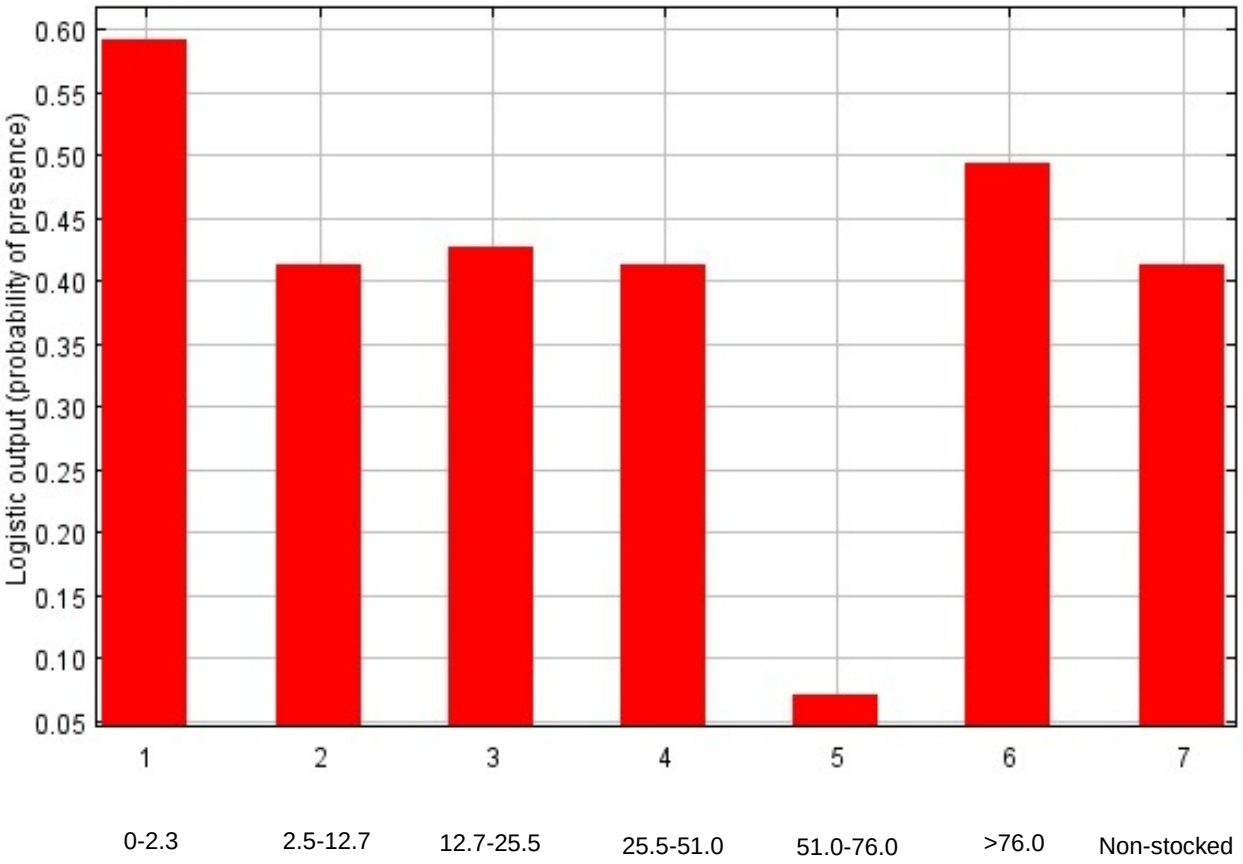
Logistic output (probability of presence)
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
1
2
3
4
5
6
7
0-2.3
2.5-12.7
12.7-25.5
25.5-51.0
51.0-76.0
>76.0
Non-stocked
Overstory tree diameter at breast height

Figure 10. Meadows along a former Mendocino Pass Blue Grouse Survey route are apparently being converted to open pine plantations by planting of pines.