Factors affecting spotted owl persistence in Northwest Washington: A 20 year retrospective

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I. *Introduction*

Over the past century, the barred owl (*Strix varia*) expanded its range westward, across the boreal and temperate forests of the northern United States and Canada, and then south along the Pacific Coast of North America, from SE Alaska to central California (Grant 1966, Taylor and Forsman 1974, Dark et al. 1998, Courtney et al. 2004). The range of the barred owl now overlaps the entire range of the northern spotted owl *(Strix occidentalis caurina*) and partially overlaps the range of the California spotted owl (*S. o. occidentalis*) (Kelly et al. 2003). The more aggressive barred owls have moved into many areas occupied by spotted owls, resulting in spotted owl displacement (Kelly et al. 2003, Pearson and Livezey 2003), mortality (Leskiw and Gutiérrez 1998) and occasionally, spotted and barred owl hybridization (Hamer et al. 1994, Kelly and Forsman 2004). The density of barred owls in the temperate forests of British Columbia and Washington has increased so rapidly that barred owls are far more numerous than spotted owls in most locations (Dunbar et al. 1991, Pearson and Livezey 2003). However, most of the recent research on spotted owl populations has taken place in the central and southern parts of their range where barred owl populations have not reached their maximum densities and are likely not occupying their full realized niche.

Recent analyses using the radio telemetry data from 1986-1988 research in the vicinity of Baker Lake (Hamer et al. 2007) found low overlap of adjacent barred owl and spotted owl home ranges suggesting that territorial barred owls exclude spotted owls from their territories, at least during the breeding season, thus reducing the amount of habitat available to spotted owls. Other research focusing on barred owl and spotted owl interactions found declines in spotted owl occupancy (Kelly et al. 2003) and productivity (Olson et al. 2004) with increases in barred owl density or presence. Anthony et al. (2004) found negative effects of barred owl presence on spotted owl survivorship in parts of Washington where barred owls were most abundant and had been present for the longest time. Furthermore, the diets of the two species in northern Washington overlap considerably, suggesting that they may be in direct competition for limited food resources (Hamer et al. 2001).

Previous landscape scale research efforts have compared the significance of fragmentation and patch area metrics in explaining spotted owl presence (Lehmkuhl and Raphael 1993). Other research on habitat characteristics surrounding barred and spotted owl nest locations compared the percentages of mature and young coniferous forest within 0.8 and 1.6 km of known nest locations (Herter and Hicks 2000). Metrics such as area of late-seral habitat, a patch isolation index, and the coefficient of variation of patch area have proven to be useful measures of habitat use patterns in spotted owl home ranges (Lehmkuhl and Raphael 1993). However, these previous studies have been unable to accurately estimate barred owl densities because of their reliance on spotted owl survey techniques.

The U.S. Forest Service, Washington Department of Fish and Wildlife, Biosystems Analysis Inc., and Puget Sound Energy Company conducted northern spotted owl surveys in the Baker Lake Basin from 1981 through 1984. The Mt. Baker Ranger District resumed surveys in 1986 and continued until 1988. In addition, from 1986-1988 spotted owl and barred owl surveys were conducted concurrently with a radio-telemetry study to determine home range size and territory boundaries individuals of both species throughout the basin (Hamer 1988). Fourteen spotted owls and 23 barred owls were outfitted with transmitters and tracked using radio-telemetry. This was a unique study in that it was designed to detect both spotted owls and barred owls, whereas almost all published studies on barred owls in the Pacific Northwest have analyzed data that was collected using only spotted owl survey methodology (Courtney et. al. 2004).

The 5-year status report on the northern spotted owl states: “the greatest uncertainties associated with the actual and potential effects of the barred owl on the spotted owl are that we lack accurate information on barred owl density, numbers, and population trends” (Courtney et al. 2004). Results from studies conducted in locations that have a longer history and higher frequency of barred owl presence, can be used to make predictions about future impacts of barred owls on northern spotted owls in Oregon and California (Olsen et al. 2005). The combination of data from 1988 and 2008 in the Baker Lake Basin provides a unique opportunity to document the changes in relative abundance of both spotted and barred owls after a 20 year period and examine spotted owl displacement rates in a region where barred owls have likely reached their highest densities. In addition, this research helped to fill an important data gap by completing surveys in an area that had not been surveyed since the federal and state listing of the spotted owl or the initiation of the Northwest Forest Plan.

Study objectives

The objectives of our research were to: 1) determine the relative abundance of spotted and barred owl populations in the vicinity of the Baker Lake Basin; 2) compare the current relative abundance of spotted and barred owls with the results from the previous study conducted in 1986-1988 to assess whether barred owl and spotted owl populations are stabilizing in the northern part of the spotted owl’s range; 3) identify landscape and habitat composition features that help predict spotted owl persistence; 4) assess how these predictive factors might be used in forest management to help the spotted owl persist and finally; 5) based on the identified landscape features leading to spotted owl persistence, and the relative abundance of both species, assess the likelihood that spotted owls can persist with barred owls in Western Washington.

Our null hypotheses relating to spotted owl persistence included:

1. **Habitat composition features correlated with spotted owl persistence:** There are no differences in the proportions of deciduous and conifer dominant habitat surrounding barred and spotted owl activity centers or a matching number of random locations.
2. **Fragmentation features correlated with spotted owl persistence:** There are no differences between the landscape fragmentation metrics (edge density, patch density and landscape proportion) for the habitat surrounding barred and spotted owl activity centers, or a matching number of random locations.
3. **Biophysical features correlated with spotted owl persistence:** There are no differences between the biophysical characteristics (e.g. elevation, slope, aspect, precipitation, and temperature) of barred and spotted owl activity centers or a matching number of random locations.

Null hypothesis relating to the local expansion in range of the barred owl:

4. **Habitat composition or biophysical characteristics of barred owl activity centers in the Baker Lake Basin:** There are no differences between the biophysical characteristics and habitat composition of barred owl activity centers identified in 1988 and those found in 2008.

II. *Study Area*

Our study area was located in northwest Washington in the Baker Lake Basin on the west slope of the North Cascades and comprised an area of 317 square kilometers (122 square miles) including the headwaters of the South Fork Nooksack River, Diobsud Creek and Bacon Creek (Figure 1). Baker Lake lies just southeast of Mount Baker with much of the study area occupying the lower forested slopes of the mountain itself. The majority of the land is managed by the USFS and is part of the Mount Baker-Snoqualmie National Forest. Portions of the study area are highly fragmented due to historic forest management practices while other areas contain large contiguous forest stands. This site is representative of much of the low-mid elevation forested lands that exist along the west-slopes of the Cascades in Washington. Therefore, the results of this study are broadly applicable for public and private forest land owners in this region. The 11 historical spotted owl activity centers (from the 1988 research) within which surveys were conducted were centered on the documented home ranges of the spotted owls from the 1988 radio-telemetry study (Hamer et al. 2007). The study area boundary was defined to include the area within 2897 m (1.8 mile) radius circles around each of the 11 historical spotted owl locations. The study area also included other suitable habitat within the Baker Lake Basin below 1500 m (4921 ft) in elevation, where no spotted owls were found in 1988.

III. *Methods*

Three nighttime survey visits were conducted independently for each species throughout the entire study area (6 visits total). This survey effort provided an 88% confidence level for locating both members of a pair of spotted owls and a 95% level of confidence for finding single territorial birds at occupied sites (Olsen et al. 2005). The geographic extent of survey coverage was designed to match 1988 survey efforts. We primarily surveyed from existing roads and trails, using standard methods for locating spotted owls (Forsman 1983). Calling stations for both species were located 0.4-0.6 km apart to obtain consistent survey coverage. A boat located approximately 50 m from shore was used to broadcast calls into the low elevation habitat on the east side of Baker Lake, as road and trail access was limited (Figure 2). We collaborated with the USFS Mount Baker Ranger District office regarding study planning, road and trail access.

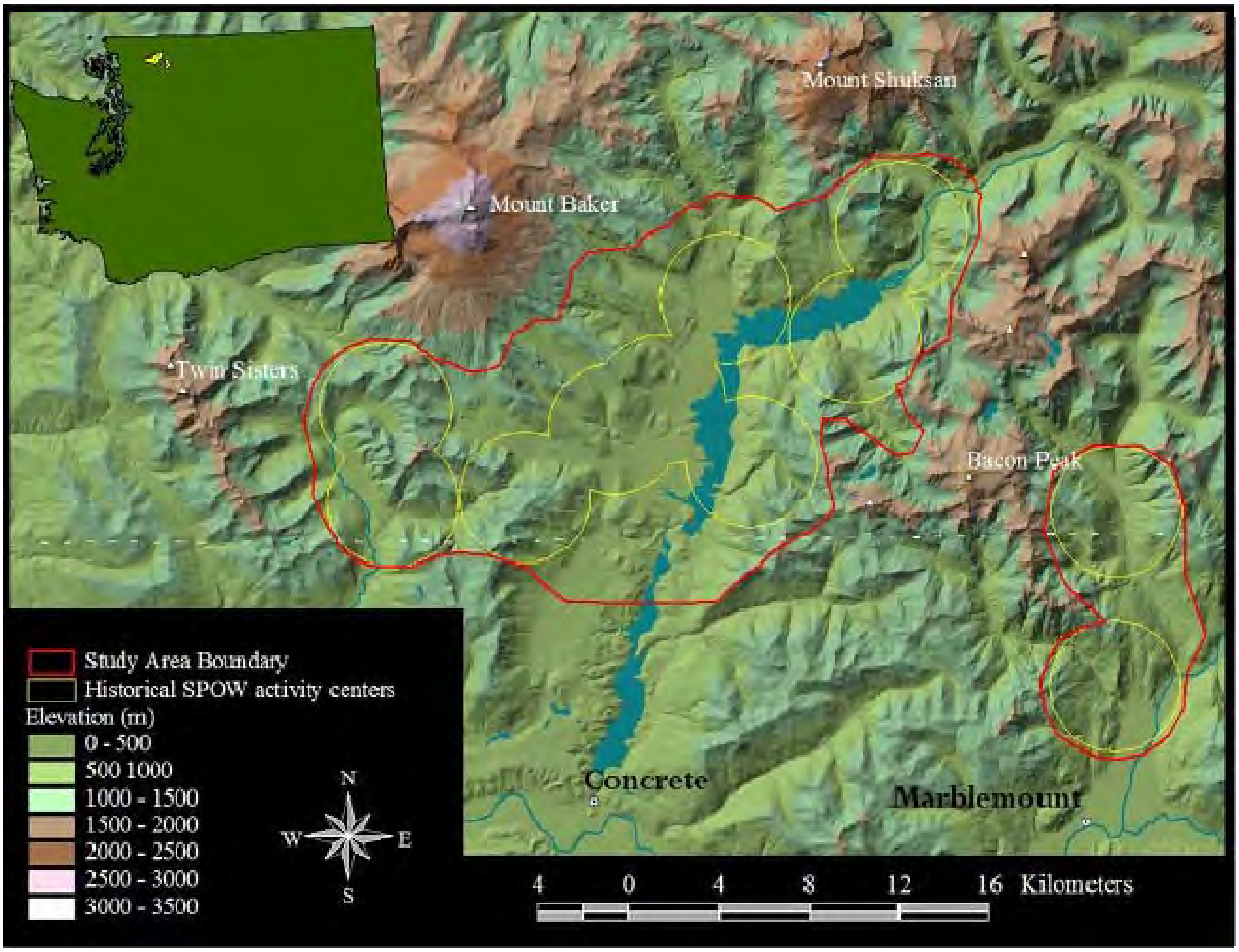


Figure 1. Approximate boundary of the Baker Lake Basin study area, Washington.

To broadcast owl calls we used Western Rivers Predation Callers (recordable mp3 broadcast call devices) and adapted owl vocalizations tracks from the Cornell Lab of Ornithology "Voices of North American Owls" database. Call types and broadcast methods were consistent throughout the study area and season to minimize variation in owl responses. Ten minutes of calling was conducted at each survey station with 3-5 call series broadcast, following standard spotted owl survey procedure (Crozier et al. 2006). If the observer's auditory ability was compromised, the survey duration was extended beyond 10 minutes. We conducted surveys from 30 min after sunset to approximately 02:00 PDT to reduce within-night variation in responsiveness (Forsman 1983). Surveys were not conducted under high winds (>12 km/hr) or heavy rain. For each owl response, we recorded the species, detection time, location of detection (bearing and distance), sex (based on call pitch), and response type (visual or vocal). In addition, we recorded the survey station location, temperature, wind, moon phase, cloud cover and precipitation intensity. The barred owl survey protocol was identical to the spotted owl protocol except barred owl calls were used for the play-back response. Daytime follow up visits were conducted on spotted owl and some barred owl responses to define activity centers more accurately.

Figure 2. Zodiac used for nocturnal broadcast surveys for the lower elevation habitat on the east side of Baker Lake.

<u>Adjustments for Potential Survey Response Bias</u>

Crozier et al. (2006) found fewer responses by spotted owls when barred owls were present, but this trend was not significant (p=0.08). Olsen et al. (2005) showed that “Barred Owl presence had a negative effect on spotted owl detection probabilities...”. There are similar concerns about the detectability of barred owls using traditional broadcast vocalization methods. Currently, there is no accepted adaptation of the traditional survey protocol to mitigate for the potential differences in species detectability, as the magnitude of difference is unknown. Although this issue is somewhat contentious in the literature, we concluded that there were not enough data on this complex subject to justify using different survey intensity for the two species. To minimize effects on spotted owl responsiveness, we surveyed for barred and spotted owls independently, with spotted owl surveys always occurring first, and barred owls surveys occurring at least one week later in this same area; as recommended by Crozier et al. (2006). To allow comparison with the 1988 data from the same area (Hamer et al. 1989) and other studies on *Strix spp*. abundance, we report the number of responses by each species per km of road/trail surveyed, and per survey station as measures of relative abundance.

Activity Centers

Activity centers were determined using the location of adult pairs with fledglings (especially early in the season before fledglings become increasingly mobile). Repeated close proximity observations of an owl pair of without fledglings on subsequent visits also warranted activity center designation. Detections of non-paired barred owls were used for the comparison of 1988 and 2008 response rates, but were not assigned activity center locations for habitat associations due to the transient nature of non-pair birds.

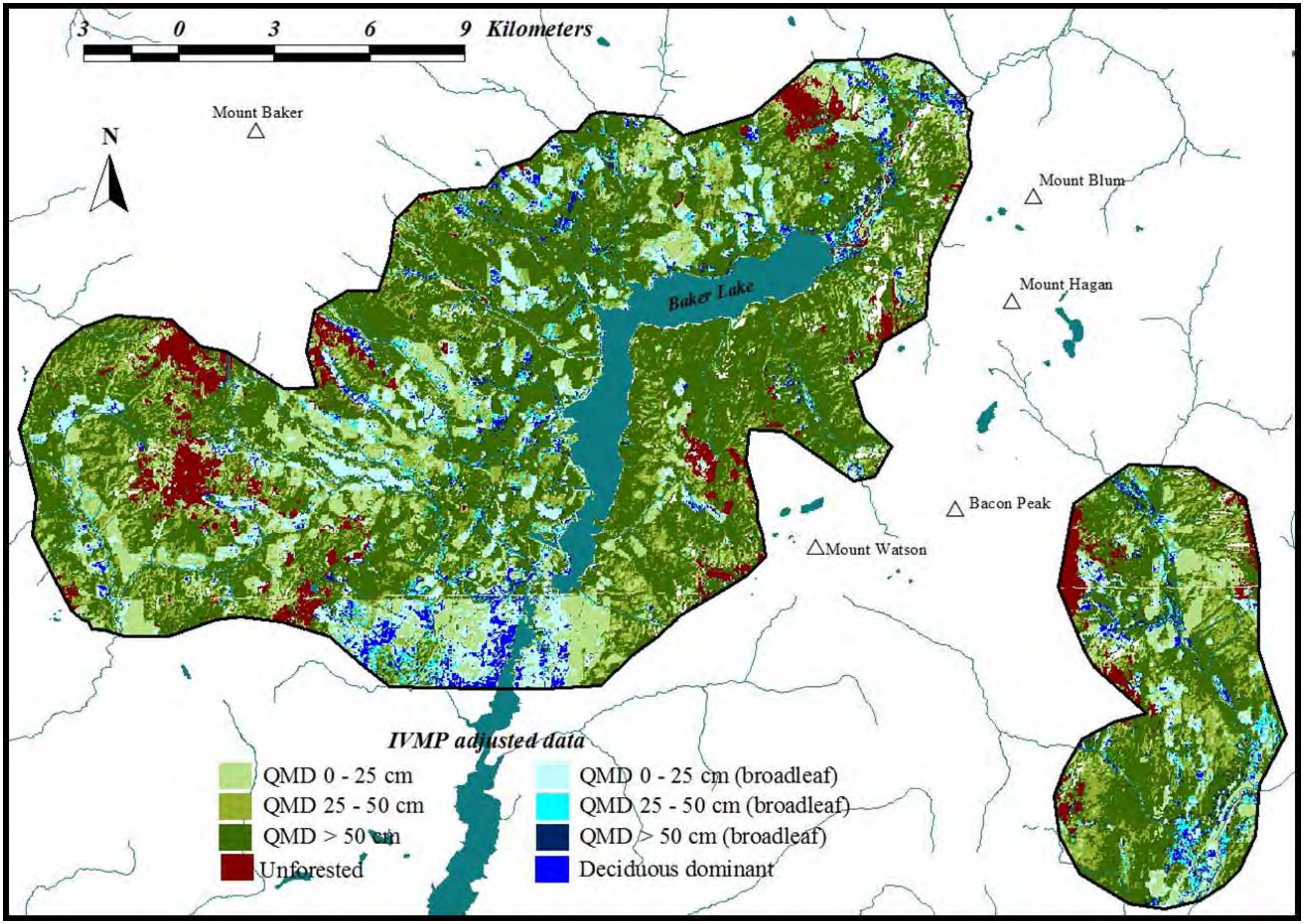
Habitat data

We used satellite data from the Interagency Vegetation Mapping Project (IVMP) to characterize the habitat and landscape condition around barred and spotted owl activity centers. The IVMP vegetation map is a digital raster map developed using geometrically rectified Thematic Mapper (TM) images. It includes themes for vegetation cover, percent conifer cover, percent broadleaf cover, quadratic mean tree diameter, and a mask for non-forested areas. Combining elevation data with quadratic mean tree diameter (QMD), and percent broadleaf cover from the IVMP database, we defined eight distinct cover types resulting in grid coverage (25 m resolution) of the entire Baker Lake Basin study area (Table 1; Figure 3). Our resulting habitat types closely mirrored those used for the analysis of 1988 data (Hamer et al. 2007). The inclusion of broadleaf cover data in the final habitat grid was to help discern whether barred owls were disproportionately colonizing bottomland forested areas with high broadleaf cover (and a more diverse prey base) as has been reported in past research (Hamer et al. 2007, and Gutierrez et al. 2004).

Table 1. Derivation of habitat classification categories using IVMP quadratic mean tree diameter (QMD) and broadleaf cover grids in combination with USGS elevation data

Habitat Classification	**IVMP QMD data**	**IVMP Broadleaf cover**	**USGS National Elevation Database (NED)**
Pole aged; conifer dominant	QMD 0-25 cm	< 30 % broadleaf cover	all elevations
Large tree; conifer dominant	QMD 25-50 cm	< 30 % broadleaf cover	all elevations
Mature forest; conifer dominant	QMD > 50 cm	< 30 % broadleaf cover	all elevations
Pole aged; deciduous component	QMD 0-25 cm	> 30 % broadleaf cover	< 1067 m (3500 ft) in elevation
Large tree; deciduous component	QMD 25-50 cm	> 30 % broadleaf cover	all elevations
Mature forest; deciduous component	QMD > 50 cm	> 30 % broadleaf cover	all elevations
Hardwoods	Deciduous dominant	> 30 % broadleaf cover	all elevations
*Unforested**	QMD 0-25 cm	> 30 % broadleaf cover	> 1067 m (3500 ft) in elevation
	barren, snow, rock	-	all elevations
	< 70 % veg cover	-	> 1067 m (3500 ft) in elevation

*Unforested habitat includes areas of subalpine shrub and parkland vegetation



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igure 3. Habitat map for the study area derived from USDA IVMP (tree composition and size) and elevation data.

The reclassification and combination of grid coverages was used to designate habitat types for the 2.90 km (1.8 mile) radius activity centers (2659 ha) of spotted owls and 1577 m (0.98 mile) radius activity centers (781 ha) of barred owls (Hamer et al. 2007). The grid data sets and a matching number of grids from random activity centers (781 ha each) were imported into the landscape analysis program FRAGSTATS to derive landscape pattern and habitat composition predictor data (McGarigal et al. 2002). The patch edge density and the percent of the landscape within each habitat type were quantified using FRAGSTATS software (McGarigal et al. 2002).

The landscape fragmentation metrics, elevation, slope and aspect were extracted for all spotted and barred owl activity centers, and a matching number of random locations. They were compared using one sample and two sample t-tests (Zar 1999). In addition, fragmentation metrics, elevation, slope and aspect data were compared between sites where spotted owls were found in 2008 and those where historical spotted owl pairs no longer exist. The number of statistical tests required to test for differences in each of the eight patch types raised concern over potentially inflating type one error rates. Therefore, a Bonferonni corrected alpha value was applied (Zar 1999, Ott 1993). Because each set of tests considered eight different patch types, we divided the typically accepted type one error rate of 0.05 by 8 leaving us with an alpha critical value of 0.0063. However, when the design was balanced (i.e. comparing the same number of activity centers [e.g. barred vs. random]), we were able to use MANOVA (Wilks λ) for a test of differences across all patch types simultaneously without conducting multiple tests (Zar 1999).

Biophysical data

Average annual maximum temperature (^{o}C) (PRISM), average annual precipitation (cm) (PRISM) and elevation (m) (USGS NED) were extracted for all spotted and barred owl activity centers, and the study area as a whole. Biophysical characteristics of 2008 barred owl and historical barred and spotted owl activity centers were compared with study area wide mean values and the 2008 spotted owl location value. Comparisons included one sample t-tests with Bonferroni corrected alpha values (alpha = 0.0167 for 3 tests: avg. annual maximum temperature (^{o}C) (Figure 4), avg. annual precipitation (cm), and elevation (m)). Slope and aspect values were also compared between 2008 barred owl and historical barred and spotted owl activity centers.

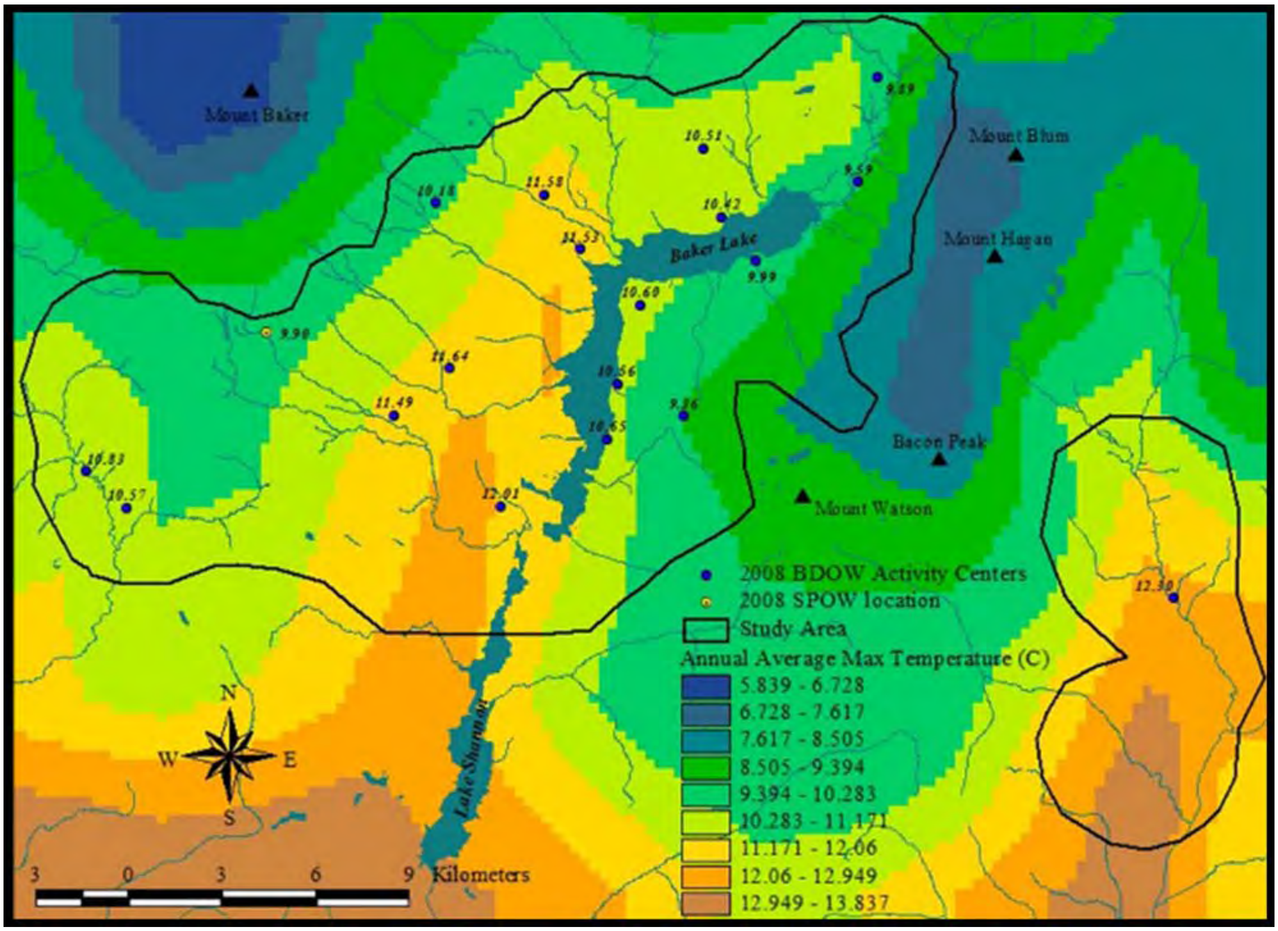

Figure 4. Example of biophysical data (average maximum temperature annually) across the study area with barred and spotted owl activity centers.

IV. *Results*

Early site reconnaissance revealed a deep snow pack and challenging road access conditions throughout Baker Lake Basin. Despite these challenges 220 survey points were installed in and near the historical spotted owl activity centers within the South Fork Nooksack River, main Baker River (Baker Lake), Diobsud, and Bacon Creek drainages (Figure 1). Numbered flagging and reflective tape was hung at each call point location, and the location was recorded and plotted in the GIS database. Of the 220 points installed, 113 points were surveyed from drivable roads, 52 points were on blocked or decommissioned roads, 39 points were on overgrown roads or trails; and 16 points on the east shore of Baker Lake were surveyed from a boat just off shore, allowing greater coverage of the upslope habitat (Figure 5). Surveys points were primarily located on the Mount Baker Snoqualmie National Forest, but were also in the Mount Baker National Recreation Area, North Cascades National Park, and on Washington State forest lands (WADNR) (Figure 6).

Crews were trained in broadcast call methods, and to identify the entire repertoire of calls from every owl species in northwestern Washington, using the Voices of North American Owls CD produced by the Cornell Lab of Ornithology (2006). Vocalization tests were given to field the field crew to ensure that they had adequate knowledge of the variety of owl vocalizations that they might be hearing.

Survey Visits

Three full survey visits were completed for both spotted and barred owls. In all, 1,295 10-minute playback call surveys were conducted during the survey visits. Using standard survey methodology, when a reproductive pair of owls (with fledgling or nestling young signifying an activity center) was identified near a survey point, subsequent surveys for that species at that point were dropped to avoid unnecessarily disrupting the nesting process. Throughout the survey season, this resulted in twenty-five of the 660 barred owl playback surveys being dropped. Surveys began May 19th and were completed by August 28th. Surveys in the South Fork

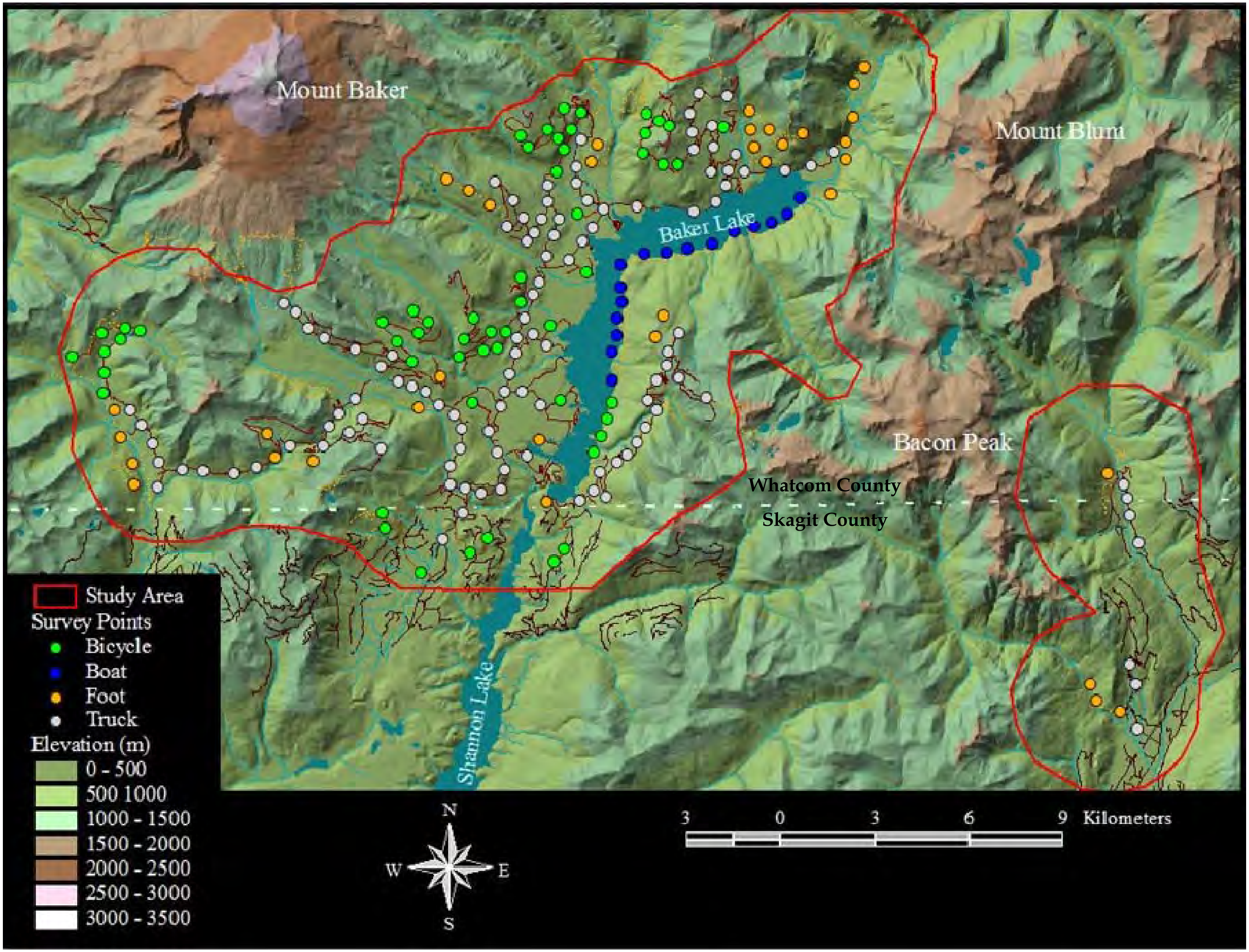

Figure 5. 2008 survey points by method of survey.

Nooksack drainage (far western portion of the study area) began later, as the area was seasonally closed due to calving elk. Access to this drainage didn't become possible until 1 July, but all six surveys were successfully completed at each point.

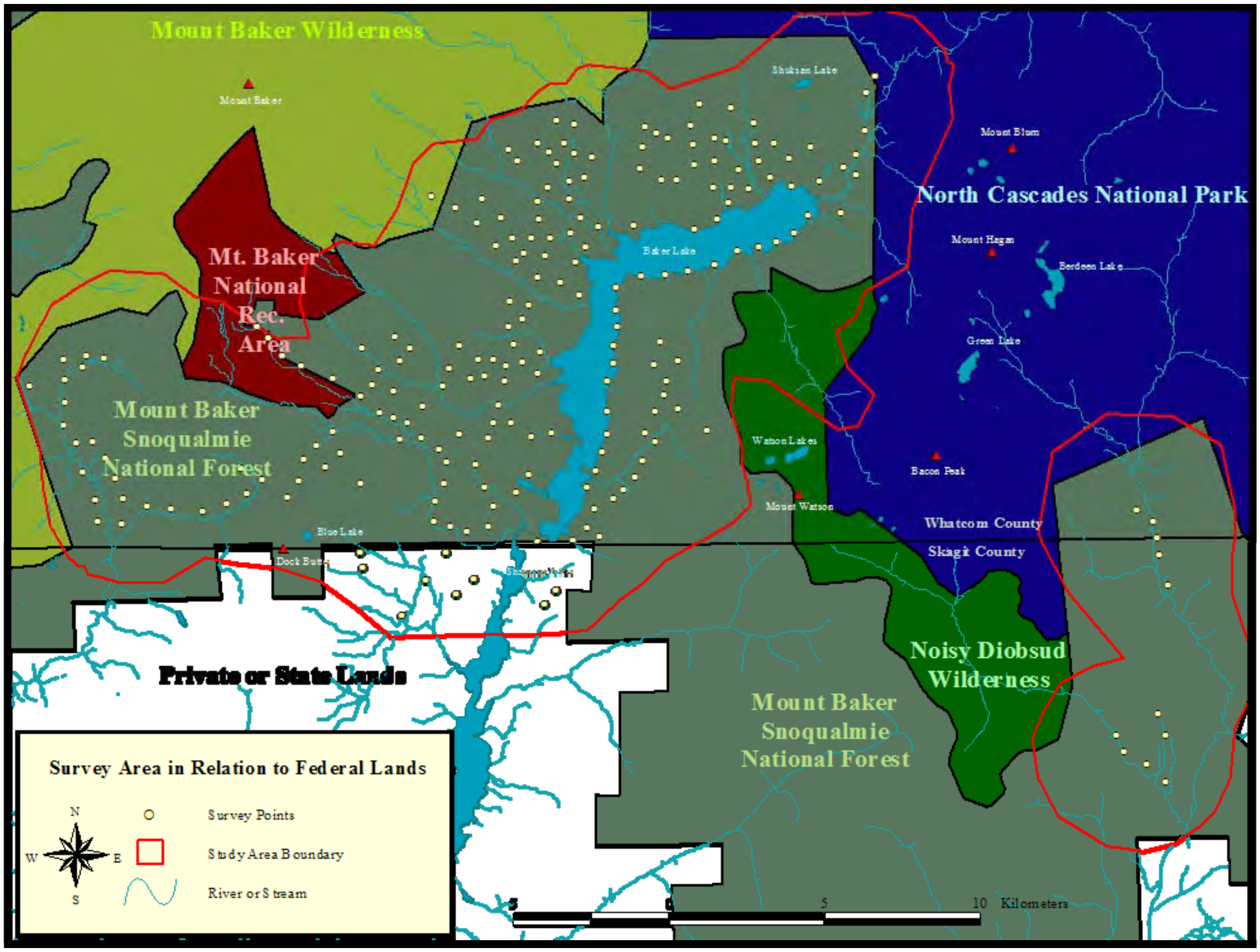

Figure 6. Survey points and their relation to surrounding Federal land designations.

Owl Responses

Although surveys began on 19 May, the first *Strix spp.* response was not until 17 June. After that date, barred owls were the most commonly detected owl with some survey nights recording as many as 11 individuals in 16 surveyed points. Only two northern spotted owl responses were recorded over the course of the surveys; these occurred near Schreiber's Meadow trailhead on 11 August at the beginning of the survey night (Figure 7). The responses were both from a substantial distance away but were clearly audible 4-note calls, likely from the same bird approaching the surveyor. Three daytime/dusk follow-up surveys were conducted near each of the two night-time responses to locate the bird(s) with no success. Forest Service accounts of a spotted owl calling at Schreiber's Meadow approximately a week prior to our detections led us to make the assumption that the detected spotted owl was a resident of the area surrounding the trailhead. The three locations were averaged to determine the activity center.

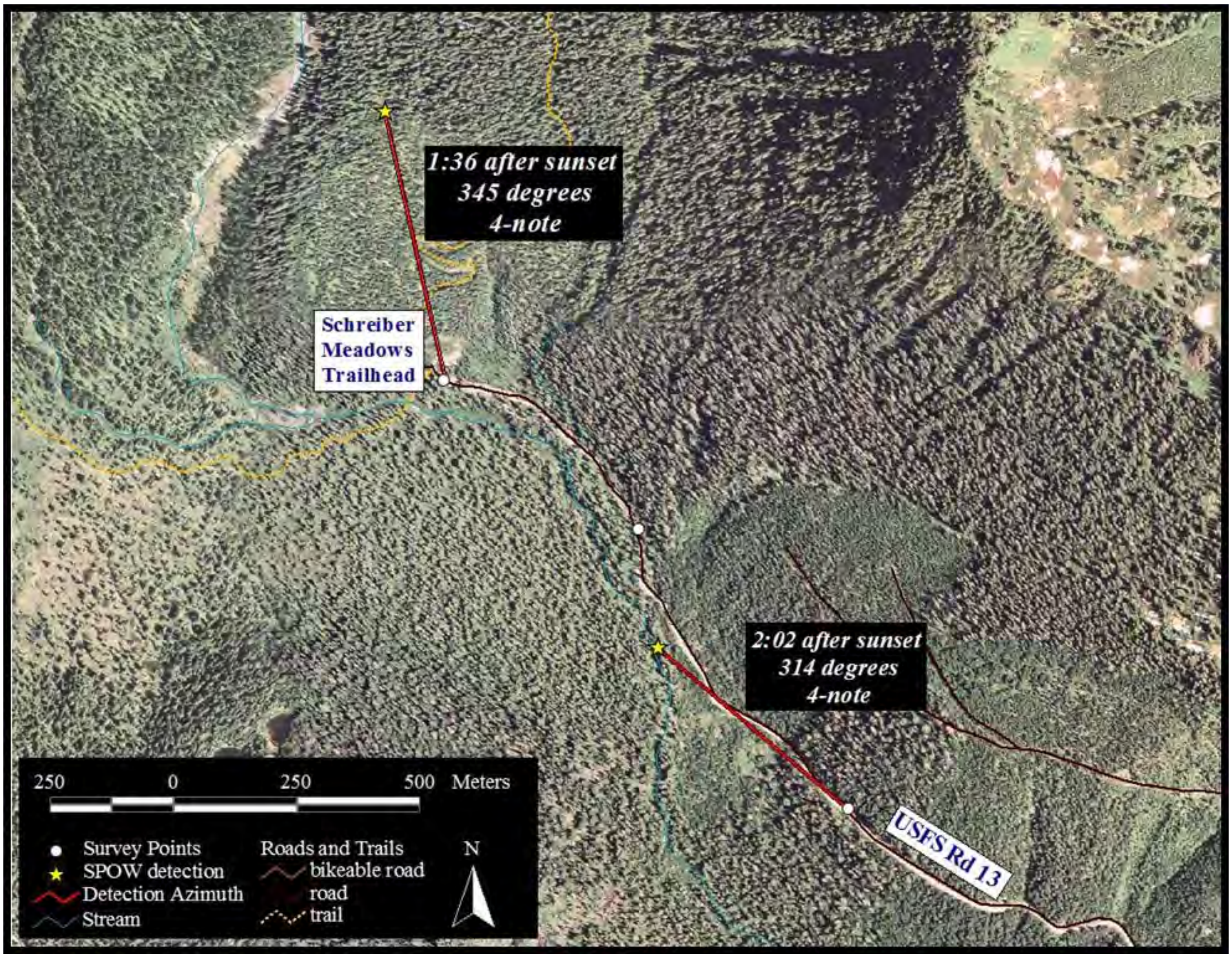

Figure 7. Spotted owl detections (See Figure 9 for overview of location)

A total of 160 adult barred owl detections were recorded during 127 of the 1,290 (9.9%) protocol surveys (Figure 8). However, we expect the total number of barred owls in the basin is lower than 160 as many adult birds were detected more than once during the six survey effort.

An additional six adult barred owl detections occurred incidentally along roads or trails (Figure 8). Eighteen barred owl activity centers were identified, with fledglings confirmed at nine sites (50%) (Figure 9). Other owl species detected included great-horned owls (*Bubo virginianus*) at six survey points (one individual per point) (Figure 4); northern saw-whet owls (*Aegolius acadicus*) at three points (one individual per point) (Figure 8); and northern pygmy owls (*Glaucidium gnoma*) at two points (one individual per point) (Figure 8).

Relative Abundance/Detection Rate Estimates

In 2008, our surveys covered 227 km or road and trail. Barred owls were encountered at a rate of 0.233 individual (non-fledgling) birds per kilometer of road or trail surveyed, and spotted owls were detected at a rate of 0.004 birds per kilometer of road or trail surveyed. Blue Lake, Bell, and Diobsud Creek were the only three historical spotted owl activity centers without a confirmed *pair* of barred owls. However, there were barred owl individuals detected within all 11 historical spotted owl activity centers. Seventy-four percent of detections were of single adult barred owls. Pairs of adult birds with no fledglings comprised 14 percent of all barred owl detections, and responses including at least one fledgling comprised the remaining 12 percent.

In 1988, surveys covered 233 km of road or trail. Barred owls were reported at a relative abundance of 0.133 detections (non-fledgling) birds per km of road or trail surveyed, and spotted owls were reported at 0.069 birds per km of road or trail surveyed. To the north, in Southwestern British Columbia, a 1985-1988 study found detection rates were 0.04 and 0.15 birds per kilometer of transect for spotted and barred owls, respectively (Dunbar et al. 1991).

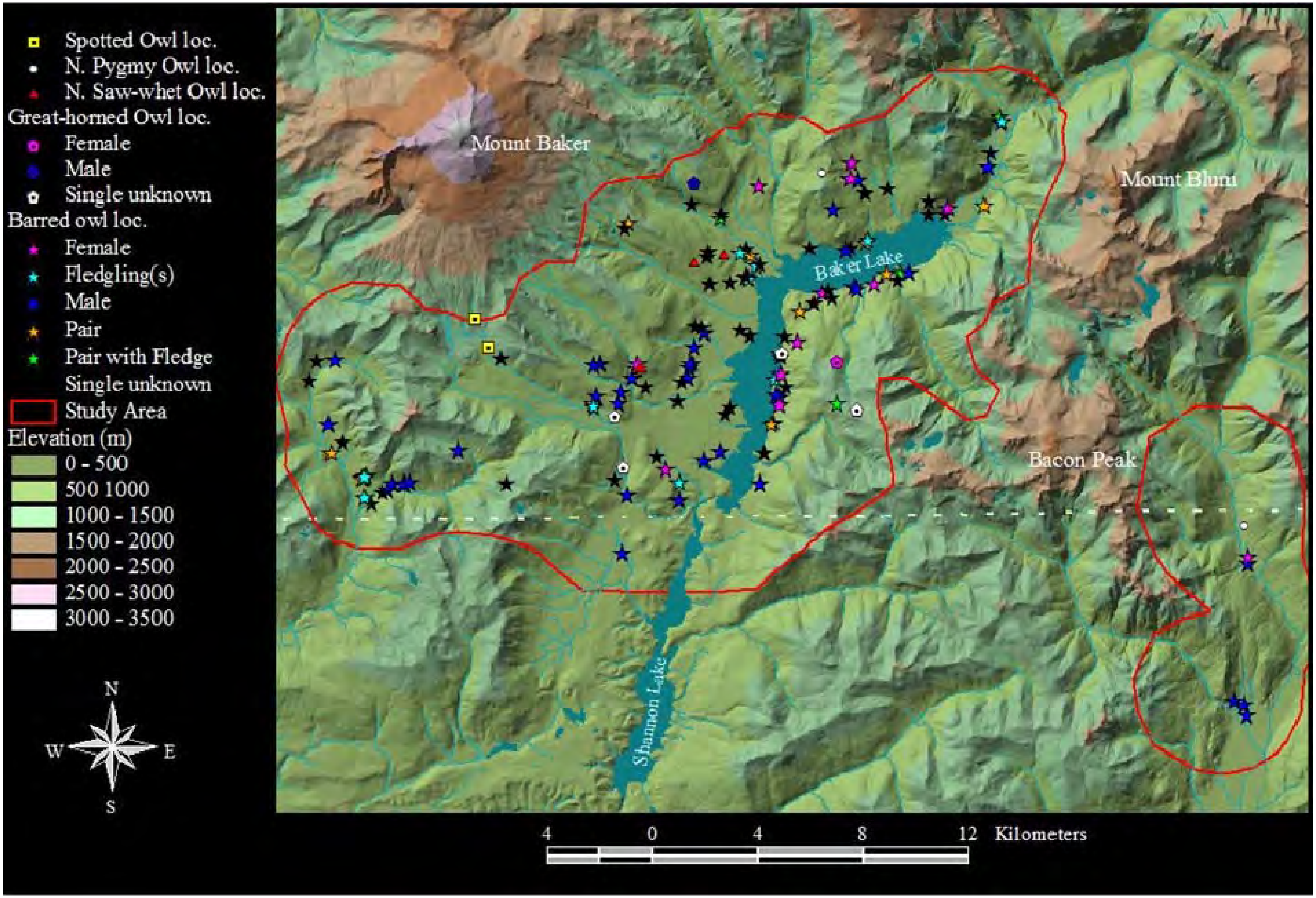

Figure 8. Spotted, barred, great-horned, northern saw-whet and northern pygmy owl detections in the Baker Lake Basin (2008) plotted at their estimated first detected location (azimuth triangulations were used when possible).

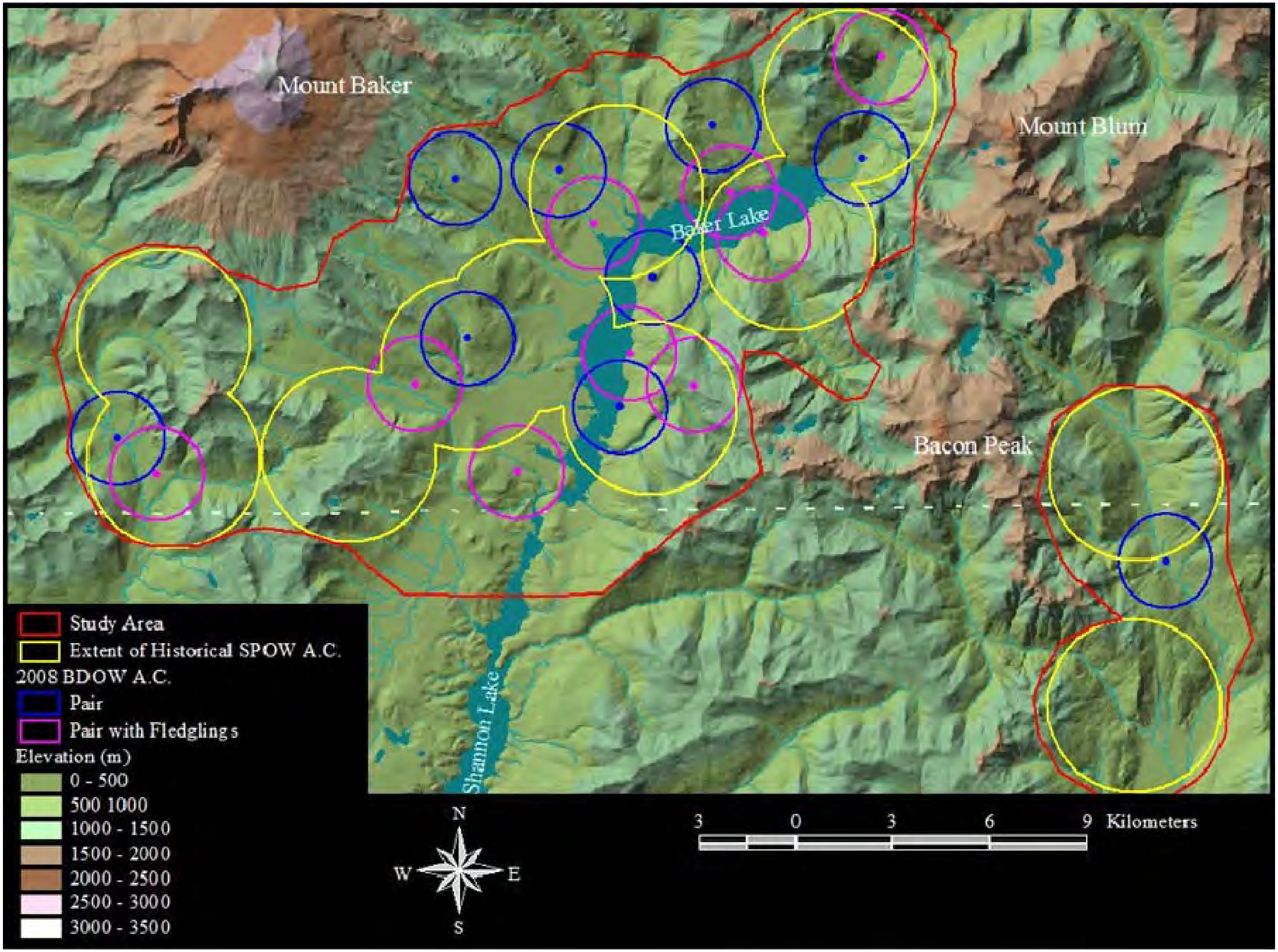

Figure 9. Barred owl activity centers in the Baker Lake Basin (2008) in relation to historical spotted owl activity centers.

Hypothesis 1: Landscape Area by Forest Type

We report on tests assessing the difference between mean habitat distribution values from barred owl, historical spotted owl, and random activity center locations and the habitat distribution surrounding the only location where spotted owls were found. These tests were not intended to discern a significant difference in habitat associations between the species, but were useful in determining whether the representation of habitat types surrounding barred owl and historical spotted owl activity centers differed in magnitude from those surrounding the only remaining location of spotted owls in the Baker Lake Basin. When assessing differences in the percent of landscape area by forest type, we conducted the following comparisons:

• 2008 Barred owl activity centers	vs.	Random activity centers	MANOVA Wilks λ
• 2008 Barred owl activity centers	vs.	Study area “expected” values	One-sample t-test Bonferonni corrected α
• Random activity centers	vs.	2008 spotted owl activity center	One-sample t-test Bonferonni corrected α
• 1988 Spotted owl activity centers	vs.	2008 spotted owl activity center	One-sample t-test Bonferonni corrected α
• 2008 Barred owl activity centers	vs.	1988 barred owl activity centers	Two-sample t-test Bonferonni corrected α

We found no significant differences between the forest composition (deciduous vs. coniferous) and tree size (QMD) of barred owl activity centers and a matching number of random activity centers (Table 2, Wilks λ = 1.18; P = 0.34). However, there was significantly less non-forested area within the barred owl activity centers than within the study area landscape as a whole (Table 3).

There was more non-forested area within the 2008 spotted owl activity center than in the collection of random activity centers (P < 0.001; Table 4). In addition, there was less mature conifer dominant (P = 0.024) and mature deciduous component forests (P = 0.025) in the 2008 spotted owl activity center than in the collection of random activity centers (Table 4). However, these differences were moderate and P-values fell above our Bonferonni adjusted acceptable type 1 error rate.

Table 2. Comparisons of the percent of landscape occupied by each forest type between 2008 barred owl activity centers and a matching number of random locations.

Forest Type	Avg. % of area within 2008 barred owl activity centers (n=18)	Avg. % of area within random activity centers (n=18)	P-Value
Pole aged; conifer dominant	15.51	15.09	0.859
Large tree; conifer dominant	14.85	14.91	0.968
Mature; conifer dominant	52.56	47.88	0.455
Pole aged; > 30% deciduous	8.35	9.72	0.591
Large tree; > 30% deciduous	2.43	2.41	0.978
Mature; > 30% deciduous	2.66	1.72	0.166
Deciduous dominant	2.22	3.18	0.405
Non-Forest	1.44	5.09	0.110

Table 3. Comparisons of the percent of landscape occupied by each forest type between 2008 barred owl activity centers and a matching number of random locations.

Forest Type	Avg. % of area within 2008 barred owl activity centers (n=18)	Landscape/Study Area Wide "Expected" Values	P-Value
Pole aged; conifer dominant	15.51	16.2	0.701
Large tree; conifer dominant	14.85	15.77	0.395
Mature; conifer dominant	52.56	46.31	0.122
Pole aged; > 30% deciduous	8.35	8.83	0.741
Large tree; > 30% deciduous	2.43	2.51	0.857
Mature; > 30% deciduous	2.66	2.37	0.579
Deciduous dominant	2.22	2.67	0.299
Non-Forest	***1.44***	***5.34***	***< 0.001***

The 1988 spotted owl activity centers had significantly less mature conifer dominant forest than was observed surrounding the one 2008 spotted owl activity center (P < 0.001; Table 5). On the other hand, the 1988 spotted owl activity centers had more surrounding large tree deciduous and mature deciduous forest habitat than did the 2008 spotted owl activity center (P = 0.001 and P = 0.001 respectively; Table 5). In addition, deciduous dominant habitat made up

11.8 percent of the total habitat area in 1988 spotted owl activity centers, which was significantly more than the 1.74 percent within the 2008 spotted owl activity center, or the 2.67 percent contained within the entire study area ($P < 0.001$ and $P < 0.001$, respectively).

Table 4. Comparisons of the percent of landscape occupied by each forest type between 2008 spotted owl activity centers and a matching number of random locations.

Forest Type	**2008 spotted owl Activity Center "Expected" Values (n=1)**	**Avg. % of area within random activity centers (n=18)**	**P-Value**
Pole aged; conifer dominant	15.96	15.09	0.571
Large tree; conifer dominant	13.93	14.91	0.461
Mature; conifer dominant	35.92	47.88	0.024
Pole aged; > 30% deciduous	11.39	9.72	0.429
Large tree; > 30% deciduous	0.97	2.41	0.047
Mature; > 30% deciduous	0.69	1.72	0.025
Deciduous dominant	1.74	3.18	0.188
Non-Forest	***19.4***	***5.09***	***< 0.001***

Table 5. Comparison of the percent of landscape occupied by each forest type between 1988 spotted owl activity centers and the 2008 spotted owl activity center.

Forest Type	**Avg. % of area within 1988 spotted owl Activity Centers (n=11)**	**2008 spotted owl Activity Center "Expected" Values**	**P-Value**
Pole aged; conifer dominant	13.89	15.96	0.192
Large tree; conifer dominant	13.98	13.93	0.965
Mature; conifer dominant	***12.22***	***35.92***	***< 0.001***
Pole aged; > 30% deciduous	11.47	11.39	0.966
Large tree; > 30% deciduous	***10.61***	***0.97***	***0.001***
Mature; > 30% deciduous	***11.09***	***0.69***	***0.001***
Deciduous dominant	***11.84***	***1.74***	***< 0.001***
Non-Forest	20.98	19.40	0.814

Hypothesis 2: Fragmentation metrics

We found no significant differences in Edge Density (total length of patch edge/ha) or Patch Density (number of patches/ha) between barred owl activity centers and randomly assigned activity centers. We were unable to test for fragmentation metric differences between spotted owl and barred owl locations due to the low sample size of spotted owls in 2008.

Hypothesis 3: Biophysical Characteristics

Barred Owl activity centers were found to be at significantly lower elevations (μ=470.0 m) on average than would be found at random (μ=725.5 m) (P=0.03). In addition, the 2008 spotted owl location was found at a significantly higher elevation (1016.2 m) than would be expected at random (P=0.005). Barred owl site locations were also significantly lower in elevation than the elevation of the solitary spotted owl detection (P<0.001). There were no significant differences in slope, aspect, precipitation or temperature between barred owl site centers and random locations.

Hypothesis 4: barred owl Site Characteristics 1988 vs. 2008

2008 barred owl activity centers were found to be at higher average elevations (μ=470.0 m) than were found in 1988 (μ=321.0 m) (P=0.05). There were no differences in slope, aspect, precipitation or temperature between the 1988 and 2008 barred owl locations. Likewise, there were no significant differences in edge density or patch density. Large tree deciduous component forests occupied a higher percent of the landscape surrounding 1988 activity centers than was found surrounding 2008 activity centers (P=0.009; Table 6). In addition, when all deciduous forest stages were combined, deciduous component forests occupied a marginally higher percent of the landscape surrounding 1988 barred owl activity centers than was found in 2008 (P= 0.053).

Barred owls were notably missing from a few portions of the project area in 1988. These included the eastern flank of Baker Lake, the South Fork of the Nooksack River, Bacon Creek, and the higher elevation zones of the study area (Figure 10). All of these areas had a limited deciduous forest component (Figure 3). In our 2008 surveys we found five barred owl activity centers along the eastern shore of Baker Lake, two in the South Fork of the Nooksack Drainage and one in Bacon Creek.

Table 6. Comparison of the percent of landscape occupied by each forest type between 1988 barred owl activity centers and the 2008 barred owl activity centers.

Forest Type	**Avg. % of area within 1988 barred owl Activity Centers (n=11)**	**Avg. % of area within 2008 barred owl Activity Centers (n=18)**	**P-Value**
Pole aged; conifer dominant	17.91	15.51	0.458
Large tree; conifer dominant	13.45	14.85	0.378
Mature; conifer dominant	44.98	52.56	0.216
Pole aged; > 30% deciduous	11.48	8.35	0.185
Large tree; > 30% deciduous	***4.36***	***2.43***	***0.009***
Mature; > 30% deciduous	3.93	2.66	0.110
Deciduous dominant	3.42	2.22	0.096
Non-Forest	0.46	1.44	0.411

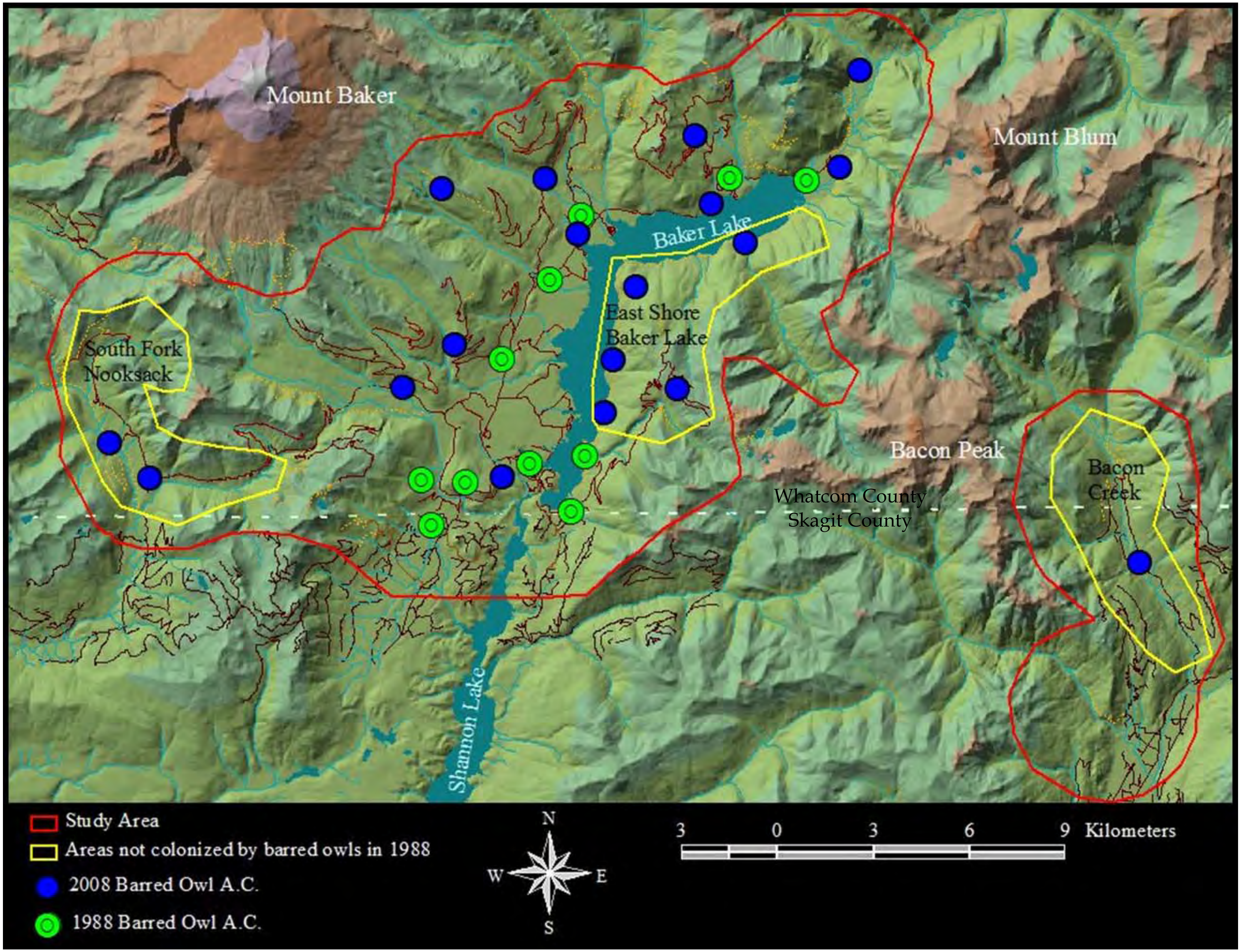

Figure 10. Barred owl site centers from 2008 and 1988 survey efforts, Baker Lake Basin.

V. Discussion

Demographic research conducted in the Olympic Peninsula, Southern Cascade and Coast Ranges of Washington and Oregon documents an increase in barred owl detections and subsequent decrease in spotted owl populations since the early 1990s (Kelly et al. 2003). However, research in Southern BC, near the northern edge of the spotted owl range, suggests that barred owl density may have peaked or be in decline in that area (Blackburn et al. 2002). In the Yakama Reservation in Washington, barred owl numbers may have stabilized or even dropped slightly after seven years of rapid increase (Gutierrez et al. 2004).

In accomplishing our first two study objectives, we found increased relative abundance of barred owls (in the Baker Lake Basin from 1988 to 2008), decreased relative abundance of spotted owls, and an expansion of habitats types and elevations used by barred owls. In 1988, barred owls had a relative abundance that was 1.93 times greater than spotted owls. By 2008, barred owls had almost completely displaced the spotted owl in the study area. From 1988 to 2008 barred owl relative abundance increased 74%. Barred owls have expanded out of the low elevation mesic forest with a heavier deciduous component, and into mid-elevations and conifer dominated forests. Barred owls appear to have out-competed spotted owls in the majority of available habitat. The one spotted owl detected was found in less desirable sub-alpine habitat where successful reproduction is less likely. In addition, the one spotted owl detected was at a higher elevation than any *Strix spp.* site centers documented in previous research (Hamer et al. 1989). Over time, spotted owls are likely being displaced by barred owls into marginal habitat found at increasingly higher elevations until they can longer sustain themselves.

In 1988, spotted owls occupied the higher elevation habitats, and pure coniferous stands of the Baker Lake Basin, and barred owls had colonized the lower elevation habitat with more deciduous component forest (Hamer et al. 2007). Barred owls may initially colonize riparian areas (i.e., moister habitats). These areas may be most preferred by the species since they are a food habits generalist and prey may be most abundant in these areas. But once they establish themselves, and the populations grow, they may move into relatively less mesic sites (Gutierrez et al. 2004). Our data provides some additional support for this concept, showing a higher percent of landscape cover with deciduous component forests (all deciduous habitat categories combined) in the land surrounding 1988 barred owl activity centers than what was found in 2008.

Due to the significantly lower than expected numbers of spotted owls left in the study area, we were unable to fully address our third and fourth objectives. Identifying landscape and habitat composition features associated with spotted owl persistence would require a larger number of existing spotted owl activity centers than we discovered in our 2008 sampling. Furthermore, the lack of differences in fragmentation metrics amongst barred owl (1988 and 2008), spotted owl, and random locations, may have been due to limited sample sizes. To fully address these objectives, this research effort would need to be replicated further south in the range of the northern spotted owl where the barred owl has not completed the cycle of displacement of spotted owls. However, finding locations where previous independent survey efforts for both species occurred and could be paired with extensive historical data (as we were able to do in the Baker Lake Basin) may prove difficult.

Despite the inability to fully address objectives related to spotted owl persistence, our research provides evidence that barred owls have significantly expanded both their range and their relative abundance in the Baker Lake Basin over the last 20 years. While this in itself may not be surprising, the near absence of spotted owls in the region is alarming. A similar study conducted at a similar latitude on the east slope of the Cascades in the North Cascades National Park documented an estimated 10 barred owl activity centers from 65 detections during the 2007 and 2008 summers. The number of spotted owl activity centers in that study area has declined from 6 to 4 since previous extensive surveys were completed in 1993 through 1996 (Siegel et al. 2008). Prior to the completion of this study, the likelihood of complete displacement of spotted owls in the northern end of their range may have not been fully realized due to the lack of current survey information from these northerly west-side forests.

In the five year status review of the spotted owl, several hypotheses were outlined for the long term stabilization of barred and spotted owl populations. Four were considered plausible by Gutierrez et al. (2004) including:

A. Barred owls would replace the northern spotted owl in the northern, more mesic areas of its range.
B. Barred owls would replace spotted owls in the northern part of their range but the spotted owl would maintain a competitive advantage in habitats where its prey is abundant and diverse.
C. The barred owl would replace the northern spotted owl over much of its range, but the spotted owl would persist in some areas with management intervention.
D. Barred Owls and northern spotted owls would compete, with the outcome being an equilibrium favoring barred owls over spotted owls in most but not all of the present NSO habitat range

The extremely low number of spotted owls detected in the Baker Lake Basin during 2008 surveys suggests that the equilibrium between Barred and spotted owl populations in the northwest corner of the spotted owl's range may favor the barred owl to the point of localized extirpation of the spotted owl. Although the final equilibrium of the two populations may not have yet occurred, we have provided some data to support hypotheses A and B (replacement of spotted owls with barred owls in northerly more mesic habitat) from the Gutierrez et al. (2004) status review. As the barred owl continues to fill habitats to the south and east of our study area, the realization of hypotheses C and D may still be in process. To determine the likelihood of hypotheses C and D would require knowledge of the degree to which northern spotted owls will persist in drier inland habitats and/or the degree to which both species might partition drier habitats and co-occur.

If in fact, the final equilibrium of species population densities across the full range of the spotted owl is similar to what we found in the Baker Lake Basin, then the long term outlook for spotted owl persistence is grim. Furthermore, lethal control methods for barred owls that are currently being discussed for application in the southerly portions of the range of the spotted owl will, at best, have limited success in areas where almost complete displacement has already occurred since there will be few spotted owls available to re-colonize habitat. From the results of this study, it is likely that the geographic range of the spotted owl will shrink from north to south as barred owl populations reach their maximum densities and these birds completely fill the range of habitats they can successfully utilize.

VI. *Literature cited*

Anthony, R. G., E. D. Forsman, A. B. Franklin, D. R. Anderson, K. P. Burnham, G. C. White, C. J. Schwarz, J. D. Nichols, J. E. Hines, G. S. Olson, S. H. Ackers, L. S. Andrews, B. L. Biswell, P. C. Carlson, L. V. Diller, K. M. Dugger, K. E. Fehring, T. L. Fleming, R. P. Gerhardt, S. A. Gremel, R. J. Gutierrez, P. J. Happe, D. R. Herter, J. M. Higley, R. B. Horn, L. L. Irwin, P. J. Loschl, J. A. Reid, and S. G. Sovern. 2006. Status and trends in demography of Northern spotted owls, 1985-2003. Wildlife Monographs 163:1-48.

Blackburn, I. R., A. Harestad, J. N. M. Smith, S. Godwin, R. Hentze, and C. Lenihan. 2002. Population assessment of the northern spotted owl in British Columbia 1992-2001. Report to B.C. Ministry of Water, Air, and Land Protection, Surrey, BC. 23 p.

Courtney, S. P., J. A. Blakesley, R.E. Bigley, M. L. Cody, J. P. Dumbacher, R. C. Fleischer, A. B. Franklin, J. F. Franklin, R. J. Gutierrez , J. M. Marzluff, and L. Sztokowski. 2004. Scientific evaluation of the status of the Northern spotted owl. Sustainable Ecosystems Institute, Portland, OR.

Crozier, M. L., M. E. Seamans, R. J. Gutierrez, P. J. Loschl, R. B. Horn, S. G. Sovern, and E. D. Forsman. 2006. Does the presence of barred owls supress the calling behavior of spotted owls? Condor 108:760-769.

Dark, S. J., R. J. Gutierrez, and S. J. Gould. 1998. The barred owl (*Strix varia*) invasion in California. Auk 115:50-56.

Dunbar, D. L., B. P. Booth, E. D. Forsman, A. E. Hetherington, and D. J. Wilson. 1991. Status of the spotted owl, *Strix occidentalis*, and barred owl, *Strix varia*, in southwestern British Columbia. Canadian Field-Naturalist 105:464-468.

Forsman, E. D. 1983. Methods and materials for locating and studying spotted owls. USFS PNW GTR -162. Portland, OR.

Grant, J. 1966. The barred owl in British Columbia. Murrelet 47:39-45.

Gutierrez, R. J., M. Cody, S. Courtney, and D. Kennedy 2004. Assessment of the potential threat of the northern barred owl. Chapter 7 In: Final report: scientific evaluation of the status of the northern spotted owl. Sustainable Ecosystems Institute, Portland, OR

Hamer, T. E. 1988. Home range size of the Northern barred owl and Northern spotted owl in western Washington. Seattle, WA: Western Washington University.

Hamer, T. E., S. G. Seim, and K. R. Dixon. 1989. Northern spotted owl and Northern barred owl Habitat Use and Home Range Size in Washington. Preliminary Report: Washington Department of Wildlife – Nongame.

Hamer, T. E., D. L. Hays, C. M. Senger, and E. D. Forsman. 2001. Diets of barred owls and Northern spotted owls in an area of sympatry. Journal of Raptor Research 35:221-227.

Hamer, T. E., E. D. Forsman, A. D. Fuchs, and M. L. Walters. 1994. Hybridization between Barred and spotted owls. Auk 111:487-492.

Hamer, T. E., E. D. Forsman, and E. M. Glenn. 2007. Home range attributes and habitat selection of barred owls and spotted owls in an area of sympatry. Condor 109:750-768.

Herter, D. R. and L. L. Hicks. 2000. Barred owl and spotted owl populations and habitat in the Central Cascade Range of Washington. Journal of Raptor Research 34:279-286.

Kelly, E. G. and E. D. Forsman. 2004. Recent records of hybridization between barred owls (*Strix varia*) and Northern spotted owls (*S. occidentalis caurina*). Auk 121:806-810.

Kelly, E. G., E. D. Forsman, and R. A. Anthony . 2003. Are barred owls displacing spotted owls? Condor 105:45-53.

Lehmkuhl, J. F. and M. G. Raphael. 1993. Habitat pattern around Northern spotted owl locations on the Olympic Peninsula, Washington. Journal of Wildlife Management 52:302-315.

Leskiw, T. and R. J. Gutierrez. 1998. Possible predation of a spotted owl by a barred owl. Western Birds 29:

McGarigal, K., S. A. Cushman, M. C. Neel, and E. Ene. 2002. FRAGSTATS: Spatial Pattern Analysis Program for Categorical Maps. www.umass.edu/landeco/research/fragstats/fragstats.html

Olson, G. S., R. G. Anthony, E. D. Forsman, S. H. Ackers, P. J. Loschl, J. A. Reid, K. M. Dugger, E. M. Glenn, and W. J. Ripple. 2005. Modeling of site occupancy dynamics for Northern spotted owls, with emphasis on the effects of barred owls. Journal of Wildlife Management 69:918-932.

Olson, G. S., R. J. Anthony, E. D. Forsman, E. Glenn, J. Reid, P. J. Loschl, and W. J. Ripple. 2004. Modeling demographic performance of northern spotted owls relative to forest habitat in Oregon. Journal of Wildlife Management 68:1039-1053.

Ott, R. L. 1993. An Introduction to Statistical Methods and Data Analysis. Fourth edition. Wadsworth, Inc. Belmont, CA.

PRISM Group, Oregon State University. www.prism.oregonstate.edu/products/matrix.phtml, created 4 Feb 2009.

Pearson, R. R. and K. B. Livezey. 2003. Distribution, numbers, and site characteristics of spotted owls and barred owls in the Cascade Mountains of Washington. Journal of Raptor Research 37:265-276.

Siegel, R. B., K. E. Jablonski, M. N. Scholer , R. C. Kuntz II, and R. L. Wilkerson. 2008. Surveying for Spotted Owls on the east slope of North Cascades National Park Service Complex, 2007-2008. Natural Resource Technical Report NPS/NCCN/NRTR—2008/000. National Park Service, Fort Collins, Colorado.

Taylor, A. L. and E. D. Forsman. 1976. Recent range extensions of the barred owl in western North America, including the first records for Oregon. Condor 78:560-561.

Zar, J. H. 1999. Biostatistical Analysis. Fourth edition. Prentice-Hall, Inc.Upper Saddle River, NJ.