

MANAGEMENT AND CONSERVATION IMPLICATIONS OF BLAKISTON'S
FISH OWL (*Ketupa blakistoni*) RESOURCE SELECTION IN PRIMORYE, RUSSIA

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Dedication

This dissertation is dedicated to Yevgenii P. Spangenberg (1898-1968) and Yuri B. Pukinskii (1932-1997), pioneers of Blakiston's fish owl research.

Abstract

The Blakiston's fish owl (*Ketupa blakistoni*) is a large owl associated with riparian old-growth forests in northeast Asia. Despite its status as a charismatic endangered species, specific conservation and management efforts for the species in Russia are limited. This is because resource use by these secretive owls is poorly known. To address this information deficit, I analyzed resource selection by these owls within a 20,213 km² study area in Primorye, Russia. Resource selection studies often begin by defining the spatial extent of a home range and then quantifying use of available resources within that home range. For animals that use habitat that are defined by linear environmental features, such as Blakiston's fish owl, traditional home range estimators often overestimate home range size, which can lead to spurious conclusions about resource availability and selection. I used a synoptic model of space use to define Blakiston's fish owl seasonal and annual home range size and within-home range resource selection, and compared results to traditional home range estimators. I also examined nest tree and foraging site selection at 14 nest and 14 foraging sites using linear discriminant analysis. I then identified areas with the highest predicted probability of use by owls to prioritize areas for conservation and management. Fish owl home range was different among most seasons, and estimated home range sizes based on the synoptic model were more biologically-realistic than kernel density-based home range estimators. Mean annual home range size (\pm standard error) for all fish owls was 15.0 ± 3.7 km² ($n = 7$) using the synoptic model, and 38.8 ± 15.4 km² using kernel density estimators. By season, winter home range was 7.0 ± 3.3 km² vs. 5.9 ± 2.3 km² ($n = 3$ owls; synoptic model vs. kernel

density estimator); in spring $13.9 \pm 5.2 \text{ km}^2$ vs. $29.5 \pm 20.4 \text{ km}^2$ ($n = 7$); in summer $11.6 \pm 2.8 \text{ km}^2$ vs. $33.2 \pm 11.9 \text{ km}^2$ ($n = 6$); and in autumn $25.2 \pm 13.4 \text{ km}^2$ vs. $85.1 \pm 56.0 \text{ km}^2$ ($n = 5$). Fish owls selected home ranges that were within valleys, were close to water, and had a greater number of river channels than available sites. Old trees and riparian old-growth forest were the primary discriminating characteristics at both nest and foraging sites, respectively. Large trees were likely necessary as owl nest sites because of the bird's large body size. Moreover, old forests have many large trees that facilitated recruitment of large woody debris in rivers, which created suitable habitat for the owl's primary prey: salmonid fish. Based on resource selection functions I predicted that 54 fish owl territories could occur within my study area. I found that the reserve network contained only 21% of primary fish owl habitat and potentially contained only 7 fish owl territories. I also found that 39% of primary habitat was within current logging leases, which was capable of supporting habitat equivalent to 18 fish owl territories. The remainder of primary habitat (40%) was on federal land not presently protected or within logging leases, and potentially contained 29 fish owl territories. The current protected area network, by itself, will be insufficient to conserve fish owls because so few owl territories are actually protected. Therefore, I developed specific conservation recommendations within logging leases based on the observed resource selection patterns by the owls. My recommendations include protecting specific locations within potential territories, maintaining integrity of riparian areas, modifying road construction techniques, and closing old logging roads to reduce human access. These simple measures have the potential not only to conserve fish owls but also many

other species, making this owl an effective umbrella species for the riparian ecosystems of the region.

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Chapter One:

Estimating home range and resource selection when animal movements are constrained by linear environmental features: an example using Blakiston's fish owl

1.1. Introduction

Estimation of resource selection by an organism is an important tool that managers and conservationists can use to develop conservation plans (Manly et al. 2002).

Traditionally, when estimating resources within an animal's home range, the outer boundary of the home range is defined using an appropriate estimator (e.g., adaptive kernel), then habitat or other resources within the boundary are quantified and compared to their relative availability to identify patterns of resource selection (e.g., Singleton et al. 2010, Vanak and Gompper 2010).

Home range estimators that employ a utilization distribution (i.e. kernel density estimators, harmonic mean, bivariate normal) are useful because they quantify an organism's probability of use of a given location (Jennrich and Turner 1969, Horne and Garton 2006), and kernel density estimators are particularly attractive because the home range areas derived using these methods often stabilize with ≤ 50 telemetry locations, which makes them popular for studies having limited location data (Kernohan et al. 2001, Millsaugh et al. 2006). However, some organisms use habitat in ways that cannot be satisfactorily described by standard utilization distribution methods (e.g., species whose ranges are described by linear features in a landscape, such as canyons, rivers, or coastlines). In these cases, most home range estimators overestimate home range size

because they include large areas of unused habitats (Melquist and Hornocker 1983, Samuel and Fuller 1996, Blundell et al. 2001, van der Ree and Bennett 2003, Horne et al. 2008). This problem is so pronounced for telemetry studies of fish that some authors omit home range estimates entirely, thereby ignoring potentially valuable information on space use (Knight et al. 2009). Consequently, attempts have been made to address the limitations of traditional estimators, including manipulation of the parameters used to define kernel density estimators (Sauer et al. 1999), use of cluster analysis (Kenward et al. 2001, Knight et al. 2009) or k nearest-neighbor convex hull (Getz and Wilmers 2004), inclusion of animal movement data (Rhodes et al. 2005), and a synoptic model of space use employing resource covariates to help define the boundaries of a home range (Horne et al. 2008).

I used telemetry to estimate within-home range resource selection by the Blakiston's fish owl (*Ketupa blakistoni*), an endangered species that may be restricted to areas close to rivers and streams (Fig. 1.1). If true, a consequence of such reliance on these linear features suggests that home range area cannot be satisfactorily defined using standard home range estimators (Yamamoto 1999). Blakiston's fish owl (hereafter, "fish owl") is endemic to northeast Asia (Surmach 1998), with most of the population (globally ~5000 birds) found in the Russian Far East and smaller populations in Japan, China, and possibly North Korea (Fig. 1.2; Takenaka 1998, Slaght and Surmach 2008).

Because of its conservation status, rarity, and possible dependence on riparian waterways, I assessed the suitability of the synoptic model of space use (Horne et al. 2008) to describe fish owl home range and resource selection. I used telemetry to define

owl locations and associated habitat conditions to estimate fish owl seasonal resource selection. I constructed a set of *a priori* models representing different hypotheses about their resource selection and evaluated them within an information-theoretic framework (Burnham and Anderson 2002). I designed these models to examine conclusions from previous observational studies of fish owls in Russia, summarized in Slaght and Surmach (2008) that speculated that fish owls selected areas based on the availability of specific resources for nesting (riparian old growth forest) and food availability (waterways). The importance of these two resources has largely been accepted as fact within the fish owl literature, although these hypotheses have not been specifically evaluated.

1.2 Methods

1.2.1. Study Area

My 20,213 km² study area was on the eastern slope of the Sikhote-Alin Mountains, in Primorye, Russia (Fig. 1.2). The study area covered ~12% of Primorye's total area, extending south to north from the Avvakumovka River drainage (near the village of Olga; 43°43'23"N, 135°15'20"E) to the Maksimovka River drainage (north of the village of Amgu; 45°50'27"N, 137°40'40"E). Elevations ranged from 0-1733 m, with an average of 478 m. Temperatures were warmest in August (mean temperature = 22°C) and coldest in January (mean temperature = -20°C; Newell and Wilson 1996).

1.2.2. Fish owl capture and marking

I captured fish owls in winters 2007-10 largely using methods described by Slaght et al. (2009). Briefly, I placed live fish or frogs in an enclosure to lure owls to a trap set near the enclosure. I captured owls in winter because ice cover greatly restricted owl fishing areas making them much easier to locate at this time of year. I banded all captured fish owls with federal Russian aluminum leg bands, and UV-resistant Darvic color bands (Haggie Engraving, Crumpton, MD).

Following capture and banding, I marked owls with radio transmitters (Fig. 1.3). I initially radio-marked fish owls with 30g AI-2BM VHF transmitters that had mortality switches (Holohil Systems Ltd., Carp, ON) and attached them with 0.44" Teflon-coated ribbon as harness material (Bally Ribbon Mills, Bally, PA) following methods outlined by Kenward (2001). However, these huge owls quickly destroyed the transmitter whip antennae, resulting in little data. Given the few data collected and the large error polygons that resulted from poor road access and rugged terrain, I discarded VHF data as unsuitable for the purposes of this study. Following this experience, I marked owls in winters 2008-2010 with GPS dataloggers (40 g and 90 g models, Sirtrack Tracking Solutions, Havelock North, New Zealand). These dataloggers had internal patch antennae that could not be destroyed by the birds. The datalogger harness attachment was identical to VHF transmitter attachment. These dataloggers required recapture of the birds to recover location data. Therefore, any animal that died or dispersed resulted in data loss. The 40 g GPS dataloggers ($n = 3$) were rechargeable, but had shorter lifespans (3-4 months) than 90 g non-rechargeable units ($n = 6$; up to 15 months). I programmed

90 g dataloggers to record one location every 660 minutes and 40 g units every 1380 minutes to conserve battery power.

Transmitter mass (including transmitter, harness, etc.) >4-5% of an animal's total mass can adversely effects breeding success and survival (Sibley and McCleery 1980, Hooge 1991). Migratory birds should not have transmitters exceeding 2-3% (Kenward 2001). Fish owls are non-migratory and big: males are >3 kg and females can reach 4.6 kg (Nechaev 1969, Yamamoto 1999). I weighed fish owls during late winter and early spring 2007-10; mean male mass was 3.10 ± 0.03 kg (mean \pm SE, $n = 7$ owls), and mean female mass was 3.25 ± 0.12 kg ($n = 5$). Therefore, all GPS dataloggers weighed $\leq 3\%$ of both sexes.

1.2.3. Sample population

I captured fish owls from eight territories in three geographical regions (Olga, Ternei, and Amgu; Fig. 1.2) to represent the entire study area. I attempted to capture only adult fish owls. If juveniles or subadults were inadvertently captured during trapping, I measured, banded, and released them without radio-marking because dispersal would likely result in lost data (Yamamoto 1999, Slaght and Surmach 2008). I estimated GPS location quality using several indicators including GPS fix success rate, proportion of 2-D versus 3-D fixes, and location error (Cain et al. 2005). I removed all GPS locations with 2-D fixes, as well as GPS locations with horizontal dilution of precision (HDOP) values >5, as these may be unreliable estimates (Rempel and Rodgers 1997, Dussault et al. 2001, Lewis et al. 2007). I did not assess the problem of fix success bias because it

would have been necessary to place stationary dataloggers in each habitat type within the study area across all seasons (using a fix rate identical to those deployed on fish owls), thereby generating sample weights (Frair et al. 2004). This was not logistically or financially feasible given the remoteness of the study area and cost of dataloggers.

1.2.4. Data analysis and model development

I estimated home range size and within-home range resource selection using a synoptic model of space use (Horne et al. 2008), which ameliorated some limitations of standard home range estimators by allowing home range estimation and resource selection estimation in the same model selection process. The basis of synoptic model structure was similar to the resource selection model structure described by Manly et al. (2002) because each model covariate can be used to predict an organism's probability of use of a given area (Horne et al. 2008). One assumption of resource selection is that availability does not change throughout the period of study (Cooper and Millspaugh 2001). I knew this would not be true because seasonal weather variation alters resource availability (e.g., winter freezing reduces availability of open water used for hunting) in my study area. Therefore, I partitioned my data into four discrete time periods (phenological seasons). I defined winter as 1 December-31 March, when the study area was typically snow covered and most waterways were frozen (i.e. access to prey restricted). If a fish owl pair was breeding, the winter season was the time that courtship (January-February), egg laying, and incubation occurred (March). I defined spring as 1 April-14 June, when snow thaw and rainfall raised water levels and fish owls were

thought to shift from a diet of fish to one consisting primarily of Far-eastern frogs (*Rana dybowskii*; Pukinskii 1976, Slaght and Surmach 2008). If a pair had bred successfully, this was also the period with dependent young. I defined summer as 15 June-14 September when pink salmon (*Oncorhynchus gorbuscha*) and masu salmon (*O. masou*) typically enter rivers to spawn (Semenchenko 2003, 2006a, 2006b, Kolpakov et al. 2008). At this time young fish owls in our study population fledged but still remained with their parents. I defined autumn as 15 September-30 November when Dolly Varden trout (*Salvelinus malma*), white-spotted char (*salvelinus leucomaenis*), and chum salmon (*O. keta*) spawn in my study area (S. Zolotukhin, *personal communication*).

I developed 14 *a priori* additive and interactive models using 10 covariates to assess within-home range resource selection (Tables 1.1, 1.2). Prior to analysis, I tested covariates for collinearity and removed highly-correlated covariates ($r \geq 0.7$). I developed each covariate based either on my knowledge or the literature of fish owl ecology and behavior. Some covariates were dichotomous (one state = 1 vs. another state = 0); others were standardized to range 0-1 to simplify likelihood estimation within the synoptic model (Horne et al. 2008). I used a covariate (VALLEY) to assess landform features important within the home range. This covariate was defined as landform with an elevation ≤ 600 m and slope $\leq 4\%$; all other areas were non valley. I chose these values because Takenaka (1998) found that most fish owl sites in Japan ($n = 61$) were ≤ 600 m elevation (95%) and $\leq 4\%$ slope (87%). I also estimated a qualitative metric depicting high likelihood of human disturbance (DISTURB), defined as all areas ≤ 30 km from a human settlement and ≤ 1 km from a road (“1,” otherwise “0”). Most people recreate

close to home (Clark and Gibbons 1991), with travel distance dependant on spatial arrangement of resources, with one estimate no more than ~2-3 hours-drive from home (Clark and Downing 1984). I chose distances based on these reports and given personal knowledge of the approximate distances villagers were likely to travel from home to fish, hunt, or picnic and how far they were willing to walk from a road. I predicted that probability of human disturbance of fish owls was greatest within the area defined by my disturbance metric. I also estimated a covariate that was defined by the presence of neighboring fish owls (NEIGH) if neighbors were known. Neighboring territories were delineated using a minimum convex polygon estimate of locations, and I assigned a value of “1” if occupied and “0” otherwise.

I created 7 standardized continuous covariates, including distance to water (D_WAT) and distance to open water in winter (D_WWAT); the amount of deciduous forest (DEC_213), riparian old-growth forest (RO_213), and open space (young forest, field, road, talus slope) within a 213 m buffer (OPEN_213). I also measured amount of open water in winter (WWAT_213). I standardized these measures by creating a 213 m buffer based on averaging the distances that all fish owl locations were to water and then adding two standard deviations to this average distance, which accounted for 95% of all fish owl locations. Since water appeared to be a critically-important resource for fish owls; I felt that this buffer distance was a reasonable indicator of the habitat that owls used. I also included one interactive term (RO*DWAT), which investigated the interaction between riparian old-growth forest and distance to water covariates.

Food availability is an important component of many resource selection studies (Manly et al 2002, McDonald et al. 2005). However, I did not directly sample rivers for prey species composition or abundance during winter due to high safety risk and high cost of fish sampling in remote areas at this time. Instead, I developed a covariate that approximated the potential for open water to exist within a territory to serve as a surrogate for fish owl prey availability (CHAN_213; the number of stream channels within a 213 m radius of each owl location). Stream channel complexity has been positively related to presence of salmonid fish because multiple stream channels provide a variety of habitats for salmonids of varying age classes (Hunter and Schmiegelow 2010, Luck et al. 2010).

Half of the models (50%, $n = 7$) were variants of what I called the “literature” model, which included the covariates landform, distance to water in winter, and presence of old-growth forest. This model was so named given the importance that many previous researchers have attributed to these covariates in the scientific literature. An additional suite of models ($n = 4$) were variants of the “Spangenberg” model, which I defined by landform, distance to water, presence of old-growth forest, and number of river channels within a 213 m circular buffer. This model was named after Y.P. Spangenberg, the Russian researcher who first described fish owl tendency to reside in areas with these specific resources (Spangenberg 1940, 1965).

I assessed availability of resources to fish owls by estimating the same metrics on a grid of points (Horne et al. 2008), which I spaced 200 m apart over the entire study area (i.e., 501,281 points across 20,213 km²). I chose this grid size because it was a tradeoff

between spatial resolution and processing speed given the large study area size. I executed the synoptic model (Horne et al. 2008) using Program R (v. 2.11, R Development Core Team, www.r-project.org) using code written by D. Johnson and J. Horne (*personal communication*). I determined model fit using Akaike's Information Criterion developed for small sample sizes (AIC_C ; Johnson and Omland 2004; Horne et al. 2008). I identified the best model by the lowest AIC_C , however, I considered all models within 2 AIC_C units of the best model to be competitive (Burnham and Anderson 2002). If >1 model was competitive, I used a variety of criteria to identify the model from which to draw inference, including AIC weights (Burnham and Anderson 2002) and strength of parameter estimates (85% confidence intervals (CI); Arnold 2010). If individual fish owl data sets had sufficient sample size (i.e., if the best model based on AIC_C score was anything but the null model [bivariate normal distribution]) I included them in seasonal analysis. If effect sizes were large, relatively few data (≥ 28 locations) could adequately describe fish owl space use. I estimated home range and resource selection individually for each owl, during each season because the synoptic model performed home range size and resource selection simultaneously. I averaged parameter estimates from all top models across individuals to generate seasonal parameter estimates, and averaged seasonal estimates to derive an annual estimate. For annual estimates I weighted parameter estimates for each season by its relative proportion of the year (i.e., spring was 75 days long, so spring selection coefficients were weighted by 0.21). In cases where standard error = 0, the smallest SE in the seasonal data set for that specific covariate was substituted to allow for proper function of averaged parameter

estimation. This occurred in one case with the dichotomous valley covariate, where all fish owl locations were located within the valley and therefore standard error could not be estimated.

I compared estimates derived using the synoptic model with estimates derived from traditional estimators using an information-theoretic approach (Horne and Garton 2006). The most parsimonious estimator, given the data, was determined using likelihood-cross-validation in the program Animal Space Use (v. 1.3; Horne and Garton 2007). In addition, I estimated the distance between the two most distant GPS locations within an owl's home range as an estimate of the length of a home range as suggested by Yamamoto (1999) for comparison to other studies because fish owls are restricted by the linear dimension of rivers. I also used this distance to estimate the potential number of fish owl territories within the study area and within each river drainage.

1.2.5. Remote sensing analysis

I used remote sensing to create a cover type map because no such map existed at the relevant scale for the study area. My final map depicted six cover types: coniferous forest, deciduous forest, riparian old-growth forest, water (river, lake, ocean), bare surface (road, village, rock, soil), and open space (agricultural field, meadow, young/open forest). For analysis, I combined bare surface and open space. I classified four cover types (coniferous forest, deciduous forest, open space, bare surface) using SPOT (satellite pour l'observation de la Terre) satellite imagery. I classified riparian old-growth cover type using Landsat Thematic Mapper (TM) imagery, acquired from the

United States Geological Survey's Earth Resources Observation and Science Center (Sioux Falls, SD; <http://glovis.usgs.gov/>), and I manually digitized the water cover type. I then merged all types into one raster file. I generated classifications using an unsupervised isodata method in program ERDAS Imagine (v. 9.3; Norcross, GA), in which many (up to 300) separate classes were automatically discriminated from one another. I then manually grouped these classes into the appropriate cover types.

I chose SPOT imagery to balance cost, spectral resolution, and spatial coverage. I used 10 full or partial summer scenes and 9 full or partial winter scenes to encompass the study area. I used winter scenes to identify and digitize patches of open water in winter. The 10 m resolution of SPOT imagery allowed most open-water patches to be identified. The presence of hot springs throughout much of the study area meant that many of the open-water patches identified were reliably ice-free each winter. I used summer scenes to discriminate among cover types. All images were taken between 2005-2009 and were orthorectified prior to analysis.

I identified riparian old-growth using 30 m resolution Landsat TM data. Older patches of riparian forest were difficult to identify using the high-resolution 10 m SPOT imagery. However, I was able to identify them using 30 m resolution Landsat data, perhaps because the coarser resolution better captured the spatial pattern of old-growth, or perhaps because Landsat TM data gather a broader range of spectral data that were more beneficial for discrimination of old growth. Most Landsat images were taken in September 2007; however, I replaced one Landsat scene for the study area (~16% of the

total area) with an image from September 2002 due to unacceptably high cloud cover on the 2007 image.

I stacked Landsat TM spectral bands with several additional bands during the classification process to enhance discrimination of the old-growth cover type. These additional bands were three ‘tasseled cap’ transformations (brightness, greenness, and wetness) and five texture measures. The tasseled cap transformation is a technique commonly used with satellite imagery to discriminate among different cover types, as the brightness, greenness, and wetness bands allows for differences to emerge among differing types of vegetation (Crist and Kauth 1986, Jin and Sader 2005). I also generated a number of texture measures. Grey-level co-occurrence matrix (GLCM) measures (Haralick et al. 1973) have successfully increased classification accuracy in numerous studies (e.g., Haralick 1979, Hay et al. 1996, Marceau 1990, Franklin et al. 2001, Maillard 2003). Angular second moment, homogeneity, dissimilarity, entropy, and mean are common textural features (Maillard 2003, Estes et al. 2008), and were the GLCM measures I used here. I derived texture using a 3 x 3 pixel moving window of the near-infrared (NIR) band. This band was chosen for texture analysis due to its strong discrimination of vegetation cover types.

I acquired a Shuttle Radar Topography Mission 90 m resolution digital elevation model (DEM) from the Global Land Cover Facility (www.landcover.org; College Park, MD), which I fit to the study area. I subsequently filled the DEM to eliminate or reduce anomalies in the data. I used this DEM to create the broad-scale landform covariate. My initial analyses showed that some valley edges were being excluded erroneously from the

valley class when a very steep slope defined the valley edge. This occurred because the 90 m DEM resolution was too coarse to capture abrupt changes in elevation. I eliminated this problem by adding a 90 m buffer to the valley landform to ensure that all valleys or parts of valleys were included in the landform class. Water in narrow channels was not visible in SPOT images despite the high resolution so I digitized the larger waterways and calculated flow direction and flow accumulation using the DEM to identify smaller streams. I converted the resulting shapefile to a raster and merged it into the final cover type map. I conducted all remote sensing analyses using ERDAS Imagine and ESRI ArcGIS (v. 9.3; Redlands, CA).

I assessed the accuracy of my final cover type classification map following the procedure outlined by Congalton and Green (1999). I allocated 50 randomly-distributed points to each cover type (except riparian old growth, see below). I assessed the accuracy of conifer and deciduous classes using winter SPOT imagery where the two classes were easily distinguished; I assessed the accuracies of the open space, bare surface, and water categories using Google Earth (v. 5; Mountain View, CA). The accuracy of the riparian old-growth classification was more difficult to quantify because this type was not readily distinguishable by eye. Therefore, I used field data collected in summer 2009 to describe vegetation within a 25 m radius of fish owl nests, near-nest sites, and random points (see Chapter Two for full description) as my reference data. I categorized a patch as 'riparian old-growth' if it had ≥ 2 trees with diameters at breast height (dbh) ≥ 80 cm. Of the 46 total vegetation plots I describe in Chapter Two, 10 fell within the old-growth cover type classification. Therefore, the sample size I used to assess accuracy of the old-growth

classification was 10. Accuracy assessment included measures of total accuracy (%), producer's accuracy (%; a measure of how accurately each class was identified), user's accuracy (%; a measure of how well each identified class corresponded to the reference data), and the Kappa statistic (a measure of agreement between the remotely-sensed classification map and the reference data; Titus et al. 1984). The final habitat map showed that my study area was composed primarily of deciduous forest (49%) and coniferous forest (37%), with open space (8%), bare surface (3%), old-growth riparian forest (2%), and water (1%) making smaller contributions to total area. Overall classification accuracy was 85%, with a Kappa statistic of 0.82 (Table 3).

1.3. Results

1.3.1. Study population

I captured 16 individual fish owls (7 M, 6 F, 3 juv.) from 2007-2010. My capture success was 94% ($n = 17$ attempts to capture individual detected birds). From 2009-10, mean time (\pm SE) from prey enclosure placement to fish owl discovery was 36 ± 11 hours, and mean time from fish owl discovery to capture was 52 ± 15 hours. I marked 8 adult resident owls from 6 territories in 4 river drainages with GPS dataloggers. One of these owls was not detected the winter following capture; his datalogger was not retrieved and his fate remains unknown.

Mean GPS fix success was 0.6 ± 0.1 (range: 0.2-1.0) for all birds across all seasons. By season, fix success was highest in winter (mean = 0.8 ± 0.1 ; range: 0.7-0.9), followed by spring (mean = 0.7 ± 0.1 , range: 0.3-1.0), autumn (mean = 0.5 ± 0.1 , range: 0.2-0.8),

and summer (mean = 0.5 ± 0.1 , range: 0.3-0.7). I caught the majority of birds in late winter/early spring, so most dataloggers were working optimally upon initial release but many had exhausted their batteries by autumn.

Ultimately, data collection resulted in a sample of 7 fish owls from 5 territories, totaling 1,892 locations. Sample sizes ranged from 28-192 locations per fish owl per season (mean = 90.2 ± 10.1 ; Table 4). Although my sample size of 7 birds is small, it is larger than the only other known telemetry study involving Blakiston's fish owls ($n = 2$; Hayashi 1997), and falls within the range of many previous home range studies of common owl species ($n = 4-15$ owls; i.e., Call et al. 1992, Mazur et al. 1998, Zimmerman et al. 2001, Churchill et al. 2002).

1.3.2. Home range

Mean home range size based on the synoptic model varied widely by season and was $7.0 \pm 3.3 \text{ km}^2$ ($n = 3$ owls), $13.9 \pm 5.2 \text{ km}^2$ ($n = 7$), $11.6 \pm 2.8 \text{ km}^2$ ($n = 6$), and $25.2 \pm 13.4 \text{ km}^2$ ($n = 5$) in winter, spring, summer, and autumn, respectively (Table 5). The high variance of home range estimates for autumn ($n = 5$, range = 5.1-77.1 km^2) resulted in a mean estimate with a 95% CI that overlapped 0, so this estimate was not as reliable as estimates from other seasons. This was largely due to a single male (Faata M, autumn home range = 77.1 km^2) who may have covered much more area than other fish owls because he was looking for a potential mate. Mean annual home range size for all birds was $15.0 \pm 3.7 \text{ km}^2$ ($n = 7$). Due to small sample size, it was unclear if seasonal home range differed by sex because all comparisons had overlapping 95% CI.

Mean home range size based on kernel density estimators was larger than home range size estimated using the synoptic model for all seasons except winter, and as predicted often included habitats not used by fish owls. Mean home range size was $5.9 \pm 2.3 \text{ km}^2$ ($n = 3$ owls), $29.5 \pm 20.4 \text{ km}^2$ ($n = 7$), $3.2 \pm 11.9 \text{ km}^2$ ($n = 6$), and $85.1 \pm 56.0 \text{ km}^2$ ($n = 5$) in winter, spring, summer, and autumn, respectively. Mean home range size estimates using kernel density estimators for winter and autumn each had 95% CI that overlapped 0, which meant that these seasonal estimates were not reliable. The mean kernel density home range size for all birds across all seasons was $38.8 \pm 15.4 \text{ km}^2$, which was more than twice the size estimated using the synoptic model.

The farthest linear distances between recorded locations within each owl home range ranged from 2.7-14.5 km (mean = 8.5 ± 3.4 , $n = 3$) in winter, 6.7-20.7 km (mean = 10.4 ± 1.8 , $n = 7$) in spring, 7.7-29.4 km (mean = 15.5 ± 3.0 , $n = 6$) in summer, and 12.0-39.1 km (mean = 20.6 ± 4.8 , $n = 5$) in autumn. The mean distance between the farthest locations within a home range for all owls was 13.4 ± 2.1 km.

1.3.3. Resource selection

The top model in 52% of analyses ($n = 11$) was the “Spangenberg” model (Table 2). This model was most important in spring (83% of analyses, $n = 5$ owls), followed by summer (60%; $n = 3$), autumn (50%; $n = 2$), and winter (33%; $n = 1$). The next most important model, which was ranked the top candidate in 24% of analyses ($n = 5$), contained the covariates for landform, distance to water, presence of old-growth forest, amount of deciduous forest, amount of open space, and human disturbance. Four other

models cumulatively accounted for the remaining 24% top candidates ($n = 5$; see Appendix 1 for a complete results of model selection). Of the 7 covariates in top models that were correlated with fish owl locations, only distance to water and number of river channels had parameter estimates that did not overlap 0 across all seasons, and landform had an annual and summer estimate that did not overlap 0 (Table 6). Annual estimates for landform and distance to water had the strongest effect on probability-of-use: 44.1 ± 12.6 ($\beta \pm 85\%$ CI) and -51.8 ± 9.1 , respectively, followed by number of river channels (1.3 ± 0.2).

1.4. Discussion

1.4.1. Synoptic model vs. traditional home range estimators

Studies of species that use habitat constrained by linear environmental features such as canyons, rivers, and valleys are typically confounded by the shortcomings of traditional home range estimators, because estimates include large proportions of unused habitat (Blundell et al. 2001, Knight et al. 2009). Similarly, home range size is usually overestimated for the same reason. For example, estimates of home range for a species that uses riparian forests and travels from a main drainage into a side drainage will encompass the ridges between the used areas, and consequently overestimate home range and underestimate riparian forest use. Several solutions have been presented in the literature, but none appear to solve this problem: Sauer et al. (1999) recommended an adaptive kernel density estimator using default kernel bandwidth to estimate coastal river otter (*Lontra canadensis*) home range. Blundell et al. (2001) advocated use of a fixed

kernel density estimator with a reference smoothing parameter for the same species. However, neither method addressed the inclusion of considerable inland habitat within the defined home range, which is almost certainly non-habitat for coastal river otters as most of their movements are restricted to shoreline (Blundell et al. 2002). Van der Ree and Bennett (2003) manually derived grid-cell measures (White and Garrott 1990) and range length to describe home range of squirrel gliders (*Petaurus norfolconsis*), and cluster analysis (Kenward et al. 2001, Knight et al. 2009) has been used to delineate core use areas, effectively eliminating peripheral, unused habitats. However, these latter methods lack a utilization distribution's ability to quantify probability of use across the home range.

Alternately, the synoptic model of space use offers an elegant solution to the linear habitat problem by restricting a home range to habitats actually used, and provides an estimation of probability of use within that area. Whereas strict utilization distribution-based methods such as kernel density estimators approximate home range using only the spatial distribution of animal locations; the synoptic model uses animal locations in conjunction with the environmental covariates associated with those locations (Horne et al. 2008). Animal home ranges are shaped by topography and other environmental features (Powell and Mitchell 1998), so their inclusion into the spatial definition of home range is intuitive. Given that appropriate environmental covariates are selected to model space use, this method has a wide range of application across taxa.

The Blakiston's fish owl is a species whose home range is defined by linear features (rivers and streams) in its environment. Mean seasonal home ranges were smaller using

the synoptic model (as opposed to kernel-density estimators) for all seasons except winter (Table 5). In summer and autumn, all individual home range estimates were smaller using the synoptic model. In spring, mean home range size was smaller using the synoptic model, but individually 43% of spring home ranges ($n=3$) were larger using the synoptic model. Similarly, in winter 67% of home ranges ($n=2$) were larger using the synoptic model. This may be because space use in these two seasons was more restricted than in summer or autumn. In winter and spring space use was typically spatially-constricted due to limited resources (e.g. open water in winter, frog availability in spring), with a few outlying points (i.e. Sha-Mi M, Appendix 2.2.1.2). In such cases, the kernel-density estimator developed a home range composed of many 'islands' instead of a contiguous area. The synoptic model merged these same points by including areas between locations and allocated probability of use to those areas and therefore, resulted in a larger overall home range size.

Regardless of home range size differences between kernel-density estimators and the synoptic model, the latter clearly outperformed the former because it could be constrained to exclude habitat that fish owls did not use, which was not possible with the kernel density estimators (Fig. 1.4). Most estimates even with large sample sizes showed more biologically-realistic fits with the synoptic model (e.g., Sha-Mi F summer, $n = 121$, Appendix 2.1.3). The most obvious bias in kernel estimators was the inclusion of ridges and slopes that occurred between connecting branches of rivers or along valley edges (see hypothetical example above), which were eliminated by the synoptic model using the landform covariate.

Previous estimates of fish owl space use based on linear estimates of travel ranged from 4-12 linear km along rivers in winter (Pukinskii 1973, Surmach 1998, Yamamoto 1999, Andreev 2009), and home ranges of 4-6 km² in winter and spring ($n = 2$, estimated using the minimum convex polygon with 11-109 locations; Hayashi 1997). My winter telemetry data generally agreed with these estimates, but my data from other seasons showed that winter resource use does not capture annual resource use, and therefore descriptions of winter alone are insufficient to understand the breadth of fish owl movements and resource needs.

1.4.2. Seasonal variation in resource selection

Many fish owl researchers (Vorobev 1954, Pukinskii 1973, Dykhan and Kisleiko 1988, Dugintsov and Teryoshkin 2005) focused on landform, proximity to open water in winter to facilitate hunting by fish owls, and amount of riparian old-growth forest for nesting to define fish owl habitat (the “literature” model in Table 2). However, this was the top candidate model in only one analysis and, unexpectedly, in summer, which was opposite of predictions. Further, neither proximity to open water in winter nor amount of riparian old-growth forest were important predictors of fish owl habitat. The top model in most cases was the “Spangenberg” model. Selection of the “Spangenberg” model over the “literature” model suggested that the presence of water is more important than its availability in winter.

Intuitively, open water should be the most important covariate in winter, as without open water fish owls cannot access their prey. The reason why this covariate was not

identified as important may be a combination of fish owl behavior and low sample size: my winter data were limited to 2 females (Kudya F, Sha-Mi F) and 1 male (Sha-Mi M). Only 5% of waterways in the study area remained unfrozen in winter, and open water within winter home ranges of these three owls accounted for a mean of 6% ($\pm 2\%$ SE, range 2-11%) of total water. Thus, use was approximately equal to availability. Although one study animal showed use of this resource more than two times its availability (Sha-Mi M, 11%), the others did not, and the potential importance of this covariate was thus diluted without a greater sample size to capture increased use. The reason that the male used open water more than the females may be related to fish owl breeding behavior. Both females had much smaller home ranges than the male (Appendix 2.3.1, 2.1.1), and were concentrating their activity near nest trees (it was the breeding season). During this period, females rely heavily on their mates for food, either waiting on the nest for prey deliveries or begging at foraging sites (J. Slaght, *personal observation*). It is therefore possible that open water in winter was not as important for these two females as they were largely not acquiring prey on their own.

In spring, all fish owls shifted their home ranges downstream such that they abutted borders of adjacent territorial fish owls (Sha-Mi pair, Sereb M, Faata M) or natural borders (the Sea of Japan; Kudya pair, Saiyon M). However, they made occasional forays to the upper reaches of rivers or tributaries. Number of river channels was found in the top candidate model most often in spring season analysis. Channel complexity is favorable for salmonids during different life stages (Luck et al. 2010), but it is also possible that there are more frogs emerging from these channels during spring. Far-

eastern frogs hibernate under the ice and in the gravel of shallow, fast-moving streams, and emerge from these waterways to spawn in nearby ephemeral ponds from late March-early June, where they gather in great numbers, after which they disperse into the forest (Korotkov 1974, Maslova 1997, Kolobaev 2000). This is the period that the number of river channels covariate was correlated with fish owl use of an area. Fish owls have been observed to scrape at gravel with their feet in shallow sections of river in the middle of March 2010, which may have been attempts to uncover hibernating frogs (J. Slaght, *personal observation*).

In summer, most fish owls shifted their home ranges upriver from their core areas around nest trees to include both upper reaches of main river channels and lesser-order tributaries. For example, the Sha-Mi M spent spring on the Sha-Mi and Amgu Rivers, and then shifted to an upper tributary of the Sha-Mi River (Appendix 2.2.3). The Kudya F moved from the lower reaches of the Amgu River upriver to the Kudya River in summer (Appendix 2.3.3). The Sereb M also had more of his locations further up tributaries in summer than any other season (Appendix 2.6.2). The Saiyon M and the Faata M shifted their ranges to the upper reaches of primary rivers where their territories were located. The Sha-Mi F followed the general pattern of her mate; however, she also had a few locations on the southern border of the Sha-Mi territory, on the Amgu River (Appendix 2.1.3).

Autumn included the most dramatic seasonal home range shifts for the Sha-Mi M (Appendix 2.2.4), the Sereb M (Appendix 2.6.3), and the Faata M (Appendix 2.7.3). The Kudya F moved up the Amgu River until she reached the border of the Kudya/Shami

territory (Appendix 2.3.4). The Sha-Mi M also spent considerable time along an upper tributary in autumn, and had no locations near the nest tree during this time. The parameter estimate for distance to water in autumn (-352.9 ± 110.5) was much larger than distance to water in winter (-133.94 ± 3.33) and spring (-148.0 ± 42.5), and larger than in summer (-231.7 ± 15.2). Perhaps the stronger association with water in autumn (and to a lesser degree, summer) was due to the owls spending greater amounts of time in narrower river valleys during these seasons, where they were naturally closer to water.

It was also possible that fish owls were spending time in the upper reaches of rivers in autumn because they were following migration and spawning of salmonid fish species, as hypothesized by S. Surmach (*unpublished data*) based on anecdotal information provided by hunters. There were three important fish prey species that spawned in the upper reaches of rivers in the study area. The masu salmon spawned in August-September in the southern part of the study area, and May-July in the northern part of the study area. The Dolly Varden trout and white-spotted char spawned in the upper reaches of rivers during autumn (Semenchenko 2003, Augerot 2005). Chum and pink salmon both spawned in the side channels and tributaries of major rivers in autumn. These species migrated to spawning grounds from the middle of June to the middle of July (pink salmon), and in August-November (chum salmon; Semenchenko 2006a, Augerot 2005). If fish owls were following the migration and spawning of these salmonids, I would have expected owl home ranges to shift toward the lower reaches of major rivers and adjacent tributaries within their territories in summer and toward the in upper reaches of rivers and adjacent tributaries in autumn. This is consistent with the movements I observed fish

owls making from summer to autumn; therefore, it is entirely plausible that fish owls were tracking prey that were vulnerable during spawning.

Differences in home range size across seasons suggest variation in resource use, however, quantifying these differences was complicated by small sample sizes and different rates of GPS fix success. I speculate that lower fix success in autumn and summer is related to increased foliage cover during these months. Low GPS success rates in autumn and summer preclude conclusive statements about home range shifts during those seasons, however, generally-high fix success in winter and spring, where fish owls did not exhibit the extreme movements of summer and autumn, lent credibility to the data showing seasonal differences in home range and resource use.

Although the covariate measuring riparian old-growth forest within a 213 m buffer was included in the majority of top models, confidence intervals of parameter estimates always overlapped 0 (Table 6). This was surprising given that fish owls always seem to be associated with this forest type. It is possible that either this cover type was not represented at a scale appropriate to fish owls in this study, or that there are specific elements of these forests that are essential to the owl that were not depicted by my covariate (see Chapter Two). Perhaps this was due to fish owl use of “residual trees and snags” for nesting (residual trees are single large trees ($\text{dbh} \geq 80$ cm) surrounded by an otherwise younger forest [sensu Hunter and Bond 2001]). In fact, fish owls nested in residual trees and snags almost equally in proportion (46% of all nests, $n = 6$) to old-growth patches (54%, $n = 7$; see Chapter Two).

The covariate estimating human disturbance potential was found in the top model in five of the 21 analyses (Appendix 1.1.1, 1.1.2, 1.1.4, 1.3.1, 1.7.2). In all cases the estimate was positive, which was misleading. The positive estimate suggested that humans and owls can coexist if unmolested—throughout the course of this study fish owls were detected on the outskirts or even within the limits of small villages. However, the single largest reported source of owl mortality is caused by humans (Slaght and Surmach 2008). During this study, one owl drowned after being trapped in a furbearer snare set on the river bank, two owls were known to be shot and killed, and five disappeared from their territories within the disturbance zone. Therefore, fitness data on birds living near humans will be needed before further conclusions can be drawn.

1.4.5. Conservation implications

Results from the synoptic model suggest that previous estimates of fish owl home range and resource use (Hayashi 1997, Takenaka 1998, Yamamoto 1999, Surmach 2006, Andreev 2009) underestimated the true spatial extent of fish owl space use. This is because most previous studies (all except Hayashi 1997) were based on visual or aural detections of owls, and therefore only a portion of movements were actually detected. Hayashi (1997) used limited telemetry data to assess home range, but these were based only on 1-2 seasons. The range of annual and seasonal movements described in this paper reveal strong reliance on riparian areas within valleys that had complex river systems, and a previously-undescribed seasonal reliance on upper reaches of rivers. These findings lead to several conservation recommendations such as road closures,

protecting key habitat zones, and creating riparian buffers (see Chapter Three for detailed conservation plan). In particular, the possible tracking of various prey species during different seasons suggests that attention needs to be paid to conservation and rational harvest strategies for prey species, and sustainable management of hydrological systems to maintain prey species populations (see Chapter Three).

Chapter Two:

The bigger the better: the importance of riparian old-growth forest for Blakiston's fish owls in Russia

2.1. Introduction

The Blakiston's fish owl (*Ketupa blakistoni*) has been called "one of the most interesting birds in the [former] Soviet Union" (Pukinskii 1973) but despite such distinction this owl remains poorly studied (Surmach 1998, Slaght and Surmach 2008). This endangered species is associated with riparian forest habitat in Japan, Russia, northeast China, and possibly North Korea (Takenaka 1998, Slaght and Surmach 1998, Duckworth 2006, Chapter One). Until recently, the majority of Blakiston's fish owl (hereafter, 'fish owl') habitat in Primorye, Russia was isolated from human contact because of poor road access and low human density. Inaccessibility also hampered scientific investigation (Surmach 1998). These conditions changed following the collapse of the Soviet Union in 1991 and the expansion of natural resource extraction into wilderness areas with a concomitant increase in human activity because of roads (Surmach 1998, Newell 2004). These factors potentially threaten fish owls and their habitat (Slaght and Surmach 2008).

In order to manage wildlife habitat effectively, conservationists and forest managers need to understand the effect of forest use on wildlife (Buchanan et al. 1995). One way this can be accomplished is by investigating habitat use by animals (Johnson 1980, Garshelis 2000). Previous studies of fish owls in Primorye have suggested that home

ranges are comprised of areas within river valleys and near waterways having multiple river channels (Spangenberg 1965, Pukinskii 1973, Chapter One). Many such areas within Primorye are leased to logging interests and, therefore, there is a high probability of impact to fish owls. Because there is so little known about fish owls, additional information is needed to help guide management of logging leases. Thus, I examined nest site and foraging site selection in Primorye, Russia. This information can help guide efforts to manage the habitat of this endangered species sustainably.

2.2. Methods

2.2.1. Study area

My 20,213 km² study area was on the Pacific slope of the Sikhote-Alin Mountains, in Primorye, Russia (from approximately 43°43'23"N, 135°15'20"E in the south to 45°50'27"N, 137°40'40"E in the north). The area was forested and mountainous. Typically, native mixed Korean pine (*Pinus koraiensis*)/deciduous forest and second-growth Mongolian oak (*Quercus mongolica*)/Japanese white birch (*Betula platyphylla*) forests were found at lower elevations, and spruce-fir (*Picea* and *Abies* sp.) were found at higher elevations (Newell and Wilson 1996, Miquelle et al. 1999). Riparian zones were diverse, and often included large-sized Japanese poplar (*Populus maximowiczii*), chosenia (*Chosenia arbutifolia*), and cork bark elm (*Ulmus propinqua*), among others (Pukinskii 1973).

Rivers were relatively narrow, shallow, fast-flowing, and often multi-channeled (Fig. 2.1). These rivers were spawning grounds for numerous salmonid species including chum salmon (*Oncorhynchus keta*), masu (or cherry) salmon (*O. masou*), pink salmon (*O. gorbuscha*), Dolly Varden trout (*Salvelinus malma*), and white-spotted char (*S. leucomaenis*; Semenchenko 2001).

2.2.2. Habitat Characteristics

I conducted all habitat and river surveys in areas that met the within-home range resource selection criteria identified in Chapter One; surveys were within river valleys and close to rivers having multiple channels. I found nest trees by systematically searching forests near observed fish owl “sign” (vocalizations, visual detections, feathers, and tracks in snow) from 2006-2010. I delineated fish owl home ranges and individual fish owl locations using GPS telemetry and a synoptic model of space use (Horne et al. 2008, Chapter One). Within each territory, I collected habitat characteristics from three 0.2 ha (25 m radius) plots: I centered vegetation plots on (1) the nest tree (“nest site”); (2) on a tree 50 m in a random direction from the nest tree (“nest stand site”); and (3) on a tree ≤ 1500 m in a random direction from the nest tree (“random site”), given that it was still within the river valley. Fish owls often have >1 nest tree within a territory (Yamamoto 1999), so in owl territories having >1 nest tree (3 territories) I selected the nest tree most recently used for sampling. In one case a territory was occupied by a single male throughout the period of study (2006-2010), therefore, there was no nest tree. In this instance, I collected data from a suspected previous nest tree (a tree having a

broken-top cavity near where the male periodically roosted). Therefore, I examined nest tree and foraging site selection of fish owls by sampling vegetation within fish owl home ranges using methods from a variety of studies (LaHaye 1988, Seamans 1994, Buchanan et al. 1995, Martin et al. 1997).

I conducted vegetation and river surveys in six of the nine major river drainages in the study area (from south to north: Avvakumovka, Dzhigitovka, Serebryanka, Kema, Amgu, Maksmovka; see Chapters One and Three for more information) during summer 2009, prior to delineation of fish owl home ranges using GPS telemetry (Chapter One). Because of this, I selected distance to the random site (≤ 1500 m) based on limited VHF telemetry data I collected in 2007, which showed linear movements up to ~ 1500 m from the nest tree in winter. I centered nest stand sites and random sites on trees with ~ 59 cm diameter at breast height (dbh; Dilworth 1981). I chose this size diameter because it was the minimum nest tree size reported in Japan (Takenaka 1998). I did this to reduce the impact that a large tree might have on both estimates of vegetation characteristics and to place the site within an area that was potentially usable as a nest site (i.e. truly “available” for the owls; Garshelis 2000).

At each site I recorded the species and measured the dbh of every tree >15 cm within 12.5 m of the center tree and the species and dbh of every tree >40 cm within 25 m of the center tree. I also measured canopy cover using a densitometer, ground cover using a density board, and recorded number of logs >15 cm dbh. I collected additional data from each nest tree, including its total height and the nest height (measured with a hypsometer), its qualitative condition (healthy, weakened, declining, dead <2 yr, dead >2

yr sensu Brandt et al. 2003), and its species. A “healthy” tree was one that had a full crown. A “weakened” tree was one with less than a full crown (some damage), and a “declining” tree was one with a poor crown (severe damage; Brandt et al. 2003). I also classified nests as one of three types: broken-top cavity, side cavity, or other. A broken-top cavity was typically a depression formed when a trunk or large branch broke and the exposed surface decayed downwards over time. A side cavity was a natural hole in the side of a trunk, i.e. where a side branch fell off. “Other” was any nest structure (cliff ledge, old raptor nest, etc.) not in a broken-top or side cavity (see *Discussion* for descriptions of known nest types in Russia and Japan).

2.2.3. River characteristics and prey estimation

I collected data on river characteristics from two plots (used and available) within each fish owl home range ($n = 14$) to better understand if fish owls might select nest sites near prey sources. I recorded river characteristics August-September 2009, before GPS telemetry revealed the actual locations of fish owls relative to rivers during night time. Therefore, I arbitrarily defined “used” river stretches as the closest point on the river to the nest tree, given prior knowledge that fish owls often hunt close to the nest, and “available” river stretches as the closest point on the river from the random vegetation site (as defined in the previous section). Subsequent GPS locations and “sign” (tracks, feathers) revealed that 79% ($n = 11$) of used locations were used by fish owls and only 21% ($n = 3$) of available locations were used by fish owls, which validated my original data collection protocol. I recorded data from 100 m stretches of river during good light

conditions (1000-1700 hours) by averaging data collected every 20 m. I recorded channel depth (mean and maximum), channel width, water flow (in m/second using a flowmeter), riffle type (cascade, rapid, glide), substrate (sand, pebble, cobble, bedrock), and water temperature (using a digital or mercury thermometer). I also estimated prey species (fish) using snorkel surveys following protocol outlined in O'Neal (2007). I started all snorkel surveys 50 m downriver of the point at which I reached the river, and crawled or swam to a point 50 m upriver of the starting point (100 m total river distance surveyed, Fig. 2.2). Before starting a survey, I allowed two minutes to acclimate to the water and allow startled fish to resume normal activity. I stopped every 20 m to dictate number of fish, fish species, and fish size (visual estimation; small = <150 mm, medium = >150 mm and <300 mm, large = >300 mm) to a recorder on the bank. I also estimated amount of nearby riparian old-growth forest (within a 50 m circular buffer of the starting point) using remote sensing (see Chapter One). I measured this variable due to the relationship between riparian old-growth forest and large woody debris in rivers, which is thought to improve habitat for salmonid fish at various life stages (Lunetta et al. 1997, Luck et al. 2010).

2.2.4. Statistical analyses

I used linear discriminant analyses (Fisher 1936) to identify important variables associated with fish owl nest and foraging site selection. I conducted vegetation and river analyses separately. I checked assumptions of discriminant analysis of all variables, and transformed data prior to analysis when necessary. I used Levene's test to confirm

homogeneity of variance, and calculated a Shapiro-Wilk statistic (W) to test normality. One vegetation variable (proportion of deciduous forest within a plot) was highly skewed towards 1.0 and could not be transformed to a normal distribution. One river variable was highly skewed towards 0 (amount of riparian old-growth forest within a 50 m buffer of the river) and similarly could not be transformed. Therefore, I did not transform these variables, but subsequently tested multivariate normality by conducting discriminant analysis and assessing the resulting canonical scores as recommended by McGarigal et al. (2000). Tests for equal covariance are difficult to conduct formally (Quinn and Keough 2002) so I conducted all analyses a second time using quadratic discriminant analysis, which produces more reliable results if the equal covariance assumption of linear discriminant analysis is violated (McGarigal et al 2000). Results of linear and quadratic discriminant analyses were identical; thus, I used results based on linear discriminant analysis for inference.

I evaluated sample size requirements following “Rule C” in McGarigal et al. (2000), which was based on simulation experiments by Williams and Titus (1988). This rule stated that sample sizes for discriminant function analyses should minimally comply with $N \geq 3P$, where N is the number of observations per group, and P is the number of variables. Because N in my data ranged from 12-14 observations (sites), P should be ≤ 4 . For vegetation data, I started with 30 variables, and removed 23 of these that were correlated with other variables ($r \geq 0.70$), or that I deemed less likely to be informative for fish owls. Following recommendations from McGarigal et al. (2000), I then partitioned the remaining 7 vegetation variables into two smaller groups, thereby

satisfying sample size requirements of $N \geq 3P$. The first group depicted vegetation structure (4 variables: dbh of the largest tree on the plot, number of snags, mean plot dbh, and canopy cover). The second group depicted vegetation composition (3 variables: percentage of deciduous forest, number of tree species, and percentage of medium-size trees [50-70 cm dbh]).

I measured 31 variables associated with rivers and removed 23 that were correlated with other variables ($r \geq 0.70$) or that I deemed uninformative. I partitioned the remaining 8 river variables into two groups. The first group depicted river structure (4 variables: water flow, riffle, substrate, and amount of riparian old-growth forest within a 50 m buffer). The second group depicted characteristics of the potential prey community (4 variables: species diversity, number of small (<150 mm) masu salmon, total fish count, and number of medium-sized (>150 mm and <300 mm) Dolly Varden trout).

I conducted separate forward stepwise discriminant analyses on each group, with *F*-to-enter and *F*-to-remove set at 0.15, and using Wilks' Lambda as criterion for variable inclusion (McGarigal et al. 2000). For vegetation analyses, prior probabilities were adjusted to group size (nest site vs. random site: 0.52 and 0.48 respectively; nest stand site vs. random site: 0.48 and 0.52 respectively), whereas for river analyses probabilities were equal (0.50) among groups. I estimated all classification accuracies using a jackknife procedure. I assessed classification accuracies of discriminate analysis by measuring total accuracy (%) and Cohen's Kappa statistic, a measure used to calculate chance-corrected classification rates (Titus et al. 1984). I estimated the eigenvalue (λ ; a measure of group separation, with larger values indicating greater separation), the

canonical correlation coefficient (R_c ; a measure of correlation among variables, ranging 0-1 where “0” is no relationship and “1” is complete association), and the squared canonical correlation (R_c^2 ; a measure of variation explained by the group means). I also used analysis of variance (ANOVA) to compare class means of the vegetation and river variables.

I conducted all statistical analyses in program R (version 2.11.0, R Development Core Team 2010) using MASS (Venables and Ripley 2002) and KlaR (Weihs et al. 2005) libraries. For vegetation, I conducted one analysis comparing nest sites to random sites, and a second analysis comparing nest stand sites to random sites. For river characteristics, I conducted a single analysis comparing used and available sites.

2.3 Results

2.3.1. Characteristics of Nest sites

I described characteristics of 7 vegetation variables at 14 nest sites, 12 nest stand sites, and 13 random sites within 14 fish owl home ranges (Table 2.2.1). My description of nest trees (Table 2.2) were based on these 14 sites, but also included data from one additional nest site. I did not include this latter site in the analysis of nest sites because a complete vegetation description was not available. Fish owls selected large, riparian old-growth trees for nest sites. Nest trees were either Japanese poplar (53%; $n = 8$), chosenia (33%; $n = 5$), or cork bark elm (13%; $n = 2$). Nest tree condition was either declining (47%; $n = 7$), dead > 2 years (33%; $n = 5$), or weakened (20%; $n = 3$). All nests (100%; $n = 15$) were “broken-top cavities” (Fig. 2.3). Mean nest tree dbh was $115.27 \text{ cm} \pm 6.49$

cm ($\bar{x} \pm \text{SE}$, range 74-150 cm dbh); mean nest tree height was 18.09 m \pm 1.47 m (range 8.6-27.1 m); and mean nest cavity height was 9.33 m \pm 0.95 m (range 4-16.8 m). Broken-top cavities were often located where the main bole broke off and banner limbs continued to add vertical growth to the tree (Rockweit 2008; see Fig. 2.2 for example), which is why mean nest height was approximately half of mean nest tree height. Nearly half of all nests were in “residual trees and snags” (47%, $n = 7$), which were trees older than the surrounding young trees in the forest (*sensu* Hunter and Bond 2001). The remaining nest trees were in forest patches having >2 trees with dbhs \geq 80 cm (53%, $n = 8$; Table 2.2).

2.3.2. *Characteristics of Rivers*

I measured 8 river variables from 14 locations near nest trees (used sites), and 14 random locations (available sites) within 14 fish owl home ranges (Table 2.3). All used sites were river channels characterized by shallow depth ($\bar{x} = 0.21$ m, ± 0.02 m SE), swift flow (1.75 m per second, ± 0.38 m per second), predominantly glide riffle (48% \pm 10%), and predominantly cobble substrate (64% \pm 6%). Mean maximum river depth was 0.78 m \pm 0.07 m. Available sites were similarly characterized by shallow depth ($\bar{x} = 0.23$ m, ± 0.02 m SE), with swift flow (2.34 m per second, ± 0.38 m per second), predominantly glide riffle (56% \pm 8%), and predominately cobble substrate (54% \pm 7%). Mean maximum river depth of available sites was 0.83 m \pm 0.11 m.

I found 9 species of fish at all sites, with slightly higher number of species at available sites ($\bar{x} = 3.21$ species, ± 0.39 species SE) than used sites (2.93 \pm 0.27). Masu

salmon (small and medium) were present at all used sites ($n = 14$ sites each) and most available sites (small $n = 13$ sites; medium $n = 12$ sites). Small Dolly Varden trout were present at 7 and 4 used and available sites, respectively while medium Dolly Varden trout were present at 10 used sites and 9 available sites, respectively. I counted more fish per survey at used sites than available sites ($\bar{x} = 214.07, \pm 39.45$ SE, range 61-576; $\bar{x} = 191.50, \pm 53.01$ SE, range = 3-788, respectively; Table 2.4).

2.3.4. Analysis of vegetation

My vegetation data met assumptions of multivariate normality (for nest sites $W = 0.980, P = 0.976$; for nest stand sites $W = 0.899, P = 0.131$, and for random sites $W = 0.898, P = 0.175$). Wilks' Lambda indicated that only two variables, both related to vegetation structure, met criteria for inclusion in a discriminant analysis for vegetation at the nest site: dbh of the largest tree ($F = 13.81, df = 1, P = 0.001$) and number of snags ($F = 9.15, df = 1, P = 0.018$; Table 2.6). No other vegetation variables met the Wilks' Lambda criteria for inclusion. The discriminant analysis showed that 81% of the variation between nest and random sites could be explained by dbh of the largest tree and the number of snags ($\lambda = 4.37, R_c = 0.90, R_c^2 = 0.81$), with nearly all of this variation (79%) due to dbh of the largest tree ($\lambda = 3.71, R_c = 0.89, R_c^2 = 0.79$). Compared to random sites, overall nest site classification accuracy was 74% (Kappa = 0.48). Nest stand sites, when compared to random sites, were classified accurately 56% of the time (Kappa = 0.12; Table 2.5). ANOVA indicated that dbh of the largest tree at nest sites was greater than at random sites ($F = 5.35, df = 2, P = 0.009$), and that there were more

snags at nest sites than either nest stand sites or random sites ($F = 3.60$, $df = 2$, $P = 0.038$; Table 2.2.1).

2.3.5. Analysis of rivers

My river data met assumptions of multivariate normality (for used sites $W = 0.88$; $P = 0.07$; for available sites $W = 0.945$, $P = 0.482$). Wilks' Lambda indicated that two variables met criteria for inclusion in a discriminant analysis for distinguishing potential fish owl foraging sites: nearby riparian old-growth forest ($F = 4.43$, $df = 1$, $P = 0.045$) and percent cobble in the river substrate ($F = 3.55$, $df = 1$, $P = 0.131$; Table 2.6).

Discriminant analysis showed that 73% of the variation between used and available sites could be explained by nearby riparian old-growth forest and cobble river substrate ($\lambda = 2.71$, $R_c = 0.85$, $R_c^2 = 0.73$), with nearly all of this (68%) due to nearby riparian old-growth forest alone ($\lambda = 2.10$, $R_c = 0.82$, $R_c^2 = 0.68$). Compared to available sites, overall classification accuracy of used sites was 68% (Kappa = 0.36). ANOVA showed that used sites had a higher proportion of riparian old-growth forest ($\bar{x} = 7\% \pm 2\%$ SE) than available sites ($\bar{x} = 1\% \pm 2\%$; $F = 3.94$, $df = 1$; $P = 0.058$).

2.4 Discussion

2.4.1. Nest trees

My descriptions of nest trees were consistent with previous reports from Russia and Japan, which found that fish owls tended to nest in cavities of large, deciduous trees (Spangenberg 1965, Pukinskii 1973, Dykhan and Kisleko 1988, Takenaka 1998). In

Russia, mean nest tree dbh from Takenaka (1998) and Andreev (2009) was 107.33 cm (\pm 10.74 SE, $n = 3$, range 90-127 cm). In Japan, Takenaka (1998) found mean nest tree dbh to be 95.50 ± 5.32 cm ($n = 12$; range 59-123 cm) and Yamamoto (1999) reported a range of nest tree dbhs of 80-130 cm (sample size unspecified).

Most nests of fish owls have been reported to be in broken-top cavities (Spangenberg 1965, Pukinskii 1973, Dykhan and Kisleiko 1988, Takenaka 1998, Yamamoto 1999, Shokhrin 2009, Andreev 2009), but there have been some deviations. Of 12 nest trees, Takenaka (1998) found most nests in broken-top cavities (67%; $n = 8$) with the remainder in side cavities (33%; $n = 4$). Takenaka (1998) also reported one pair that nested on a cliff ledge. Yamamoto (1999) noted a preference for broken-top cavity nests, but indicated that fish owls in Japan also periodically nested in abandoned black kite (*Milvus migrans*) nests (open top, stick nests). In Russia, Pukinskii (1973) reported one fish owl nest in the exposed crotch of a large Japanese poplar.

2.4.2. Fish owls and riparian old-growth trees

Although I found few differences between used and available sites within fish owl home ranges, riparian old-growth trees were clearly the most important discriminating characteristics of both nest and foraging sites. Snags were a secondary indicator of suitable nesting habitat; cobble substrate in rivers was a secondary indicator of suitable foraging habitat. The number of large trees and the proportion of riparian old-growth forest accounted for most of the variation among classes and featured prominently in plot discrimination at both nest and foraging sites, respectively. The squared canonical

correlation (R_c^2) provided strong evidence that the gradient of riparian old-growth and number of snags was a function of the difference between vegetation at nest and random sites. This suggested that tree size was sufficient to discriminate potential fish owl nest sites from random forest locations. The importance of this single habitat feature was supported by my comparisons of nest stand sites with random sites, which showed very low predictive power ($Kappa = 0.12$). This suggested that without the presence of very large trees found at nest sites, my discriminant analysis could not distinguish used fish owl habitat from random forest sites. Spangenberg (1965) stated that vegetation structure within a forest was largely irrelevant for fish owls; only the presence of massive trees was important. Despite basing this claim on only a few scattered observations without formal data collection, it appeared that his conclusions may have been correct.

Although it might be considered intuitive that large trees would be important for nesting because fish owls are huge birds, the association between surrounding riparian old-growth forest and fish owl foraging sites was unexpected. Because there was no difference between the distances of nest trees or random vegetation sites to used or available foraging sites, respectively ($\bar{x} = 72.50$ m, ± 13.27 m SE; $\bar{x} = 83.71$ m, ± 13.27 m SE; $n = 14$) the relationship between old growth riparian habitat and fish owl foraging sites was not simply an artifact of distance to nest. River channel complexity, identified in Chapter One as an important indicator of suitable fish owl habitat, has also been associated with large woody debris in waterways (Lunetta et al. 1997, Luck et al. 2010). Fallen trees caused by natural senescence, storms, and flooding can clog waterways, creating additional channels and subsequently increase diversity of freshwater habitat by

facilitating a mosaic of fast-moving channels interspersed with slow-moving, deep pools (Reeves et al. 1991). This will result in ideal habitat for salmonid fish of varying life stages, with large woody debris having a strong correlation with salmonid abundances and survival, particularly in winter (Hicks et al. 1991, Reeves et al. 1991). Thus, the presence of old-growth forest along waterways in fish owl home ranges probably increased the probability of large woody debris recruitment, which in turn increased the probability of suitable salmonid habitat and fish owl foraging habitat. Additionally, large woody debris also afforded suitable hunting perches for fish owls (i.e., fish owls have been observed frequently hunting from snags or fallen logs along or in river channels (Spangenberg 1965, Pukinskii 1973, J. Slaght, *personal observation*). My analysis in Chapter One did not identify old growth forest as an important variable in describing fish owl space use within home ranges. However, a conclusion that old forest was not important for fish owls would not be correct; this analysis clearly showed that it was an important variable distinguishing owl nesting and foraging habitat.

Tree size alone was inadequate to identify a fish owl nest site because trees must also be in suitable condition for nesting. All nest trees that I found were in some stage of physical decline, and all trees had some form of cavity suitable for fish owl nest. Similarly, the mere presence of old-growth forest along river banks did not necessarily imply suitable foraging habitat because rivers that were too deep, broad, or with current too swift may have precluded recruitment of large woody debris. Nevertheless, riparian old-growth seemed to be a good indicator of fish owl nesting and foraging sites, given

that it was adjacent to streams of suitable size and structure (as identified in *Characteristics of rivers*, above).

2.4.3. Conservation implications

Riparian old-growth forest plays an important role in fish owl ecology, both for recruitment of nest trees and enhancement of foraging sites, hence, conservation of riparian old growth forests is important to fish owl conservation. I recommend that specific locations within riparian zones that meet the habitat conditions I observed be protected from timber harvest and other disturbances, such as road construction. Although fish owls show some plasticity in nesting, they appear to prefer broken-top cavities. Therefore, declining specimens of Japanese poplar, chosenia, cork bark elm, and others should not be removed from a forest because they serve as potential nest trees. In addition, smaller representatives of these species also should not be removed to ensure not only the sustainability of these forests but also to enhance recruitment of nest trees over time. The importance of riparian old-growth forest along waterways used for foraging also underscores the importance of enforcing buffer zones between rivers and roads to preserve the recruitment of large woody debris (see Chapter Three for elaboration on these and other recommendations).

Chapter Three:

Blakiston's fish owls and logging: applying resource selection information to conserve a charismatic endangered species in Russia

3.1. Introduction

The Blakiston's fish owl (*Ketupa blakistoni*) is a globally-endangered species of northeast Asia that uses riparian old-growth forest for nesting and foraging (Pukinskii 1973, Takenaka 1998, Slaght and Surmach 2008, Chapters One and Two). These birds are among the most enigmatic avian species in the region because they are the largest owl in the world, they hunt primarily aquatic prey (atypical for most owls), and yet are poorly known to science and the general public (Pukinskii 1973, Surmach 1998, Yamamoto 1999, Surmach 1998, Slaght and Surmach 2008). In the Russian Far East, Blakiston's fish owls (hereafter, 'fish owls') are threatened by poaching, habitat degradation from logging, and unsustainable fishing practices, which are thought to affect prey abundance (Mikhailov and Shibnev 1998, Surmach 1998, Slaght and Surmach 1998). Old-growth riparian forests in the region are relicts of the Soviet era when strict tree harvest moratoriums within a 5 km riparian buffer zone protected these areas (Surmach 1998). Since the collapse of the Soviet Union, logging restrictions were greatly weakened and regulatory oversight is poor (Newell 2004, Lesniewska et al. 2008). This has led to an expansion of logging with a concomitant increase in logging roads. Much of the Russian Far East is uninhabited, thus, placement of logging roads largely dictates access by humans to wilderness areas, which in turn results in both legal and illegal use of fish,

wildlife and other natural resources in such forests (Clark and Gibbons 1991, Furniss et al. 1991). Roads are constructed along rivers to access legal tree harvest units (Slaght 2005), but inadequately-regulated “sanitation harvests” and other loopholes allow commercially-valuable Korean pine (*Pinus koraiensis*) [CITES Appendix III] and other riparian tree species (especially Manchurian ash [*Fraxinus mandshurica*]) to be harvested legally in great quantity (Newell and Wilson 1996). Additionally, illegal logging is rampant in the area (Vandergert and Newell 2003).

In Russia, mortality of fish owls likely increases wherever they come into contact with humans. They accidentally drown when caught in fishing nets, freeze in winter when trapped in snares set for furbearing mammals, and are either wantonly shot or shot for fear they will ruin the pelts of furbearers (Spangenberg 1965, Dykhan and Kisleiko 1988; Mikhailov and Shibnev 1998, Slaght and Surmach 1998, Andreev 2009). Of 26 recorded mortalities in the Russian literature and in unpublished data (Pukinskii 1993, Surmach 1998, Yelsukov 2005, Andreev 2009, J. Slaght and S. Surmach, *unpublished data*) only two are not human-caused deaths. In Japan, collisions with vehicles also result in fish owl mortality (Yanagawa 1993, Saito 2002).

Logging roads have indirect impacts on fish owls. First, large, riparian old-growth tree species such as Japanese poplar (*Populus maximowiczii*) and chosenia (*Chosenia arbutifolia*), which appear to be favored by fish owls as nest trees (Dykhan and Kisleiko 1988, Takenaka 1998, Andreev 2009, Chapter Two), are used by the logging companies for bridge construction (Slaght and Surmach 1998). A nest tree in my study area near the Maksimovka River was felled for this purpose. Second, roads built near waterways

increase water temperature and siltation, which degrades habitat for the owl's salmonid prey (Chamberlain et al. 1991, Hunter and Schmiegelow 2010).

Threats to fish owl conservation are exacerbated because despite having international, federal, and regional protected status, there is no specific conservation plan for this species in Russia. In part, this is due to the lack of scientific data that can be used to create a credible conservation plan. Few fish owl studies in Russia contain sufficient scientific or statistical rigor to guide conservation and management recommendations (Slaght and Surnach 1998).

Therefore, my objectives here are to assess the ability of currently-protected areas within Primorye, Russia to conserve fish owl populations and to develop recommendations for fish owl conservation and management for areas that are not under current conservation protection (see below). My intent is not to exclude areas used by fish owls from logging or other resource extraction, but rather to encourage multiple uses of these forests in an informed, sustainable fashion.

3.2. Methods

3.2.1. Study Area

My 20,213 km² study area was located along the Sea of Japan in Primorye, Russia (Fig. 3.1). The study area was primarily forested (88%; 51% deciduous and 37% coniferous) and mountainous, with slopes bisected by nine major rivers (described here from south to north: Avvakumovka, Zerkalnaya, Tetyukhe, Dzhigitovka, Serebryanka, Belimbe, Kema, Amgu, Maksimovka) that flowed into the Sea of Japan. Following a century of anthropogenically-caused fire and high-grading tree harvest practices, many of

the original mixed Korean pine/deciduous forests, particularly in the southern portions of the study area, were converted to second-growth forests dominated by Mongolian oak (*Quercus mongolica*) and Japanese white birch (*Betula platyphylla*; Newell and Wilson 1996, Miquelle et al. 1999). River valleys typically contained high vegetation diversity, with tree species such as Japanese poplar, chosenia, Korean pine, Manchurian ash, Cork bark elm (*Ulmus propinqua*), and Asian birch (*Betula costata*).

During my study, approximately 38% of my study area (7,815 km²) was leased to private logging companies by the provincial government, and 18% (3,839 km²) was protected at the federal or provincial levels (Fig. 3.1). However, few protected areas received conservation enforcement (Newell 2004). One of the exceptions was the Sikhote-Alin Biosphere Reserve, a “strict” federal nature preserve of which 58% (2,355 km² of 4,011 km² total) was found within my study area. The human population in the study area was ~100,000 residents; most of whom lived in small cities in the south (Dalnegorsk ~40,000 inhabitants; Kavalárovo ~30,000 inhabitants). The remaining settlements were small, typically having 500-5,000 residents.

3.2.2. *Estimating probability-of-use by fish owls*

I developed a map depicting probability-of-use by fish owls for the study area using selection coefficients and an availability grid derived from a previous analysis of resource selection by fish owls in this area (see Chapter One for details). Briefly, I assessed resource selection by 7 global positioning system (GPS)-marked fish owls using the synoptic model of space use, a method that integrates home range size and resource

selection within an information-theoretic framework (Horne et al. 2008). I developed 14 *a priori* models and 10 covariates, then used the synoptic model to compare 1,894 used sites (fish owl locations) with 501,281 available sites (a grid of points spaced evenly at 200 m intervals across my 20,213 km² study area; see Chapter One for more details). Three covariates in the top models were the most important resources predicting fish owl use: river valleys, distance to water, and the number of river channels.

I estimated mean selection coefficient values for river valley, distance to water, and number of river channels and their associated standard errors by averaging the selection coefficients from each owl following methods adapted from Biggerstaff and Tweedie (1997) using the DerSimonian and Laird (1986) method-of-moments estimator. I standardized each selection coefficient using:

$$H_j^*(x_i) = \frac{[H_j(x_i) - H_j(\min)]}{[H_j(\max) - H_j(\min)]}$$

where $H_j(x_i)$ was the unstandardized value of each covariate j at grid cell (x_i) , and $H_j(\min)$ and $H_j(\max)$ were the minimum and maximum values from the unstandardized covariate, respectively. I then assigned these standardized values to each of the 501,281 cells across the study area. The relative probability of use by a fish owl at a given grid cell (x_i) was defined as:

$$\Pr(x_i) = \frac{\text{Exp}(\bar{\beta}_1 H_1^*(x_i) + \bar{\beta}_2 H_2^*(x_i) + \bar{\beta}_3 H_3^*(x_i) \dots)}{\sum_{i=1}^M \text{Exp}(\bar{\beta}_1 H_1^*(x_i) + \bar{\beta}_2 H_2^*(x_i) + \bar{\beta}_3 H_3^*(x_i) \dots)}$$

where $\Pr(x_i)$ was the probability of finding a fish owl in a particular grid cell, and $\bar{\beta}_j$ was the mean selection coefficient of variable j . The denominator was simply the numerator summed over the study area grid.

3.2.3. *Model assessment*

I assessed model fit of the final probability-of-use map following empirical methods similar to those outlined by Durner et al. (2009), in which I divided the study area into 20 units of equal size using the range of probability-of-use values identified by the synoptic model. Thus, I designated the area having the top 5% of predicted cumulative probability-of-use values as “20,” the next 5% of predicted use values designated area “19” and so forth until the last category was “1,” which was the area with the lowest 5% cumulative probability-of-use (Fig. 3.2). I then assigned each fish owl GPS location to one of these categories. I expected that fish owl locations would follow an exponential distribution if model fit was good, because probability of resource use is proportional to the exponential linear function of the covariates (Manly et al. 2002, Durner et al. 2009). I assessed model prediction by plotting fish owl GPS locations ($n = 275$) that were not used to build the predictive model onto a map that predicted probability-of-use based on the original location data. If model prediction was good, I similarly expected that these locations would follow an exponential distribution. I also assessed model fit by plotting locations of fish owl “sign” from 10 known, but independent fish owl territories (i. e., owls that were not marked with GPS dataloggers) from across the study area, and

compared those locations to the predicted probability of use. I defined “sign” as nest locations, tracks in snow, or visual detections.

Fish owls showed strong patterns of resource selection at multiple spatial scales (Chapters One, Two). These patterns were identified by consistent elements (resources) that formed the core of an owl’s home range. I defined the suite of resources as representing “primary habitat,” using both biological and statistical criteria. Biologically, primary habitat was forest patches $>0.10 \text{ km}^2$ (4 adjacent high probability-of-use pixels on my map) most likely to contain the resources associated with fish owl breeding and hunting (nest trees and foraging sites, see Chapter Two). Statistically, primary habitat was the area within the top 10% predicted probability of use (categories “20” and “19”, cumulative probability ≤ 0.287981 , see 3.2. *Model Fit* for justification). Using this statistical delineation of primary habitat and the maximum length of a fish owl territory (13.41 km, Chapter One), I estimated its distribution in the study area and then used this distribution to estimate the potential number of fish owl territories within the study area.

Results

3.3.1. Owl monitoring

I collected GPS data from 7 fish owls on 5 territories in 3 river drainages (Amgu: $n = 4$ birds, Serebyanka: $n = 2$, Saiyon: $n = 1$). I collected GPS data from 2008-2010, but only used data from 2009-2010 to create the predictive model (I reserved data from 2008 to assess model fit). Mean number of GPS locations per fish owl was 271 ± 74 (mean \pm SE, range 52-536 locations).

3.3.2. *Model fit*

The frequency distributions of fish owl locations followed the exponential function, which suggested that the covariates in the synoptic model accurately identified fish owl resource selection (Fig. 3.2). Histograms of fish owl locations showed that 62% of all locations fell within the top two (10%) probability-of-use categories (cumulative probabilities ≤ 0.287981). I used the lower end of this range of values (0.287981) as an arbitrary cutoff to identify the distribution of primary habitat. The frequency distributions of fish owl GPS locations used for model verification also followed an exponential function, which suggested that the model had high predictive power (Fig. 3.2). All 10 locations of independent fish owl sign fell within areas predicted to contain the highest 10% of fish owl use (mean cumulative probability = 0.102 ± 0.021 SE), which further supported the model's predictive power.

3.3.3. *Primary habitat*

The synoptic model predicted that there was 101.79 km² of primary habitat (areas with ≤ 0.287981 cumulative probability of use), which represents a mere 0.5% of the study area, distributed in all major river drainages (Fig. 3.1). Approximately 40% of primary habitat (40.72 km²) was outside the boundaries of protected areas and logging leases, and 39% of primary habitat (38.12 km²) fell within logging leases. Only 21% of primary habitat (20.90 km²) was within current or proposed protected areas. The vast majority of primary habitat within logging leases (88%, 33.40 km²) was concentrated in

the northern portion of the study area in the adjacent Amgu, Kema, and Maksimovka River drainages.

Based on probability-of-use distribution and maximum linear distances (Chapter One), I estimated ~54 fish owl territories could be within the study area. The Avvakumovka, Kema, Maksimovka, and Serebyanka River drainages contained the greatest number of potential fish owl territories ($n = 7$ each), followed by the Dzhigitovka River drainage ($n = 6$), and the Amgu and Belimbe River drainages ($n = 4$ each). All of these drainages (except the Avvakumovka) were within Ternei County. The remaining drainages, mostly minor, potentially supported 1-2 territories each.

3.4. Discussion

3.4.1. Model Inference

The synoptic model provided a good indication of primary fish owl habitat across the study area because of its ability to predict owl use based on fish owl telemetry locations and habitat conditions thereat, but was not without shortcomings. In the first example, the presence of riparian old growth was omitted from the predictive model, which would be an indicator of presence of suitable tree cavities large enough for nesting owls. In Chapter One I speculated that this omission occurred because fish owls were sometimes nesting in “remnant trees and snags” in disturbed forest; individual habitat features like snags could not be identified using available satellite imagery. In the second example of misclassification, primary habitat was predicted to occur at the mouth of the Dzhigitovka River. This was an area within a river valley, close to water, and contained multiple river

channels all of which were predictors of owl occurrence. However, this area was also an estuary with no riparian old-growth forest, and as such was not suitable for fish owls. To compensate for these few misclassifications of the predictive model, all areas identified as primary habitat should be scrutinized for potential errors prior to submittal as part of a management plan. Furthermore, all primary habitat should be surveyed for presence of large trees (\geq ~80 cm dbh) and nearby suitable foraging habitat (see Chapter Two) to confirm suitability for protected area designation (see below).

3.4.2. Protected Area Designation

My estimate of ~54 potential fish owl territories within the total study area was similar to that proposed by Surmach (1998; 50-70 breeding pairs) based on both his extensive natural history observations and responses from hunter surveys. Given dispersion and amount of primary fish owl habitat within areas currently receiving conservation protection, I estimated these areas could sustain ~7 fish owl territories. Within logging leases in the Amgu, Kema, and Maksimovka drainages, there was sufficient potential primary habitat for ~18 fish owl territories. It was clear from the dispersion of primary fish owl habitat across the study area that the existing protected areas alone were not sufficient to conserve fish owl populations on the eastern slope of the Sikhote-Alin Mountains; therefore, additional management actions will be necessary to conserve the owls.

Russian law is convoluted regarding the creation of new protected areas, with no clearly-defined process for proposal or designation (Krever et al. 2009), so the establishment of new protected areas is unlikely in the short term. Under the current legal system, the Forest Code of the Russian Federation requires establishment of ‘water protection zones’ along waterways to maintain proper ecosystem function and to protect spawning grounds of commercially-valuable salmonids. These buffer zones vary in width depending on river length (100 m for rivers 10-50 km from source to mouth, and 200 m for rivers >50 km in length; Shestakov 2003). All primary habitat, as defined above, would be contained within the borders of these water protection zones. However, this law does little to protect fish owls or their habitat because the only legally-prohibited activities within water protection zones are clear felling of forests and chemical application, and even these restrictions are not absolute (Forest Code of the Russian Federation 2006). Therefore, timely alternative conservation strategies need to be developed, including agreements with logging lease holders to integrate existing law with sustainable use and management of resources important to fish owls.

One attractive management possibility that would incorporate knowledge of fish owl resource selection with their conservation is the designation of the “specially-protected forest patch,” described here using the transliterated Russian acronym OZUL (Особо Защитный Участок Леса). These micro-protected areas are designed to conserve specific habitat patches on federal land leases while otherwise allowing resource extraction to occur (Shubin 1993). OZULs vary in size depending on conservation need and are actions that can be implemented by the leaseholder. Examples

of existing OZULs include 300 m radius areas around black-billed capercaillie (*Tetrao parvirostris*) leks, and 100 m strips along rivers in Eurasian beaver (*Castor fiber*) habitat (Russian Federal Forest Service 1993).

OZULs have the potential to be the keystone of a fish owl conservation plan, if combined with existing riparian conservation measures and additional recommendations on logging road construction and maintenance, because they would protect potential nesting sites close to foraging sites (see Sections 4.3 and 4.4, below). Primary habitat as I delineated it can act as a principal guide for OZUL placement, thereby protecting key habitat components within fish owl territories. Once a logging leaseholder agrees to allow creation of fish owl OZULs within a river drainage, biologists should survey primary habitat as identified in Figure 3. The purpose of such surveys would be to confirm presence of key habitat characteristics (number of potential nest trees, availability of foraging locations; see Chapter Two). Each patch of primary habitat would then be ranked by its suitability to meet these habitat needs (Fig. 4). Known nest trees would have the highest priority for conservation and OZUL designation (First Category OZUL). In primary habitat where no nest tree is known, sites with both potential nest trees and appropriate foraging locations should also be considered highest priority for OZUL designation. If only one criterion is present (either potential nest trees or shallow, multi-channel rivers for foraging) then the area has secondary priority for OZUL designation (Second Category OZUL). If neither feature is found, that patch of primary habitat should be eliminated as an OZUL candidate. In territories where fish owl nest trees are known, the establishment of additional First Category OZULs are important

because fish owls often have more than one nest tree in a territory (Yamamoto 1999, Chapter Two).

Within the major fish owl drainages identified above (Amgu, Avvakumovka, Belimbe, Dzhigitovka, Kema, Maksimovka, Serebryanka) there should be no less than one fish owl OZUL for every five linear km where suitable primary habitat is present. A greater density of fish owl OZULs is encouraged, but this minimum would allow for approximately three OZULs per fish owl territory to facilitate occupancy. The rationale for a minimum of three OZULs per territory is that fish owls typically hunt near the nest tree (see Chapter Two) and have several other preferred foraging spots as well. Therefore, three OZULs would minimally meet nesting and foraging requirements. If a territory has multiple First and Second Category OZUL candidates, then final designation of OZULs, including number and location, should be done on a territory-by-territory basis. At the discretion of the surveyor, a map of equally-valuable OZUL candidates can be presented to the logging leaseholder, who can be involved in the process by selecting options that best meet their needs.

An OZUL should have a 175 m radius protected area around both the nest tree and the foraging site (whenever present) to minimize human disturbance (fish owls often flush when humans come within 100-150 m; Nechaev 1969, J. Slaght, *personal observation*). Although clear felling is prohibited in an OZUL, the selective removal of dead or damaged trees is permissible by existing legislation (Article 17, Forest Code of the Russian Federation 2006), but would be inappropriate within fish owl OZULS because these trees are either characteristic of old-growth forest or are used as nest sites

by owls (see Chapter Two). Thus, a ban on snag or damaged tree harvest within a fish owl OZUL should be imposed, specifically on Japanese poplar, chosenia, and elm that are ≥ 80 cm dbh, as these large trees are the most likely to be suitable fish owl nest trees (Chapter Two).

3.4.3. Recommendations for developing logging roads

A network of fish owl OZULs coupled with existing legal riparian buffer zones has the potential to protect the core breeding and feeding sites of territorial fish owls. However, primary habitat represents the area where important owl activities are centered (or could be centered), but it does not represent total habitat necessary for a home range. Fish owl home ranges include multiple ‘islands’ of primary habitat, and fish owls show substantial plasticity in habitat use within river valleys. They hunt along waterways ranging from broad rivers to narrow stream channels; they nest in riparian old-growth stands; and they nest in remnant snags within disturbed forest (Chapter Two). Home ranges are found both near and far from human settlements (Chapter One). Therefore, I stress that OZULs would form only a part of management plan with a goal to maintain healthy riparian ecosystems within river drainages.

Logging roads have a particularly high potential to impact fish owls because they are often in the same areas used by fish owls: river valleys, areas near water, and rivers with multiple channels. Logging lease contracts include details regarding the construction and maintenance of logging roads (Article 40, Forest Code of the Russian Federation 2006). Therefore, I recommend such contracts include two management restrictions in addition

to existing law regarding riparian buffers: (1) no road construction in a fish owl OZUL and (2) no logging of any sort (including sanitation harvests and removal of dead and damaged trees) within a fish owl OZUL.

Road construction is considered an acceptable form of forest use within a water protection zone (Forest Code of the Russian Federation 2006). I recommend caution when constructing logging roads through water conservation zones in order to maintain habitat suitability for salmonid prey species. Roads should be constructed as far from water as feasible and with a riparian buffer of at least 100 m between the road and the river because roads that eliminate or degrade riparian buffers reduce the recruitment of large woody debris to waterways and increase siltation (Hunter and Schmiegelow 2010). Large woody debris may be particularly important for fish owls, which appear to prefer foraging in streams near riparian old-growth (the primary source of large woody debris; Chapter Two), perhaps due to the greater suitability of these river stretches for juvenile salmonids. If logging roads absolutely must be built within 100 m of a waterway due to topographical or other constraints, which is sometimes the case, the buffer between waterway and road should be no less than 25 m (Hunter and Schmiegelow 2010). Roads built farther from rivers will likely result in less recreational use of that waterway than roads built near them (Clark and Gibbons 1991). Hence, less use of the waterway may lead to reduced fish owl mortality.

Roads can change channel morphology (Furniss et al. 1991), so road construction should be limited in multi-channel areas. When this is unavoidable, stream crossings should be minimized, and placed where they reduce channel changes (Furniss et al.

1991). Bridges are preferable to culverts for stream crossings, as they have less impact on channel morphology, and are less likely to impede salmonid migration (Furniss et al. 1991). In any case, bridge constructors should avoid felling live Japanese poplar, choosenia, and elm ≥ 50 cm dbh or snags of these species ≥ 80 cm to use as culverts or bridge supports because large specimens of these tree species are either existent fish owl nest trees or candidate nest trees (Chapter Two). White birch, Dahurian larch (*Larix gmelinii*), aspen (*Populus tremula*), and alder (*Alnus* sp.) are often common in these areas and their removal for bridge construction would likely not have a detrimental effect on fish owls. Temporary, transportable bridges are a relatively cost-effective means of minimizing habitat degradation, and have been used elsewhere with success (Larcombe 1999).

3.4.4. Recommendations for maintaining logging roads

Roads have been shown to negatively impact other endangered wildlife within the study area (Kerley et al. 2002), and logging roads also result in mortality of bird species by allowing increased access by generalist predators (Yahner and Mahan 1997, Boulet and Darveau 2000). I consider humans to be generalist predators in this case. Roadless areas receive little recreational use, and what use they do receive is dispersed across a broad area. Roads, however, provide many entry points to local habitats and, therefore, increase or concentrate use (Clark and Gibbons 1991). Road location and design dictate use, and regardless of initial purpose, recreational activity in an area increases dramatically after road construction (Clark and Gibbons 1991). Therefore, control of

human access is important for wildlife (Mannan et al. 1996, Oregon Department of Forestry 2000) and for fish owls it is critical that unneeded roads be closed. Roads can be closed by erecting barricades such as deep trenches, boulders, or gates (Oregon Department of Forestry 2000). Boulders, if available, may be the best alternative as trenches have the potential to cause erosion, and gates are easily vandalized or stolen. Furthermore, road closures minimize road maintenance and reopening costs (Oregon Department of Forestry 2000). At present within the study area, sporadic road closures (typically trenches/berms) are implemented on an ad-hoc basis. I recommend that in areas with high probability-of-use by fish owls, such as within the Amgu, upper Kema, and Maksimovka River drainages, road closures should be a high priority following cessation of logging activities. Just as known fish owl nest trees should be prioritized for OZUL designation, unused logging roads near nest trees should be prioritized for closure.

3.4.5. Implementation and conservation impact

Most primary fish owl habitat within the Amgu, Kema, and Maksimovka drainages are within logging leases controlled by the same organization, TerneiLes, which is one of the largest timber companies in the Russian Far East (Newell 2004). This company has attained Forest Stewardship Council (FSC) certification, and has previously solicited recommendations from conservation organizations and biologists for placement of OZULs within its leases. TerneiLes and other leaseholders benefit by the prestige and economic rewards of FSC certification when protecting riparian forest patches that are often not legal to harvest anyway.

3.4.6. Assessment of fish owls as an umbrella species

An umbrella species is one that has either large area requirements or very specific habitat needs, and the protection of this species facilitates the protection of a broad suite of additional species (Caro 2003). The umbrella species concept has conservation merit based on a meta-analysis of empirical studies by Branton and Richardson (2011). In fact, they found that birds may be better umbrella species than mammals due to a marked increase in species richness in studies where birds were used as umbrella species. Riparian forests occupy a small proportion of an overall landscape, but they have disproportionately high value for biodiversity and ecosystem service (Hunter and Schmeigelow 2010). My management recommendations presented above (OZUL creation, riparian road placement/buffer enforcement, road closures) have conservation implications far beyond fish owls; there are biological, geographical, and political reasons why fish owls are ideal umbrella species candidates for the riparian ecosystem.

Biologically, there are several other charismatic or endangered species that are also dependent on riparian habitat, but none are as suitable as fish owls for umbrella species candidacy. For example, Asiatic black bears (*Ursus thibetanus*) frequently den in hollow Japanese poplar snags (Seryodkin et al. 2003). Managing forest patches for fish owls (in the form of OZULs) would also assure sustainable den access for Asiatic black bears. However, the reverse is not true as bears use snags in advanced stages of senescence, at which point they are no longer useful for fish owls (who require less cavity decay for nesting). Another endangered species, scaly-sided merganser (*Mergus squamatus*), also nest in riparian tree cavities (Kolomystev 1991). However, this is a migratory bird so

management is only relevant during the breeding season. My fish owl conservation recommendations are necessary to conserve fish owl populations year-round, and, therefore, have greater conservation potential (for example, road closures need to be enforced in winter, not just spring or summer, to reduce poaching). Similarly, the legal protection afforded to riparian areas in the form of water protection zones are partially in place to protect salmonid spawning, another seasonal occurrence. However the Forest Code of the Russian Federation explicitly allows harvest of old-growth within water protection zones, and overwintering juvenile salmonids (important prey objects for fish owls in winter) are, therefore, at risk due to reduced recruitment of large woody debris into waterways (Luck et al. 2010). Fish owl protection measures strengthen salmon conservation.

Geographically, fish owls have the broadest distribution of all the terrestrial vertebrates mentioned above. Focusing conservation efforts on Asiatic black bears or scaly-sided mergansers as umbrella species is limited to the southern Russian Far East alone, and could not be applied to other geographical regions within Russia because those species do not occur elsewhere. On the other hand, fish owls have distributions as far north as Magadan (60° latitude), so as demand for lumber pushes roads further north along the Sea of Japan and Sea of Okhotsk coasts, a conservation plan will be ready for implementation with a precedent from southern logging leases. Therefore, designating fish owls as an umbrella species has far-reaching geographical conservation implications.

Politically, fish owls are not conservation lightning rods as are other species in the region, such as Amur tigers (*Panthera tigris altaica*), nor are they commercially-valuable

(such as anadromous salmonids). I believe that management recommendations based on the needs of fish owls are less vulnerable to resistance given that less is at stake both politically and financially, but the end result is the same: conservation of the riparian ecosystem.

My recommendations are fish owl habitat conservation strategies that integrate the OZUL system with other forest management methods to protect primary habitat and to minimize potential negative impacts on fish owls. They are based on ecological data, are timely and actionable, and will have legitimate and positive consequences for fish owl conservation. They will also provide economic incentive to the major logging company in the region. Most importantly, my recommendations are relatively straightforward and inexpensive to apply, and once implemented can benefit fish owls and other wildlife almost immediately.

Figure 1.1. Male Blakiston's fish owl. Photo taken in Primorye, Russia, February 2009
Photograph © J. Slaght.



Figure 1.2. Map of study area in Primorye, Russia, showing forest types and locations of villages around which Blakiston's fish owl captures were based 2007-2010. Inset map shows location of study area (dark box) within northeast Asia. Shading in inset map shows estimated Blakiston's fish owl global distribution.

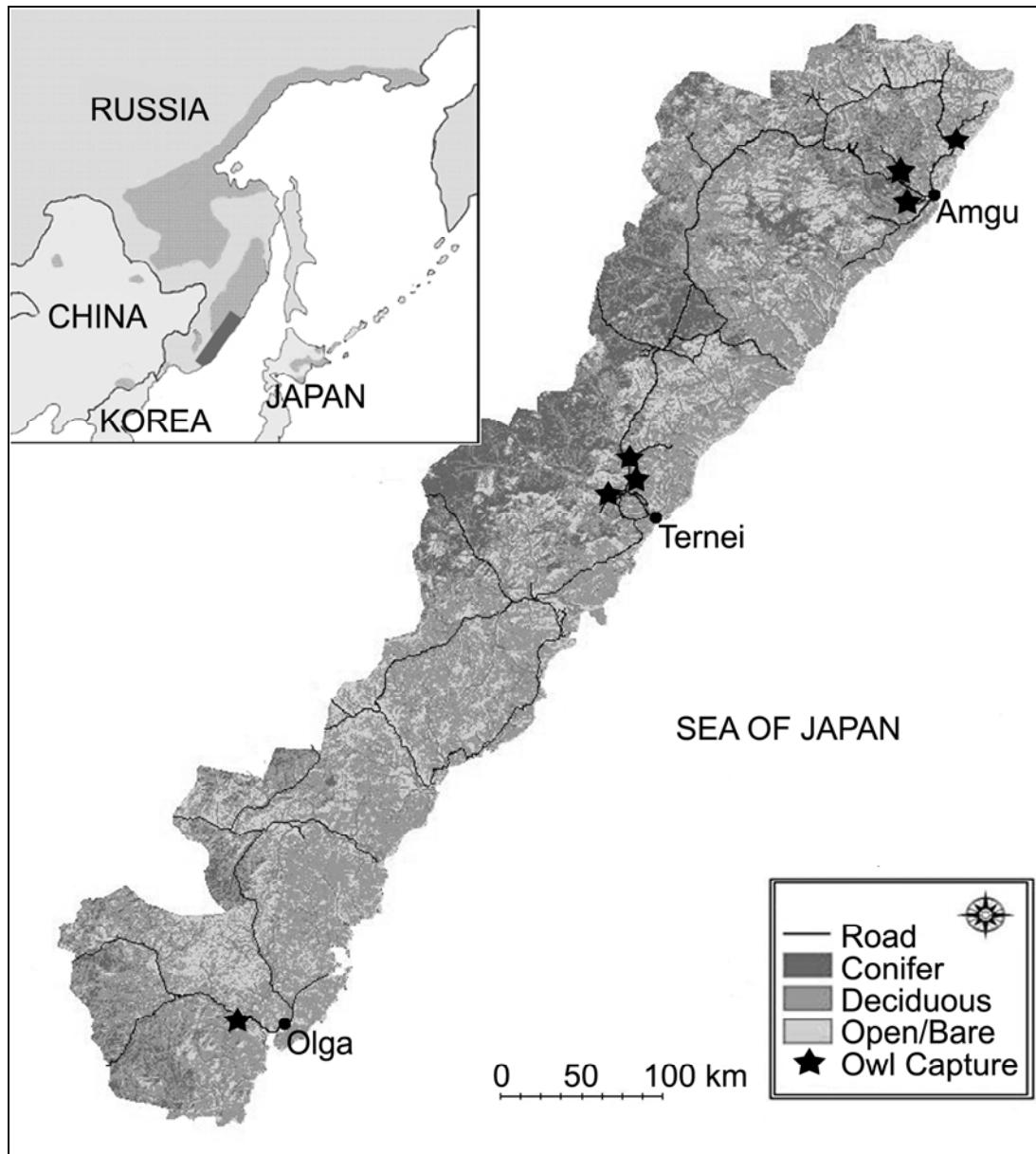


Figure 1.3. Male Blakiston's fish owl marked with 90 g GPS datalogger in February 2009. Photo © Blakiston's Fish Owl Project, courtesy A. Katkov.



Figure 1.4. Example of synoptic model output overlaid on adaptive kernel density home range estimator for a female Blakiston's fish owl with $n = 121$ GPS locations at the Sha-Mi territory, in Primorye, Russia, summer 2009.

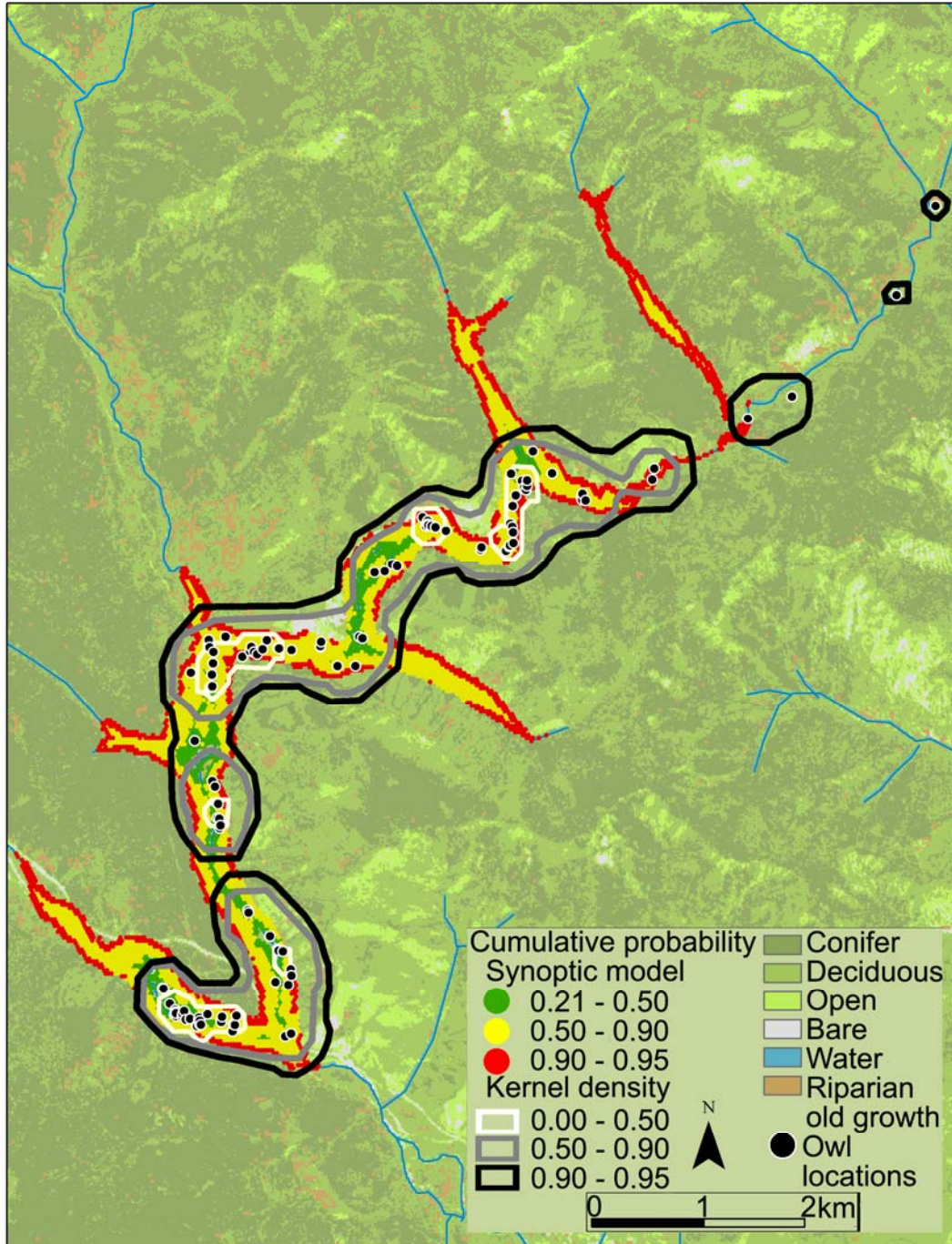


Figure 2.1. Sherbatovka River in northern Primorye, Russia, September 2009. Rivers in coastal Primorye are often shallow, rocky, fast-moving, and multi-channeled. Photo courtesy K.T. Gutiérrez -Westcott.



Figure 2.2. Snorkel survey on one of the Tunsha River channels in Primorye, Russia, in August 2009. Photo © Blakiston's Fish Owl Project, courtesy A. Katkov.



Figure 2.3. Blakiston's fish owl nest cavity (broken-top type) in a chosenia (*Chosenia arbutifolia*) at the Kudya River, in Primorye, Russia. Photograph taken February 2010 © J. Slaght.

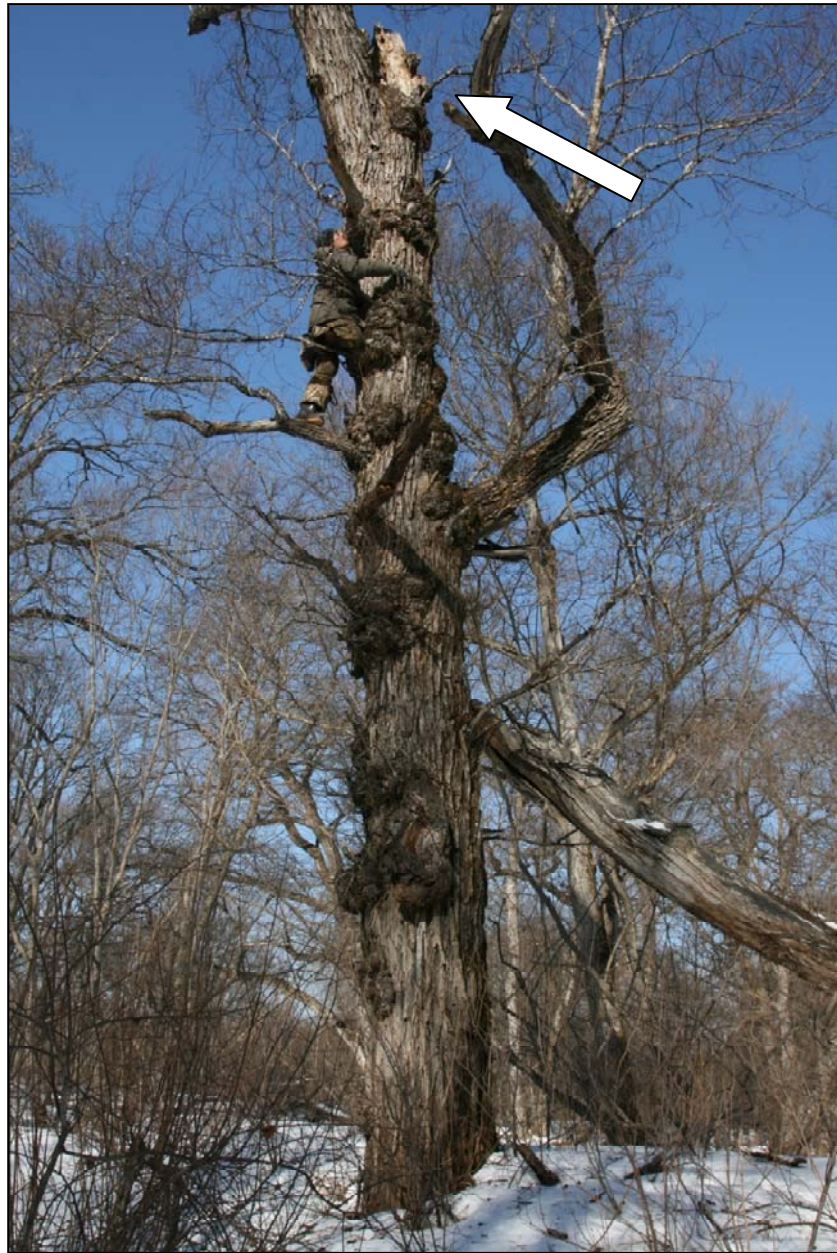


Figure 3.1. Map of study area in Primorye, Russia, showing locations of protected areas, lands leased for logging, primary Blakiston's fish owl habitat, and some human settlements for reference. Cities are shown in capital letters; remainder are mid-sized settlements (1000-5000 residents). Inset map shows location of study area within northeast Asia, with fish owl global distribution estimated by dark shading.

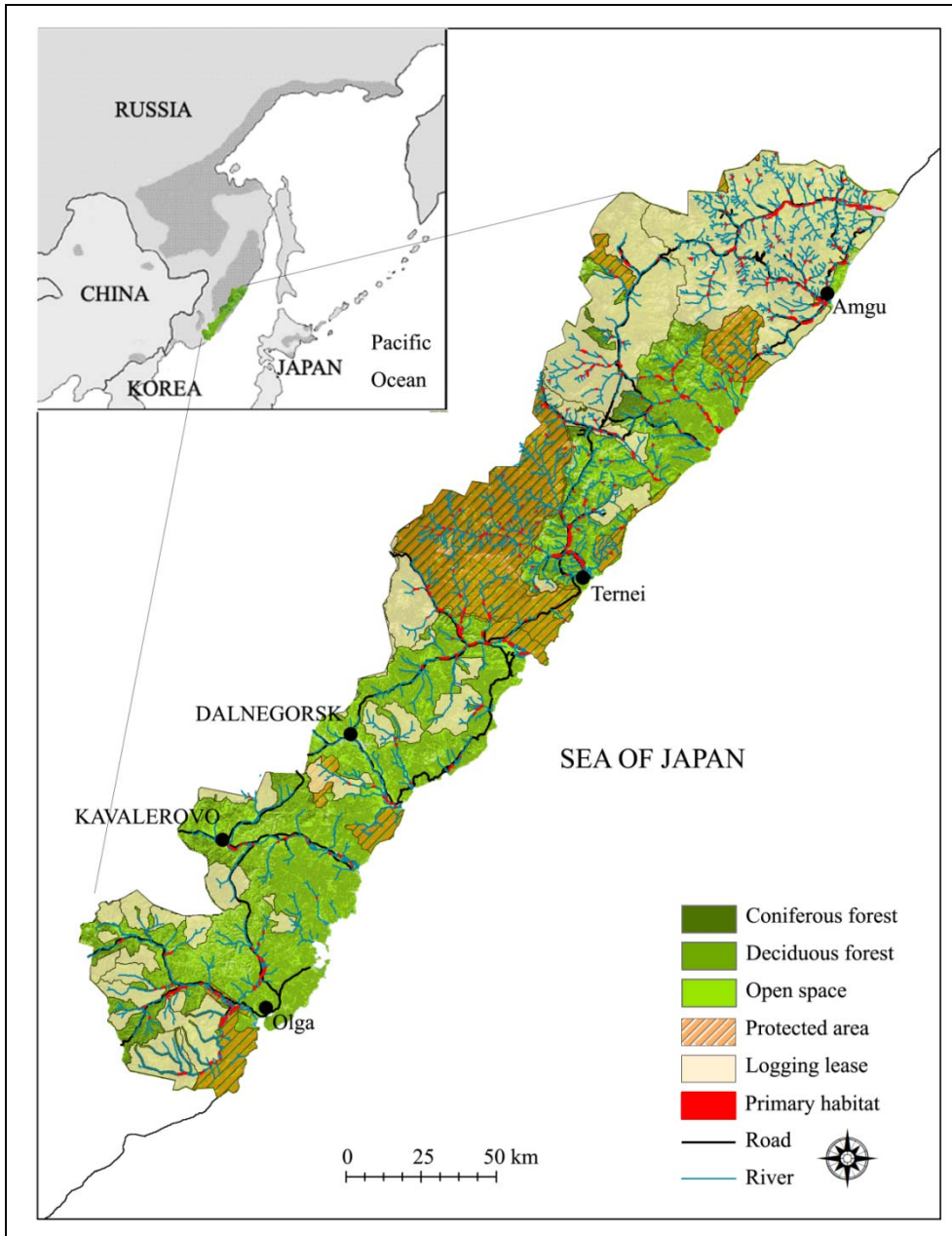


Figure 3.2. Histogram of Blakiston’s fish owl locations used to develop model prediction (black bars, $n = 1894$) and verify model prediction (open bars, $n = 275$) grouped by equal-area probability of use categories, where “20” contains the highest 5% probability of use, and “0” contains the lowest 5% probability of use. Most development data (62%) and verification data (63%) fell within the top 10% of probability-of-use bins (cumulative probabilities from 0.0000681-0.287981). The negative exponential distributions indicate good model fit.

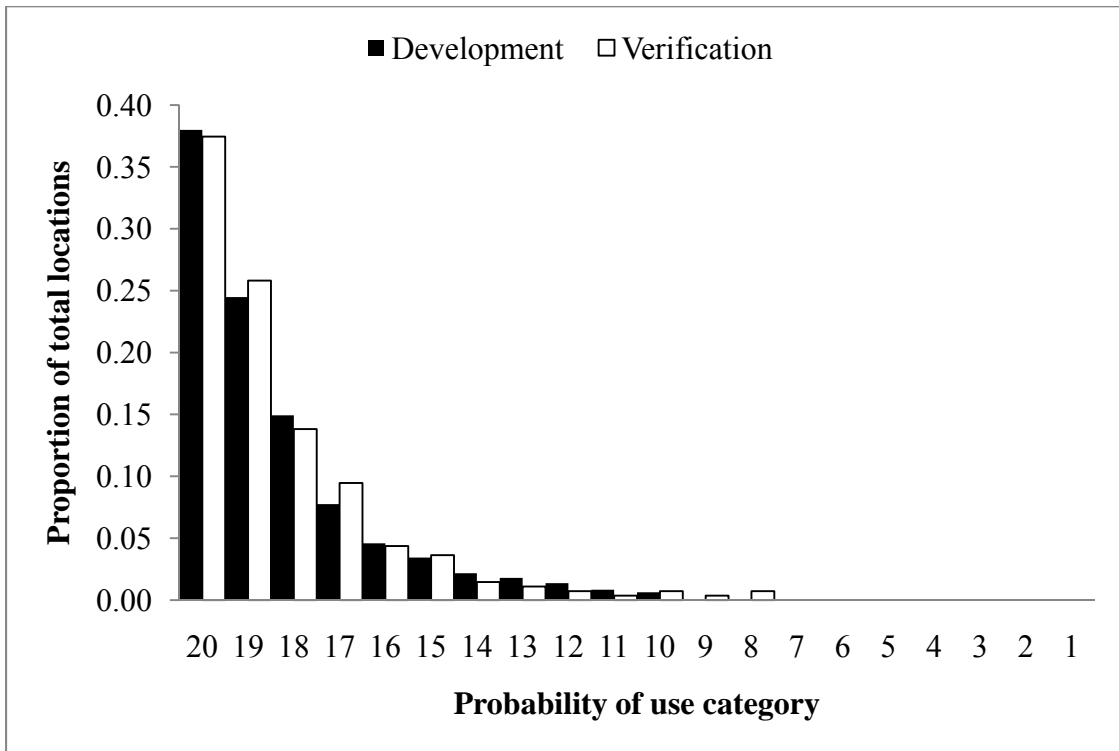


Figure 3.3. Makimovka River drainage, in northern Primorye, Russia, showing distribution Blakiston's fish owl primary habitat. These areas should be assessed for protected area (OZUL) designation. Locations of known fish owl territories (independent data used to verify model prediction) are designated by white stars, are within primary habitat, and are within the network of logging roads (bold, checkered line). This road network should be closed following use, and monitored to ensure closures remain in place.

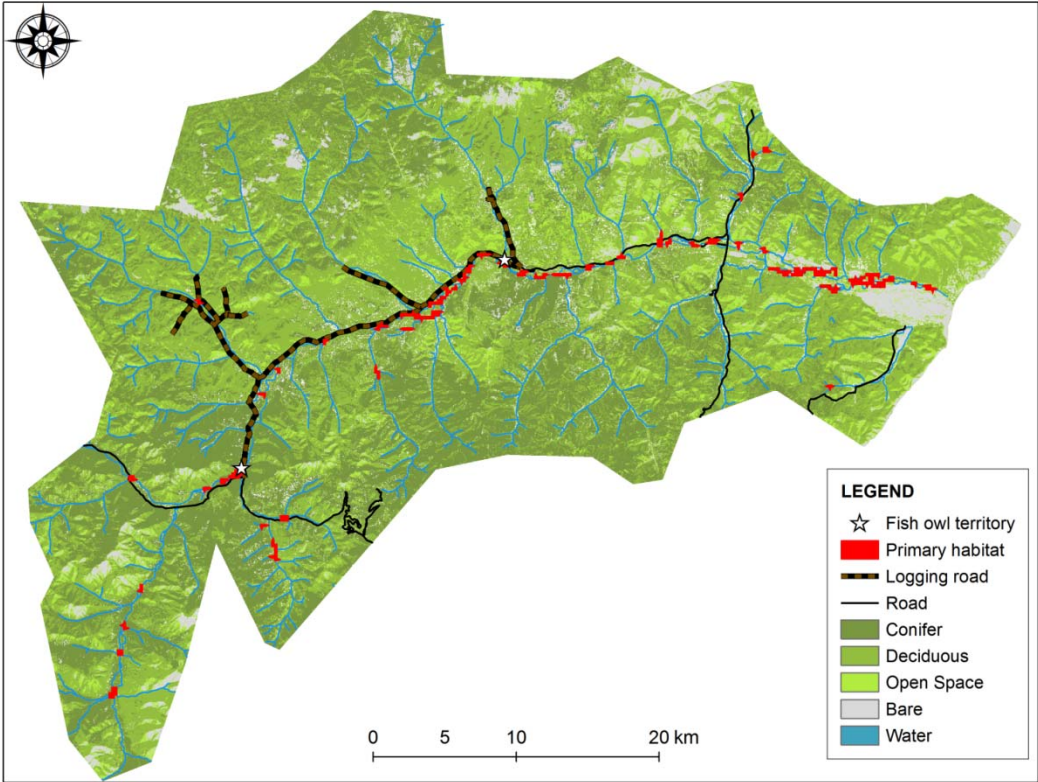


Figure 3.4. Hierarchical process for identifying protected areas (OZULs) for Blakiston’s fish owls in Primorye, Russia. Primary habitat predicted from model should be surveyed for presence of either old-growth forest (for nesting) or shallow, multi-channel waterways (for hunting). If both criteria are present or a nest tree is known, the area should be given highest priority for OZUL designation (First Category). If only one criterion is present, then the area should be given secondary priority for OZUL designation (Second Category). If neither criterion is present, the area should not be considered for OZUL designation.

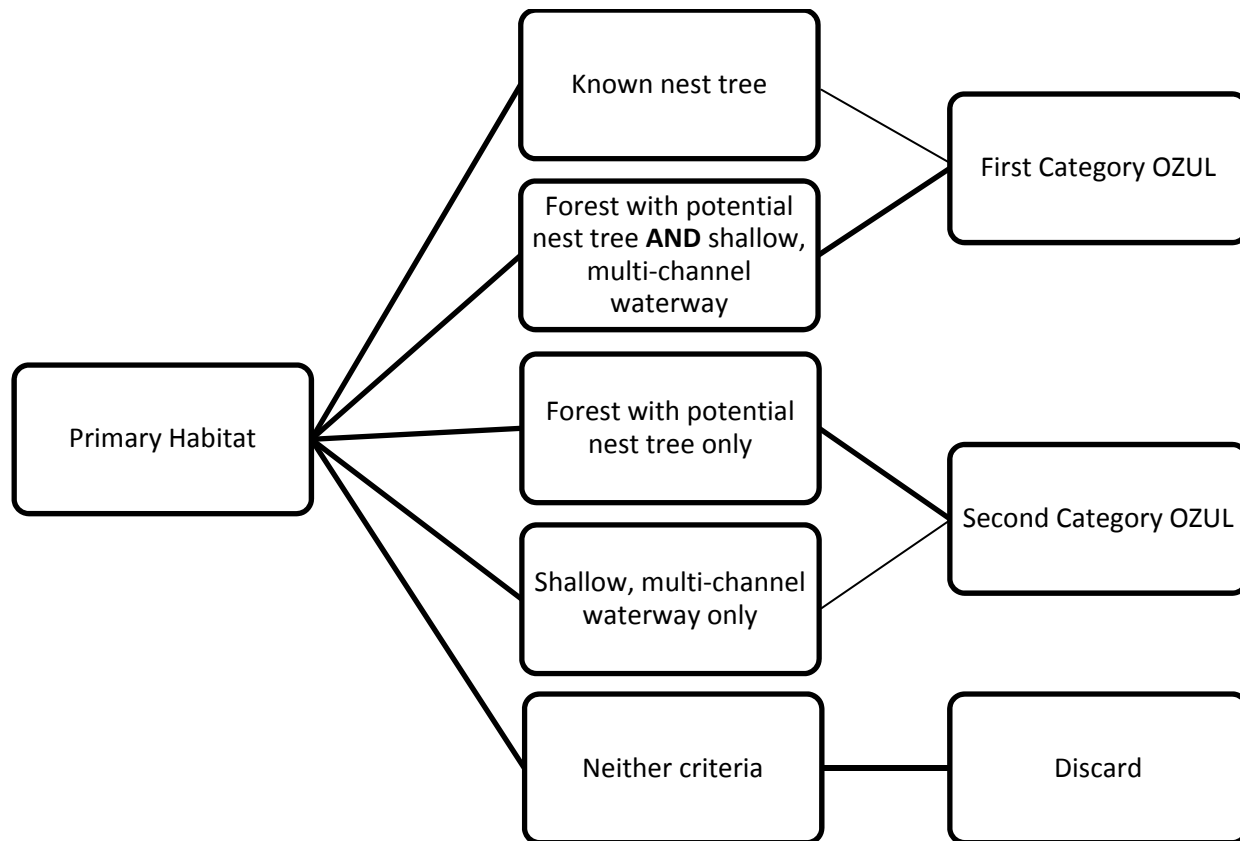


Table 1.1. Covariates used in model selection to describe Blakiston’s fish owl home range and resource selection in Primorye, Russia, with a description of their relevance to fish owls.

VARIABLE	CODE	DESCRIPTION
Landform	VALLEY	Binary. Defined as all areas ≤ 600 m elevation and $\leq 4\%$ slope.
Habitat Composition (213)	[<i>type</i>] ₂₁₃	Percentage of each habitat type within a 213 m buffer. Habitats were deciduous forest (DEC), riparian old-growth forest (RO), and open area (OPEN; agriculture, meadow, young forest, rock, road, human settlement).
Distance to Water	D_WAT	Distance to the nearest water source, in meters. Fish owls seem highly dependent on water.
Distance to Open Water in Winter	D_WWAT	Distance to the nearest patch of open water in winter, in meters. Fish owls may center their year-round territories around this important seasonal resource.
Stream Channels (213)	CHAN_213	Number of stream channels within a 213 m radius. An increased number of channels suggests stream complexity, which can indicate better habitat for salmonid fish, major prey species for fish owls.
Human Disturbance	DISTURB	Binary. Areas within 1 km of a road, and within 30 km of a settlement
Neighboring Owls	NEIGH	Binary. Identifies all areas within a known neighboring fish owl territory (delineated using minimum convex polygon).
Riparian forest/ Water Interaction	RO*DWAT	Interaction term between riparian old-growth forest (RO_213) and distance to water (D_WAT)

Table 1.2. Set of 14 models tested to describe Blakiston’s fish owl home range and resource selection in Primorye, Russia, showing covariates used and model descriptions. The parameter VALLEY was river valley, D_WAT was distance to water, D_WWAT was distance to open water in winter, DISTURB was a human disturbance metric, and RO_213, DEC_213, OPEN_213, CHAN_213 were amount of riparian old-growth, deciduous forest, open space, and number of river channels within a 213 m buffer, respectively. Note that all models beyond BVN (bivariate normal, the null model) include covariates BVN and NEIGH (neighboring owl territories).

MODEL	DESCRIPTION
BVN	Bivariate normal distribution; the null model of space use
VALLEY+D_WAT	Basic model; tests reliance on VALLEY covariate and distance to water
VALLEY+CHAN_213	Basic model; tests reliance on VALLEY covariate and number of river channels within a 213 m buffer
VALLEY+D_WWAT+RO_213	“Literature” model; tests hypothesis that fish owl distribution is limited by amount of riparian old-growth forest (RO_213) and availability of open water in winter (D_WWAT)
VALLEY+D_WWAT+RO_213+DEC_213	Same as “literature” model, but adds amount of deciduous forest (DEC_213)
VALLEY+D_WAT+RO_213	Similar to “literature” model, but tests hypothesis that distance to water (D_WAT) is more important than distance to open water in winter
VALLEY+D_WAT+RO_213+RO*DWAT	Similar to “literature” model, but includes interaction term of riparian old-growth forest and distance to water (RO*DWAT)

MODEL**DESCRIPTION**

VALLEY+D_WAT+RO_213+CHAN_213

“Spangenberg” model, named after the researcher who first identified channel complexity as an important resource for fish owls

VALLEY+D_WAT+RO_213+CHAN_213+RO*DWAT

Same as “Spangenberg” model, but includes an interaction term of riparian old-growth forest and distance to water (RO*DWAT)

VALLEY+WWAT_213+RO_213

Similar to “literature” model, but tests hypothesis that amount of water available in winter is more important than distance to open water in winter

VALLEY+CHAN_213+RO_213

Similar to “Spangenberg” model, but omits distance to water

VALLEY+CHAN_213+RO_213+DEC_213

Same as above, but adds amount of deciduous forest

VALLEY+D_WAT+RO_213+DEC_213+OPEN_213

Similar to “literature” model, but adds amount of deciduous forest and amount of open space

VALLEY+D_WAT+RO_213+DEC_213+OPEN_213+
DISTURB

Same as above, but adds covariate testing probability of human disturbance (DISTURB)

Table 1.3. Accuracy assessment table of remote sensing classification of habitat map created for my 20,213 km² study area in Primorye, Russia, using a combination of SPOT 5 and Landsat TM imagery. Measures of accuracy are overall accuracy, producer's accuracy (%; a measure of how accurately each class was identified), user's accuracy (%; a measure of how well each identified class corresponded to the reference data), and the Kappa statistic (a measure of agreement between the remotely-sensed classification map and the reference data). Overall accuracy and the associated Kappa statistic suggest a suitable level of classification accuracy.

	CON	DEC	OPEN	BARE	WATR	RO	Ni+ ⁸	OVERALL ACCURACY: 0.85 KAPPA STATISTIC: 0.82			
CON ¹	43	1	0	1	0	0	45	PRODUCER'S ACCURACY		USER'S ACCURACY	
DEC ²	6	44	6	4	0	2	62	CON	0.86	CON	0.96
OPEN ³	1	4	40	5	0	0	50	DEC	0.88	DEC	0.71
BARE ⁴	0	0	4	40	3	0	47	OPEN	0.80	OPEN	0.80
WATR ⁵	0	0	0	0	47	0	47	BARE	0.80	BARE	0.85
RO ⁶	0	1	0	0	0	8	9	WATR	0.94	WATR	1.00
N+j ⁷	50	50	50	50	50	10	260	RO	0.80	RO	0.80

¹CON = coniferous forest type

²DEC = deciduous forest type

³OPEN = open space (agriculture, meadow, young forest),

⁴BARE = bare surface (rock, road, human settlement),

⁵WATR = water

⁶RO = riparian old growth forest.

⁷N+j = column total count

⁸Ni+ = row total count

Table 1.4. Summary of GPS data used for analysis from adult, territorial Blakiston's fish owls in Primorye Russia, collected from 2008-2010. Numbers in **bold** show sufficient sample size for inclusion into seasonal analysis.

TERRITORY	SEX	FIX ¹	FWS ²	FNS ³	TOTAL ⁴	WIN ⁵	SPR ⁶	SUM ⁷	AUT ⁸	DAYS ⁹	DUTY CYCLE ¹⁰	WT ¹¹	SUCCESS ¹²
Sha-Mi	F	569	276	34	879	179	122	121	112	361*	660	90	0.65
Sha-Mi	M	344	391	2	737	113	128	47	28	335*	660	90	0.47
Kudya	F	590	183	0	773	192	121	119	104	352*	660	90	0.76
Kudya	M	79	8	1	88	25	52	0	0	40	660	90	0.90
Saiyon	M	175	4	0	179	0	63	89	11	168	1380	40	0.98
Sereb	M	204	414	1	619	16	58	47	59	268	660	90	0.33
Faata	M	163	416	15	594	12	38	69	33	254	660	90	0.27

¹FIX = number of successful satellite acquisitions. Includes all data points.

²FWS = failures with satellites (unsuccessful fixes with some satellites present)

³FNS = failures without satellites (unsuccessful fixes without any satellites)

⁴TOTAL is the sum of fix attempts

⁵WIN= winter locations (01 December-31 March) with HDOP ≤ 5

⁶SPR = spring locations (01 April-14 June) with HDOP ≤ 5

⁷SUM = summer locations (15 June-14 September) with HDOP ≤ 5

⁸AUT = autumn locations (15 September-30 November) with HDOP ≤ 5

⁹DAYS = total number of days each unit collected data (* indicates unit was still active when retrieved)

¹⁰DUTY CYCLE is recorded in minutes

¹¹WT = tag weight (grams, including datalogger and all harness material)

¹²SUCCESS = overall fix success (proportion of successful fixes given total attempts)

Table 1.5. Seasonal and annual home range estimates for individual Blakiston’s fish owls in Primorye, Russia, from data collected 2008-2010. Home ranges varied by season, and were much smaller using the synoptic model as compared to kernel density methods for all seasons except winter. Annual home range size derived from the synoptic model was also much smaller than its kernel density counterpart.

BIRD	WINTER			SPRING			SUMMER			AUTUMN			ANNUAL		
	Syn. ¹	Kern. ²	Lin. ³	Syn.	Kern.	Lin.	Syn.	Kern.	Lin.	Syn.	Kern.	Lin.	Syn.	Kern.	Lin.
Sha-Mi F	2.1	2.0	2.7	8.0	4.6	9.4	6.8	8.8	13.0	5.1	22.9	12.0	5.5	2.6	9.3
Sha-Mi M	13.3	9.7	14.5	7.0	6.0	9.6	7.8	31.0	12.7	10.7	16.6	18.0	9.7	15.9	13.7
Kudya F	5.7	5.9	8.1	20.7	15.1	11.6	13.4	17.0	14.5	9.1	30.1	15.0	12.2	17.0	12.3
Kudya M		-		11.1	7.2	7.6		-			-		11.1	7.2	7.6
Saiyon M		-		1.1	12.5	7.1	2.9	11.1	7.7		-		2.0	11.8	7.4
Sereb M		-		7.4	9.5	6.7	20.1	46.2	15.6	24.2	47.6	19.1	17.3	32.4	13.8
Faata M		-		41.6	151.7	20.7	18.7	85.2	29.4	77.1	308.2	39.1	45.8	181.7	29.7
Total	7.0	5.9	8.5	13.9	29.5	10.4	11.6	33.2	15.5	25.2	85.1	20.6	15.0	38.8	13.4
SE	3.3	2.3	3.4	5.2	20.4	1.8	2.8	11.9	3.0	13.4	56.0	4.8	3.7	15.4	2.1

¹Syn = estimates derived from the synoptic model (km²)

²Kern = estimates derived from either fixed or adaptive kernel density methods (km²)

³ Lin = estimates of maximum linear distance between points (km).

Table 1.6. Parameter estimates (β) and associated standard errors (SE) used to develop seasonal home range and probability-of-use by Blakiston’s fish owls in Primorye, Russia, using GPS telemetry data collected 2008-2010. Asterisk (*) indicates significant value (85% confidence interval). Results suggest that river valley and distance to water had the strongest influences on Blakiston’s fish owl resource selection, followed by number of river channels. Only distance to water and number of river channels were significant across all seasons.

Parameter	Winter		Spring		Summer		Autumn		Annual	
	β	SE	β	SE	β	SE	β	SE	β	SE
VALLEY	79.8	78.3	158.0	118.9	316.4*	61.1	175.0	137.2	44.1*	12.6
D_WAT	-133.9*	3.3	-148.0*	42.5	-231.7*	15.2	-352.9*	110.5	-51.8*	9.1
RO_213	-0.2	2.2	-0.5	2.2	4.6	5.4	1.6*	0.6	0.3	0.3
CHAN_213	4.9*	0.9	7.3*	2.2	4.8*	0.8	4.3*	0.4	1.3*	0.2
DEC_213	-7.1	1.3	--		8.5	6.6	0.8	5.9	0.0 ⁴	1.1
OPEN_213	0.6	3.6	--		--		--		--	
D_WWAT	--		--		-132.9*	13.5	--		--	

¹Parameter: “VALLEY” = river valley, “D_WAT” = distance to water, “D_WWAT” = distance to open water in winter, “RO_213” = amount of riparian old-growth within a 213 m buffer, “DEC_213” = amount of deciduous forest within a 213 m buffer, “OPEN_213” = amount of open space within a 213 m buffer, “CHAN_213” = number of river channels within a 213 m buffer.

²Dashes (--) = parameters not used for inference due to absence from top candidate models during those seasons.

³Annual parameter estimates were calculated as the mean of all seasonal parameter estimates weighted by proportion of the year.

⁴Based only on three seasons

Table 2.1. Comparisons of habitat characteristics within 14 Blakiston's fish owl home ranges in Primorye, Russia, summer 2009.

Variable ¹	Unit	Nest Site ²		Nest Stand Site ³		Random Site ⁴		F^5	Prob > F^6
		mean	SE	mean	SE	mean	SE		
largeDBH	cm	121.71*	8.55	110.75	9.23	82.36*	8.87	5.35	0.01*
DBHplot	cm	43.35	2.93	42.42	3.16	38.99	3.04	0.57	0.57
snag	count	3.14*	0.59	1.50	0.64	0.92*	0.62	3.60	0.04*
canopy	proportion	0.80	0.23	0.83	0.24	0.85	0.23	1.16	0.33
perDEC	proportion	0.92	0.04	0.87	0.05	0.89	0.05	0.29	0.75
∞ Tree5070	proportion	0.17	0.03	0.16	0.04	0.17	0.04	0.01	0.99
Tree_sp	count	3.83	0.43	3.73	0.45	2.77	0.42	1.91	0.16

¹ Variables: “largeDBH” = tree diameter at breast height (dbh, in cm) of the largest tree at a site; “DBHplot” = mean dbh at the site, “snag” = number of snags, “canopy” = canopy cover (%), “perDEC” = proportion of deciduous trees, “Tree5070” = proportion of trees with dbh between 50-70 cm dbh, “Tree_sp” = number of tree species

² Nest site = characteristics centered on nest tree, $n = 14$

³ Nest stand site = characteristics centered on tree ~59 cm dbh at 50 m distance from nest tree, $n = 12$

⁴ Random site = characteristics centered on tree ~59 cm dbh ≤ 1500 m distance from nest tree, $n = 13$

⁵ $F = F$ -statistic

⁶ Prob > $F = P$ -value associated with F -statistic used to test null hypothesis that all sites are the same. An asterisk (*) denotes significant differences among means

Table 2.2. Characteristics of 15 Blakiston's fish owl nest trees in Primorye, Russia, 2005-2009.

Territory	Nest Tree Species	Nest Tree Condition	Nest Type	DBH (cm)	Tree Height (m)	Nest Height (m)
Faata ¹	Japanese Poplar	Declining	Top Cavity	120	24	8
Kudya	Chosenia	Weakened	Top Cavity	100	16	11
Leonovka	Japanese poplar	Declining	Top Cavity	145	20	11.8
Losevka	Japanese poplar	Dead >2 Yr.	Top Cavity	150	8.6	8.1
Margaritovka	Chosenia	Dead >2 Yr.	Top Cavity	115	-	8
Mineralnaya	Japanese poplar	Declining	Top Cavity	110	16.6	12
Sadoga	Elm	Declining	Top Cavity	85	12	7
∞ Saiyon	Chosenia	Declining	Top Cavity	143	17.5	4
Samarga ²	Chosenia	Dead >2 Yr	Top Cavity	92	15	5
Serebyanka	Japanese poplar	Weakened	Top Cavity	125	22.2	16.8
Sheptun ³	Japanese poplar	Dead >2 Yr	Top Cavity	130	10	9
Sherbatovka	Japanese poplar	Declining	Top Cavity	150	27.1	16.5
Tekunzha	Elm	Declining	Top Cavity	85	18.5	8
Tunsha	Japanese poplar	Dead >2 Yr	Top Cavity	105	14.7	7.7
Vetka ³	Chosenia	Weakened	Top Cavity	74	21	7

¹ description of presumed nest tree

² used only for nest tree (not nest site) analysis due to lack of additional data.

³ described nest tree is no longer functional (felled due to storms during the study period 2006-2010)

Table 2.3. Comparisons of river characteristics within 14 Blakiston's fish owl home ranges in Primorye, Russia, summer 2009.

Variable	Unit	Used Site ¹		Available Site ²		F^3	Prob > F^4
		mean	SE	mean	SE		
Mean water flow	m per second	1.75	0.37	2.34	0.37	1.20	0.28
Riffle type	proportion glide	0.48	0.10	0.51	0.10	0.07	0.80
	proportion rapid	0.34	0.10	0.31	0.10	0.03	0.88
	proportion cascade	0.19	0.06	0.17	0.06	0.03	0.87
Substrate	proportion cobble	0.64	0.06	0.56	0.08	0.53	0.47
	proportion pebble	0.21	0.07	0.23	0.07	0.05	0.83
	proportion boulder	0.11	0.06	0.11	0.07	0.00	1.00
	proportion sand	0.04	0.02	0.09	0.04	1.50	0.23
Riparian old-growth	proportion	0.07	0.02	0.01	0.02	4.43	0.05*
Number of fish	count	214.07	39.45	191.50	53.01	0.12	0.74
Number of species	count	2.93	0.293	3.21	0.293	0.48	0.48
Small masu salmon	count	93.71	11.94	91.71	11.94	0.01	0.90
Medium trout	count	11.29	5.02	13.29	5.02	0.08	0.78

¹ Used site = river characteristics measured along a 100 m stretch of river closest to the nest tree

² Available site = river characteristics measured along a 100 m stretch of river closest to the random vegetation site

³ $F = F$ -statistic

⁴ Prob > $F = P$ -value associated with the F -statistic, used to test null hypothesis that used and available sites were the same. An asterisk (*) indicates significant difference between sites.

Table 2.4. Comparison of fish species and relative abundance detected during snorkel surveys in 14 used foraging sites and 14 available sites within Blakiston's fish owl home ranges in Primorye, Russia. Surveys were conducted August-September 2009.

Species	Common name	Size ¹	Used site ²			Available site ³			F^4	Prob > F^5
			mean	SE	# ⁶	mean	SE	# ⁶		
<i>Oncorhynchus masou</i>	Masu salmon	S	99.07	11.81	14	86.36	11.81	13	0.58	0.45
		M	29.93	10.55	14	31.62	10.95	12	0.01	0.91
		L	5.14	5.88	4	9.31	6.10	5	0.24	0.63
<i>O. keta</i>	Chum salmon	L	--	--	0	0.07	0.05	1	1.00	0.33
8 <i>Salvelinus malma</i>	Dolly Varden trout	S	8.79	4.67	7	8.00	4.67	4	0.01	0.91
		M	11.07	5.01	10	13.50	5.01	9	0.12	0.74
		L	1.36	0.90	5	1.92	0.90	4	0.20	0.66
<i>S. leucomaenis</i>	White-spotted char	M	0.07	0.16	1	0.21	0.16	1	0.40	0.53
<i>Brachymystax lenok</i>	Lenok	M	0.29	1.07	1	--	--	0	1.00	0.33
		L	0.07	0.05	1	--	--	0	1.00	0.33
<i>Barbatula barbatula</i>	Stone loach	S	0.07	0.05	1	--	--	0	1.00	0.33
		M	0.07	0.41	1	0.57	0.41	1	0.75	0.39

Species	Common name	Size ¹	Used site ²			Available site ³			F^4	Prob > F^5
			mean	SE	# ⁶	mean	SE	# ⁶		
<i>Rhynchocypris lagowskii</i>	Amur minnow	S	26.79	12.11	3	10.86	12.11	5	0.87	0.36
		M	17.29	10.07	3	15.57	10.07	4	0.02	0.91
<i>Tribolodon brandtii</i>	Pacific redfin	S	3.21	3.65	1	5.21	3.65	2	0.15	0.70
		M	3.43	2.11	2	1.14	2.11	2	0.59	0.45
<i>Cottus sp.</i>	Sculpin sp.	S	1.07	0.77	6	2.28	0.77	8	1.23	0.28
		M	0.14	0.20	2	0.50	0.20	3	1.53	0.23
		L	--	--	0	0.14	0.10	1	1.00	0.33
Total			214.07	39.45		191.50	53.01		0.12	0.74

¹ Fish were partitioned by size, where S = small (<150 mm), M = medium (150 mm and <300 mm), and L = large (300 mm)

² Used site = fish detected along a 100 m stretch of river closest to the nest tree

³ Available site = fish detected along a 100 m stretch of river closest to the random vegetation site

⁴ $F = F$ -statistic

⁵ Prob > $F = P$ -value associated with the F -statistic, used to test null hypothesis that used and available sites were the same. An asterisk (*) indicates significant difference between sites.

⁶ # = number of surveys for which fish of that species and size class were recorded

Table 2.5. Accuracy assessment of discriminant analysis for predicting Blakiston's fish owl habitat in Primorye, Russia: (A) nest sites versus random sites, and (B) nest stand sites versus random sites, based on the diameter of the largest tree and the number of snags at the site.

A.	NEST RANDOM		N_{i+} ¹	B.	NEST STAND		RANDOM	N_{i+} ¹
NEST	11	4	15	NEST STAND	6		5	11
RANDOM	3	9	12	RANDOM	6		8	14
N_{+j} ²	14	13		N_{+j} ²	12	13		
OVERALL ACCURACY ³ : 0.74				OVERALL ACCURACY ³ : 0.56				
KAPPA STATISTIC ⁴ : 0.48				KAPPA STATISTIC ⁴ : 0.12				

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¹ N_{i+} = row total count

² N_{+j} = column total count

³ Overall accuracy = proportion of sites accurately identified using a jackknife procedure

⁴ Kappa statistic = measure of chance-corrected classification rates

Table 2.6. Results of linear discriminant analysis of habitat and river variables within 14 Blakiston's Fish Owl home ranges in Primorye, Russia, 2009.

Variable ¹	Wilks' Lam. ²	F^3	$Prob > F^4$	F -diff ⁵	P -diff ⁶	LD ⁷	λ^8	R_c^9	$R_c^{2\ 10}$
<i>Vegetation</i>									
largeDBH	0.77	13.81	<0.01	5.35	<0.01	-0.03	3.71	0.89	0.79
snag	0.68	9.15	<0.01	2.27	0.12	-0.41	4.37	0.90	0.81
<i>Rivers</i>									
ripOG	0.89	4.43	<0.05	4.43	<0.05	-11.35	2.10	0.82	0.68
cobble	0.78	3.55	<0.05	2.43	0.13	-2.49	2.71	0.85	0.73

¹ Variables: "largeDBH" = diameter at breast height of the largest tree at the site; "snag" = number of snags at the site; "ripOG" = proportion of riparian old-growth forest within a 50 m buffer of the center point of the river survey; "cobble" = proportion of cobble river substrate

² Wilks' Lam.= Wilks' lambda

³ F = F -statistic of the model overall

⁴ $Prob > F$ = corresponding P -value

⁵ F -diff = F -statistic of the partial Wilks' lambda

⁶ P -diff = P -value associated with the F -statistic

⁷ LD = linear discriminant coefficient

⁸ λ = eigenvalue

⁹ R_c = canonical correlation coefficient

¹⁰ R_c^2 = squared canonical correlation

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Appendix 1.1.1. Results of model selection for female Blakiston's fish owl at the Sha-Mi River territory, during winter 2009. The model chosen for inference is in bold. Null model (BVN) includes parameters mean of x , mean of y , standard deviation of x , standard deviation of y , and correlation. All models (except BVN) include BVN and NEIGH (neighboring owl territories).

<u>Model</u>	<u>n</u>	<u>K</u>	<u>ΔAIC_C</u>	<u>$\xi(g_i x)$</u>	<u>w</u>
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213+DISTURB	179	12	0.00	1.00	1.00
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213	179	11	57.14	0.00	0.00
VALLEY+D_WWAT+RO_213+DEC_213	179	10	61.92	0.00	0.00
VALLEY+CHAN_213+RO_213+DEC_213	179	10	79.39	0.00	0.00
VALLEY+D_WAT+RO_213+CHAN_213	179	10	82.84	0.00	0.00
VALLEY+D_WAT+RO_213+CHAN_213+RO*DWAT	179	11	84.75	0.00	0.00
VALLEY+D_WAT+RO_213	179	9	89.38	0.00	0.00
VALLEY+CHAN_213+RO_213	179	9	92.10	0.00	0.00
VALLEY+D_WWAT+RO_213	179	9	92.97	0.00	0.00
VALLEY+CHAN_213	179	8	98.39	0.00	0.00
VALLEY+D_WAT+RO_213+RO*DWAT	179	10	93.18	0.00	0.00
VALLEY+D_WAT	179	8	98.89	0.00	0.00
VALLEY+WWAT_213+RO_213	179	9	118.91	0.00	0.00
BVN	179	5	129.07	0.00	0.00

Appendix 1.1.2. Results of model selection for female Blakiston's fish owl at the Sha-Mi River territory, during spring 2009. The model chosen for inference is in bold. Null model (BVN) includes parameters mean of x , mean of y , standard deviation of x , standard deviation of y , and correlation. All models (except BVN) include BVN and NEIGH (neighboring owl territories).

<u>Model</u>	<u>n</u>	<u>K</u>	<u>ΔAIC_C</u>	<u>$\xi(g_j x)$</u>	<u>w</u>
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213+DISTURB	122	12	0.00	1.00	0.87
VALLEY+D_WAT+RO_213+CHAN_213	122	10	5.82	0.05	0.05
VALLEY+D_WAT	122	8	6.84	0.03	0.03
VALLEY+D_WAT+RO_213+CHAN_213+RO*DWAT	122	11	7.25	0.03	0.02
VALLEY+D_WAT+RO_213	122	9	7.32	0.03	0.02
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213	122	11	11.36	0.00	0.00
VALLEY+D_WAT+RO_213+RO*DWAT	122	10	11.49	0.00	0.00
VALLEY+CHAN_213+RO_213+DEC_213	122	10	64.57	0.00	0.00
VALLEY+CHAN_213	122	8	64.61	0.00	0.00
VALLEY+CHAN_213+RO_213	122	9	64.73	0.00	0.00
VALLEY+D_WWAT+RO_213+DEC_213	122	10	105.57	0.00	0.00
VALLEY+D_WWAT+RO_213	122	9	106.25	0.00	0.00
VALLEY+WWAT_213+RO_213	122	9	119.49	0.00	0.00
BVN	122	5	266.98	0.00	0.00

Appendix 1.1.3. Results of model selection for female Blakiston's fish owl at the Sha-Mi River territory, during summer 2009. Two models were within $2 \Delta AIC_C$, but the inclusion of the additional terms were not well supported (85% confidence interval overlapped 0). The model chosen for inference is in bold. Null model (BVN) includes parameters mean of x, mean of y, standard deviation of x, standard deviation of y, and correlation. All models (except BVN) include BVN and NEIGH (neighboring owl territories).

<u>Model</u>	<u>n</u>	<u>K</u>	<u>ΔAIC_C</u>	<u>$\hat{f}(g_j x)$</u>	<u>w</u>
VALLEY+D_WAT+RO_213+CHAN_213	121	10	0.00	1.00	0.45
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213+DISTURB	121	12	0.35	0.84	0.37
VALLEY+D_WAT+RO_213+CHAN_213+RO*DWAT	121	11	1.86	0.39	0.18
VALLEY+D_WAT	121	8	10.49	0.01	0.00
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213	121	11	11.29	0.00	0.00
VALLEY+D_WAT+RO_213	121	9	11.39	0.00	0.00
VALLEY+D_WAT+RO_213+RO*DWAT	121	10	24.71	0.00	0.00
VALLEY+CHAN_213+RO_213+DEC_213	121	10	118.29	0.00	0.00
VALLEY+CHAN_213+RO_213	121	9	124.21	0.00	0.00
VALLEY+CHAN_213	121	8	150.26	0.00	0.00
VALLEY+D_WWAT+RO_213+DEC_213	121	10	157.99	0.00	0.00
VALLEY+D_WWAT+RO_213	121	9	165.02	0.00	0.00
VALLEY+WWAT_213+RO_213	121	9	194.62	0.00	0.00
BVN	121	5	436.48	0.00	0.00

Appendix 1.1.4. Results of model selection for female Blakiston's fish owl at the Sha-Mi River territory, during autumn 2009. The model chosen for inference is in bold. Null model (BVN) includes parameters mean of x, mean of y, standard deviation of x, standard deviation of y, and correlation. All models (except BVN) include BVN and NEIGH (neighboring owl territories).

<u>Model</u>	<u>n</u>	<u>K</u>	<u>ΔAIC_C</u>	<u>$f(g_i x)$</u>	<u>w</u>
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213+DISTURB	112	12	0.00	1.00	1.00
VALLEY+D_WAT+RO_213+CHAN_213	112	10	30.88	0.00	0.00
VALLEY+D_WAT+RO_213+CHAN_213+RO*DWAT	112	10	32.37	0.00	0.00
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213	112	11	35.59	0.00	0.00
VALLEY+D_WAT+RO_213	112	9	37.89	0.00	0.00
VALLEY+D_WAT+RO_213+RO*DWAT	112	10	39.95	0.00	0.00
VALLEY+D_WAT	112	8	67.97	0.00	0.00
VALLEY+D_WWAT+RO_213	112	9	206.37	0.00	0.00
VALLEY+D_WWAT+RO_213+DEC_213	112	10	208.31	0.00	0.00
VALLEY+CHAN_213+RO_213	112	9	263.91	0.00	0.00
VALLEY+CHAN_213+RO_213+DEC_213	112	10	265.88	0.00	0.00
VALLEY+WWAT_213+RO_213	112	9	269.56	0.00	0.00
VALLEY+CHAN_213	112	8	289.83	0.00	0.00
BVN	112	5	519.72	0.00	0.00

Appendix 1.2.1. Results of model selection for male Blakiston's fish owl at the Sha-Mi River territory, during winter 2009. One model was within 2 ΔAIC_C , but the inclusion of the interactive term did not have statistical support (85% confidence interval overlapped 0). The model chosen for inference is in bold. Null model (BVN) includes parameters mean of x, mean of y, standard deviation of x, standard deviation of y, and correlation. All models (except BVN) include BVN and NEIGH (neighboring owl territories).

<u>Model</u>	<u>n</u>	<u>K</u>	<u>ΔAIC_C</u>	<u>$\xi(g_j x)$</u>	<u>w</u>
VALLEY+D_WAT+RO_213 +CHAN_213	114	10	0.00	1.00	0.69
VALLEY+D_WAT+RO_213 +CHAN_213+RO*DWAT	114	11	1.63	0.44	0.31
VALLEY+D_WAT+RO_213 +RO*DWAT	114	10	33.44	0.00	0.00
VALLEY+D_WAT+RO_213	114	9	38.38	0.00	0.00
101 VALLEY+D_WAT+RO_213+DEC_213+OPEN_213	114	11	39.52	0.00	0.00
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213+DISTURB	114	12	39.74	0.00	0.00
VALLEY+D_WAT	114	8	41.97	0.00	0.00
VALLEY+CHAN_213+RO_213	114	9	55.98	0.00	0.00
VALLEY+CHAN_213+RO_213+DEC_213	114	10	57.95	0.00	0.00
VALLEY+CHAN_213	114	8	65.83	0.00	0.00
VALLEY+D_WWAT+RO_213	114	9	69.79	0.00	0.00
VALLEY+D_WWAT+RO_213+DEC_213	114	10	71.67	0.00	0.00
VALLEY+WWAT_213+RO_213	114	9	196.81	0.00	0.00
BVN	114	5	395.00	0.00	0.00

Appendix 1.2.2. Results of model selection for male Blakiston's fish owl at the Sha-Mi River territory, during spring 2009. One model was within 2 ΔAIC_C , which had stronger statistical support than the top model (85% confidence interval did not overlap 0). The model chosen for inference is in bold. Null model (BVN) includes parameters mean of x, mean of y, standard deviation of x, standard deviation of y, and correlation. All models (except BVN) include BVN and NEIGH (neighboring owl territories).

<u>Model</u>	<u>n</u>	<u>K</u>	<u>ΔAIC_C</u>	<u>$\mathcal{L}(\mathbf{g} \mathbf{x})$</u>	<u>w</u>
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213+DISTURB	128	12	0.00	1.00	0.60
VALLEY+D_WAT+RO_213 +CHAN_213	128	10	1.99	0.37	0.22
VALLEY+D_WAT+RO_213 +CHAN_213+RO*DWAT	128	11	33.07	0.00	0.00
VALLEY+D_WAT+RO_213	128	9	3.74	0.15	0.09
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213	128	11	4.91	0.09	0.05
VALLEY+D_WAT+RO_213 +RO*DWAT	128	10	6.35	0.04	0.02
VALLEY+D_WAT	128	8	7.49	0.02	0.01
VALLEY+CHAN_213+RO_213	128	9	53.50	0.00	0.00
VALLEY+CHAN_213+RO_213+DEC_213	128	10	54.23	0.00	0.00
VALLEY+CHAN_213	128	8	59.57	0.00	0.00
VALLEY+D_WWAT+RO_213+DEC_213	128	10	101.83	0.00	0.00
VALLEY+D_WWAT+RO_213	128	9	101.92	0.00	0.00
VALLEY+WWAT_213+RO_213	128	9	105.82	0.00	0.00
BVN	128	5	260.05	0.00	0.00

Appendix 1.2.3. Results of model selection for male Blakiston's fish owl at the Sha-Mi River territory, during summer 2009. One model was within 2 ΔAIC_C , but the inclusion of the interactive term did not have statistical support (85% confidence interval overlapped 0). The model chosen for inference is in bold. Null model (BVN) includes parameters mean of x, mean of y, standard deviation of x, standard deviation of y, and correlation. All models (except BVN) include BVN and NEIGH (neighboring owl territories).

<u>Model</u>	<u>n</u>	<u>K</u>	<u>ΔAIC_C</u>	<u>$f(g_j x)$</u>	<u>w</u>
VALLEY+D_WAT+RO_213 +CHAN_213	47	10	0.00	1.00	0.70
VALLEY+D_WAT+RO_213 +CHAN_213+RO*DWAT	47	11	1.70	0.43	0.30
VALLEY+D_WAT+RO_213 +RO*DWAT	47	10	22.31	0.00	0.00
VALLEY+D_WAT+RO_213	47	9	23.48	0.00	0.00
≡ VALLEY+D_WAT	47	8	23.59	0.00	0.00
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213+DISTURB	47	12	25.84	0.00	0.00
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213	47	11	26.07	0.00	0.00
VALLEY+CHAN_213+RO_213	47	9	46.15	0.00	0.00
VALLEY+CHAN_213+RO_213+DEC_213	47	10	47.84	0.00	0.00
VALLEY+WWAT_213+RO_213	47	9	97.13	0.00	0.00
VALLEY+CHAN_213	47	8	115.35	0.00	0.00
VALLEY+D_WWAT+RO_213	47	9	130.95	0.00	0.00
VALLEY+D_WWAT+RO_213+DEC_213	47	10	132.99	0.00	0.00
BVN	47	5	194.75	0.00	0.00

Appendix 1.2.4. Results of model selection for male Blakiston's fish owl at the Sha-Mi River territory, during autumn 2009. Five models were within $2 \Delta AIC_C$, but only the inclusion of RO_213 had statistical support (85% confidence interval did not overlap 0). The model chosen for inference is in bold. Null model (BVN) includes parameters mean of x, mean of y, standard deviation of x, standard deviation of y, and correlation. All models (except BVN) include BVN and NEIGH (neighboring owl territories).

<u>Model</u>	<u>n</u>	<u>K</u>	<u>ΔAIC_C</u>	<u>$f(g x)$</u>	<u>w</u>
VALLEY+D_WAT	28	8	0.00	1.00	0.27
VALLEY+D_WAT+RO_213+CHAN_213	28	10	0.68	0.71	0.19
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213	28	11	0.89	0.64	0.17
VALLEY+D_WAT+RO_213	28	9	1.18	0.55	0.15
VALLEY+D_WAT+RO_213+RO*DWAT	28	10	1.30	0.52	0.14
VALLEY+D_WAT+RO_213+CHAN_213+RO*DWAT	28	11	2.51	0.29	0.08
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213+DISTURB	28	12	7.38	0.02	0.01
VALLEY+WWAT_213+RO_213	28	9	55.82	0.00	0.00
VALLEY+CHAN_213+RO_213+DEC_213	28	10	61.88	0.00	0.00
VALLEY+CHAN_213+RO_213	28	9	62.44	0.00	0.00
VALLEY+CHAN_213	28	8	74.15	0.00	0.00
VALLEY+D_WWAT+RO_213	28	9	75.77	0.00	0.00
VALLEY+D_WWAT+RO_213+DEC_213	28	10	77.84	0.00	0.00
BVN	28	5	130.16	0.00	0.00

Appendix 1.3.1. Results of model selection for female Blakiston's fish owl at the Kudya River territory, during winter 2009. The model chosen for inference is in bold. Null model (BVN) includes parameters mean of x, mean of y, standard deviation of x, standard deviation of y, and correlation. All models (except BVN) include BVN and NEIGH (neighboring owl territories).

<u>Model</u>	<u>n</u>	<u>K</u>	<u>ΔAIC_C</u>	<u>$\mathcal{L}(\mathbf{g}_j \mathbf{x})$</u>	<u>w</u>
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213+DISTURB	192	12	0.00	1.00	0.88
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213	192	11	4.01	0.13	0.12
VALLEY+D_WAT	192	8	44.60	0.00	0.00
VALLEY+D_WAT+RO_213+CHAN_213+RO*DWAT	192	11	44.94	0.00	0.00
VALLEY+D_WAT+RO_213	192	9	46.74	0.00	0.00
VALLEY+WWAT_213+RO_213	192	9	47.29	0.00	0.00
VALLEY+D_WAT+RO_213+RO*DWAT	192	10	47.70	0.00	0.00
VALLEY+D_WAT+RO_213+CHAN_213	192	10	53.40	0.00	0.00
VALLEY+D_WWAT+RO_213+DEC_213	192	10	66.26	0.00	0.00
VALLEY+D_WWAT+RO_213	192	9	66.32	0.00	0.00
VALLEY+CHAN_213	192	8	177.23	0.00	0.00
VALLEY+CHAN_213+RO_213	192	9	178.08	0.00	0.00
VALLEY+CHAN_213+RO_213+DEC_213	192	10	179.68	0.00	0.00
BVN	192	5	208.85	0.00	0.00

Appendix 1.3.2. Results of model selection for female Blakiston's fish owl at the Kudya River territory, during spring 2009. The inclusion of the interaction term in the top model was not well supported (85% confidence interval overlapped 0). The model chosen for inference is in bold. Null model (BVN) includes parameters mean of x, mean of y, standard deviation of x, standard deviation of y, and correlation. All models (except BVN) include BVN and NEIGH (neighboring owl territories).

<u>Model</u>	<u>n</u>	<u>K</u>	<u>ΔAIC_c</u>	<u>$\mathcal{L}(\mathbf{g} \mathbf{x})$</u>	<u>w</u>
VALLEY+D_WAT+RO_213+CHAN_213RO*DWAT	121	11	0.00	1.00	0.54
VALLEY+D_WAT+RO_213+CHAN_213	121	10	0.30	0.86	0.46
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213+DISTURB	121	12	13.38	0.00	0.00
VALLEY+D_WAT	121	8	16.21	0.00	0.00
VALLEY+CHAN_213+RO_213+DEC_213	121	10	16.58	0.00	0.00
VALLEY+D_WAT+RO_213+RO*DWAT	121	10	16.70	0.00	0.00
VALLEY+D_WAT+RO_213	121	9	17.27	0.00	0.00
VALLEY+CHAN_213+RO_213	121	9	18.16	0.00	0.00
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213	121	11	20.49	0.00	0.00
VALLEY+CHAN_213	121	8	22.94	0.00	0.00
VALLEY+D_WWAT+RO_213+DEC_213	121	10	32.19	0.00	0.00
VALLEY+D_WWAT+RO_213	121	9	48.99	0.00	0.00
VALLEY+WWAT_213+RO_213	121	9	77.12	0.00	0.00
BVN	121	5	119.22	0.00	0.00

Appendix 1.3.3. Results of model selection for female Blakiston's fish owl at the Kudya River territory, during summer 2009. The inclusion of DEC_213 (deciduous forest) in the top model was not well supported (85% confidence interval overlapped 0). The model chosen for inference is in bold. Null model (BVN) includes parameters mean of x, mean of y, standard deviation of x, standard deviation of y, and correlation. All models (except BVN) include BVN and NEIGH (neighboring owl territories).

<u>Model</u>	<u>n</u>	<u>K</u>	<u>ΔAIC_C</u>	<u>$\xi(g_i x)$</u>	<u>w</u>
VALLEY+D_WWAT+RO_213+DEC_213	119	10	0.00	1.00	0.51
VALLEY+D_WWAT+RO_213	119	9	0.41	0.81	0.41
VALLEY+D_WAT+RO_213+RO*DWAT	119	10	3.85	0.15	0.07
VALLEY+D_WAT+RO_213+CHAN_213	119	10	14.35	0.00	0.00
VALLEY+D_WAT+RO_213+CHAN_213+RO*DWAT	119	11	16.37	0.00	0.00
115 VALLEY+D_WAT+RO_213+DEC_213+OPEN_213	119	11	16.57	0.00	0.00
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213+DISTURB	119	12	18.25	0.00	0.00
VALLEY+D_WAT	119	8	20.56	0.00	0.00
VALLEY+D_WAT+RO_213	119	9	22.41	0.00	0.00
VALLEY+WWAT_213+RO_213	119	9	47.85	0.00	0.00
VALLEY+CHAN_213+RO_213	119	9	83.63	0.00	0.00
VALLEY+CHAN_213+RO_213+DEC_213	119	10	84.73	0.00	0.00
VALLEY+CHAN_213	119	8	86.54	0.00	0.00
BVN	119	5	200.01	0.00	0.00

Appendix 1.3.4. Results of model selection for female Blakiston's fish owl at the Kudya River territory, during autumn 2009. The inclusion of DISTURB (human disturbance) in the top model was not well supported (85% confidence interval overlapped 0). The model chosen for inference is in bold. Null model (BVN) includes parameters mean of x, mean of y, standard deviation of x, standard deviation of y, and correlation. All models (except BVN) include BVN and NEIGH (neighboring owl territories).

<u>Model</u>	<u>n</u>	<u>K</u>	<u>ΔAIC_C</u>	<u>$\xi(g_i x)$</u>	<u>w</u>
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213	102	11	0.00	1.00	0.58
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213+DISTURB	102	12	0.63	0.73	0.42
VALLEY+D_WAT+RO_213+CHAN_213+RO*DWAT	102	11	24.87	0.00	0.00
VALLEY+D_WAT	102	8	41.99	0.00	0.00
VALLEY+D_WWAT+RO_213+DEC_213	102	10	43.83	0.00	0.00
VALLEY+D_WAT+RO_213	102	9	51.62	0.00	0.00
VALLEY+D_WAT+RO_213+RO*DWAT	102	10	53.48	0.00	0.00
VALLEY+D_WWAT+RO_213	102	9	56.33	0.00	0.00
VALLEY+WWAT_213+RO_213	102	10	116.31	0.00	0.00
VALLEY+D_WAT+RO_213+CHAN_213	102	10	92.11	0.00	0.00
VALLEY+CHAN_213+RO_213+DEC_213	102	10	220.86	0.00	0.00
VALLEY+CHAN_213	102	8	222.74	0.00	0.00
VALLEY+CHAN_213+RO_213	102	9	224.95	0.00	0.00
BVN	102	5	257.34	0.00	0.00

Appendix 1.4.1. Results of model selection for male Blakiston's fish owl at the Kudya River territory, during spring 2009. Although two models were within $2 \Delta AIC_C$, the inclusion of the additional terms were not well supported (85% confidence interval overlapped 0). The model chosen for inference is in bold. Null model (BVN) includes parameters mean of x, mean of y, standard deviation of x, standard deviation of y, and correlation. All models (except BVN) include BVN and NEIGH (neighboring owl territories).

<u>Model</u>	<u>n</u>	<u>K</u>	<u>ΔAIC_C</u>	<u>$f(g_j x)$</u>	<u>w</u>
VALLEY+D_WAT	52	8	0.00	1.00	0.30
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213	52	11	0.77	0.68	0.21
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213+DISTURB	52	12	0.88	0.64	0.20
VALLEY+D_WAT+RO_213+RO*DWAT	52	10	1.46	0.48	0.15
VALLEY+D_WAT+RO_213	52	9	1.90	0.39	0.12
VALLEY+D_WAT+RO_213+CHAN_213+RO*DWAT	52	11	5.19	0.07	0.02
VALLEY+D_WAT+RO_213+CHAN_213	52	10	8.27	0.02	0.00
VALLEY+WWAT_213+RO_213	52	9	13.40	0.00	0.00
VALLEY+CHAN_213	52	8	23.39	0.00	0.00
VALLEY+CHAN_213+RO_213	52	9	25.24	0.00	0.00
VALLEY+CHAN_213+RO_213+DEC_213	52	10	26.92	0.00	0.00
VALLEY+D_WWAT+RO_213	52	9	27.17	0.00	0.00
BVN	52	5	29.03	0.00	0.00
VALLEY+D_WWAT+RO_213+DEC_213	52	10	29.05	0.00	0.00

Appendix 1.5.1. Results of model selection for male Blakiston's fish owl at the Saiyon River territory, during spring 2009. The model chosen for inference is in bold. Null model (BVN) includes parameters mean of x, mean of y, standard deviation of x, standard deviation of y, and correlation. All models (except BVN) include BVN and NEIGH (neighboring owl territories).

<u>Model</u>	<u>n</u>	<u>K</u>	<u>ΔAIC_C</u>	<u>$\mathcal{L}(\mathbf{g}_i \mathbf{x})$</u>	<u>w</u>
VALLEY+D_WAT+RO_213+CHAN_213	62	10	0.00	1.00	0.92
VALLEY+D_WAT+RO_213+CHAN_213+RO*DWAT	62	11	4.80	0.09	0.08
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213+DISTURB	62	12	14.26	0.00	0.00
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213	62	11	18.27	0.00	0.00
VALLEY+CHAN_213+RO_213+DEC_213	62	10	55.61	0.00	0.00
VALLEY+CHAN_213	62	8	60.21	0.00	0.00
VALLEY+CHAN_213+RO_213	62	9	60.74	0.00	0.00
VALLEY+D_WAT+RO_213	62	9	84.26	0.00	0.00
VALLEY+D_WAT	62	8	88.58	0.00	0.00
VALLEY+D_WAT+RO_213+RO*DWAT	62	10	104.36	0.00	0.00
VALLEY+WWAT_213+RO_213	62	9	111.35	0.00	0.00
VALLEY+D_WWAT+RO_213	62	9	123.46	0.00	0.00
VALLEY+D_WWAT+RO_213+DEC_213	62	10	125.11	0.00	0.00
BVN	62	5	207.83	0.00	0.00

Appendix 1.5.2. Results of model selection for male Blakiston's fish owl at the Saiyon River territory, during summer 2009. The model chosen for inference is in bold. Null model (BVN) includes parameters mean of x, mean of y, standard deviation of x, standard deviation of y, and correlation. All models (except BVN) include BVN and NEIGH (neighboring owl territories).

<u>Model</u>	<u>n</u>	<u>K</u>	<u>ΔAIC_C</u>	<u>$f(g x)$</u>	<u>w</u>
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213	89	11	0.00	1.00	1.00
VALLEY+D_WAT+RO_213	89	9	42.93	0.00	0.00
VALLEY+D_WAT+RO_213+CHAN_213+RO*DWAT	89	11	45.13	0.00	0.00
VALLEY+D_WAT+RO_213+CHAN_213	89	10	45.16	0.00	0.00
VALLEY+D_WAT	89	8	46.40	0.00	0.00
VALLEY+D_WAT+RO_213+RO*DWAT	89	10	47.35	0.00	0.00
VALLEY+D_WWAT+RO_213	89	9	54.09	0.00	0.00
VALLEY+D_WWAT+RO_213+DEC_213	89	10	54.40	0.00	0.00
VALLEY+CHAN_213+RO_213+DEC_213	89	10	99.26	0.00	0.00
VALLEY+CHAN_213+RO_213	89	9	99.28	0.00	0.00
VALLEY+WWAT_213+RO_213	89	9	106.63	0.00	0.00
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213+DISTURB	89	12	106.84	0.00	0.00
VALLEY+CHAN_213	89	8	114.22	0.00	0.00
BVN	89	5	250.57	0.00	0.00

Appendix 1.6.1. Results of model selection for male Blakiston's fish owl at the Serebyanka River territory, during spring 2009. Two models were within $2 \Delta AIC_C$. Although the inclusion of RO_213 (riparian old-growth) was not well supported, the inclusion of D_WAT (distance to water) was (85% confidence interval overlapped 0). The model chosen for inference is in bold. Null model (BVN) includes parameters mean of x, mean of y, standard deviation of x, standard deviation of y, and correlation. All models (except BVN) include BVN and NEIGH (neighboring owl territories).

Model	<i>n</i>	<i>K</i>	ΔAIC_C	$\underline{f}(g_i x)$	<i>w</i>
VALLEY+CHAN_213	57	8	0.00	1.00	0.34
VALLEY+D_WAT+RO_213+CHAN_213	57	10	0.22	0.89	0.31
VALLEY+CHAN_213+RO_213	57	9	1.13	0.57	0.20
VALLEY+CHAN_213+RO_213+DEC_213	57	10	2.59	0.27	0.09
120 VALLEY+D_WAT+RO_213+CHAN_213+RO*DWAT	57	11	3.64	0.16	0.06
VALLEY+D_WWAT+RO_213+DEC_213	57	10	11.07	0.00	0.00
VALLEY+D_WWAT+RO_213	57	9	11.35	0.00	0.00
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213	57	11	21.01	0.00	0.00
VALLEY+D_WAT	57	8	22.83	0.00	0.00
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213+DISTURB	57	12	22.98	0.00	0.00
VALLEY+WWAT_213+RO_213	57	9	24.14	0.00	0.00
BVN	57	5	24.45	0.00	0.00
VALLEY+D_WAT+RO_213	57	9	24.97	0.00	0.00
VALLEY+D_WAT+RO_213+RO*DWAT	57	10	29.19	0.00	0.00

Appendix 1.6.2. Results of model selection for male Blakiston's fish owl at the Serebyanka River territory, during summer 2009.

One model was within 2 ΔAIC_C , but the inclusion of the interactive term was not well supported (85% confidence interval overlapped 0). The model chosen for inference is in bold. Null model (BVN) includes parameters mean of x, mean of y, standard deviation of x, standard deviation of y, and correlation. All models (except BVN) include BVN and NEIGH (neighboring owl territories).

<u>Model</u>	<u>n</u>	<u>K</u>	<u>ΔAIC_C</u>	<u>$f(g_j x)$</u>	<u>w</u>
VALLEY+D_WAT+RO_213+CHAN_213	47	10	0.00	1.00	0.63
VALLEY+D_WAT+RO_213+CHAN_213+RO*DWAT	47	11	1.30	0.52	0.33
VALLEY+CHAN_213	47	8	7.76	0.02	0.01
VALLEY+D_WAT	47	8	7.86	0.02	0.01
VALLEY+D_WAT+RO_213	47	9	9.67	0.01	0.01
VALLEY+CHAN_213+RO_213	47	9	9.71	0.01	0.00
VALLEY+CHAN_213+RO_213+DEC_213	47	10	11.02	0.00	0.00
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213	47	11	12.63	0.00	0.00
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213+DISTURB	47	12	14.54	0.00	0.00
VALLEY+D_WAT+RO_213+RO*DWAT	47	10	22.26	0.00	0.00
VALLEY+D_WWAT+RO_213+DEC_213	47	10	86.71	0.00	0.00
VALLEY+D_WWAT+RO_213	47	9	86.92	0.00	0.00
VALLEY+WWAT_213+RO_213	47	9	88.78	0.00	0.00
BVN	47	5	139.74	0.00	0.00

Appendix 1.6.3. Results of model selection for male Blakiston's fish owl at the Serebyanka River territory, during autumn 2009. The model chosen for inference is in bold. Null model (BVN) includes parameters mean of x, mean of y, standard deviation of x, standard deviation of y, and correlation. All models (except BVN) include BVN and NEIGH (neighboring owl territories).

<u>Model</u>	<u>n</u>	<u>K</u>	<u>ΔAIC_C</u>	<u>$f(g x)$</u>	<u>w</u>
VALLEY+D_WAT+RO_213+CHAN_213	60	10	0.00	1.00	0.78
VALLEY+D_WAT+RO_213+CHAN_213+RO*DWAT	60	11	2.53	0.28	0.22
VALLEY+D_WAT+RO_213	60	9	18.07	0.00	0.00
VALLEY+D_WAT_RO_213+RO*DWAT	60	10	20.89	0.00	0.00
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213	60	11	21.81	0.00	0.00
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213+DISTURB	60	12	23.81	0.00	0.00
VALLEY+D_WAT	60	8	30.79	0.00	0.00
VALLEY+CHAN_213+RO_213	60	9	42.26	0.00	0.00
VALLEY+CHAN_213+RO_213+DEC_213	60	10	43.13	0.00	0.00
VALLEY+CHAN_213	60	8	49.58	0.00	0.00
VALLEY+D_WWAT+RO_213	60	9	92.25	0.00	0.00
VALLEY+D_WWAT+RO_213+DEC_213	60	10	92.36	0.00	0.00
VALLEY+WWAT_213+RO_213	60	9	138.21	0.00	0.00
BVN	60	5	218.05	0.00	0.00

Appendix 1.7.1. Results of model selection for male Blakiston's fish owl at the Faata River territory, during spring 2009. Although one model was within 2 ΔAIC_C , the inclusion of the interaction term was not well supported (85% confidence interval overlapped 0). The model chosen for inference is in bold. Null model (BVN) includes parameters mean of x, mean of y, standard deviation of x, standard deviation of y, and correlation. All models (except BVN) include BVN and NEIGH (neighboring owl territories).

<u>Model</u>	<u>n</u>	<u>K</u>	<u>ΔAIC_C</u>	<u>$f(g_j x)$</u>	<u>w</u>
VALLEY+D_WAT+RO_213+CHAN_213	38	10	0.00	1.00	0.50
VALLEY+D_WAT+RO_213+CHAN_213+RO*DWAT	38	11	0.45	0.80	0.40
VALLEY+CHAN_213+RO_213	38	9	5.10	0.08	0.04
VALLEY+CHAN_213	38	8	5.35	0.07	0.03
VALLEY+CHAN_213+RO_213+DEC_213	38	10	6.39	0.04	0.02
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213+DISTURB	38	12	11.42	0.00	0.00
VALLEY+D_WAT	38	8	21.67	0.00	0.00
VALLEY+D_WAT+RO_213	38	9	22.32	0.00	0.00
VALLEY+D_WAT+RO_213+RO*DWAT	38	10	23.12	0.00	0.00
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213	38	11	25.96	0.00	0.00
VALLEY+D_WWAT+RO_213	38	9	50.57	0.00	0.00
VALLEY+D_WWAT+RO_213+DEC_213	38	10	52.61	0.00	0.00
VALLEY+WWAT_213+RO_213	38	10	62.98	0.00	0.00
BVN	38	5	126.04	0.00	0.00

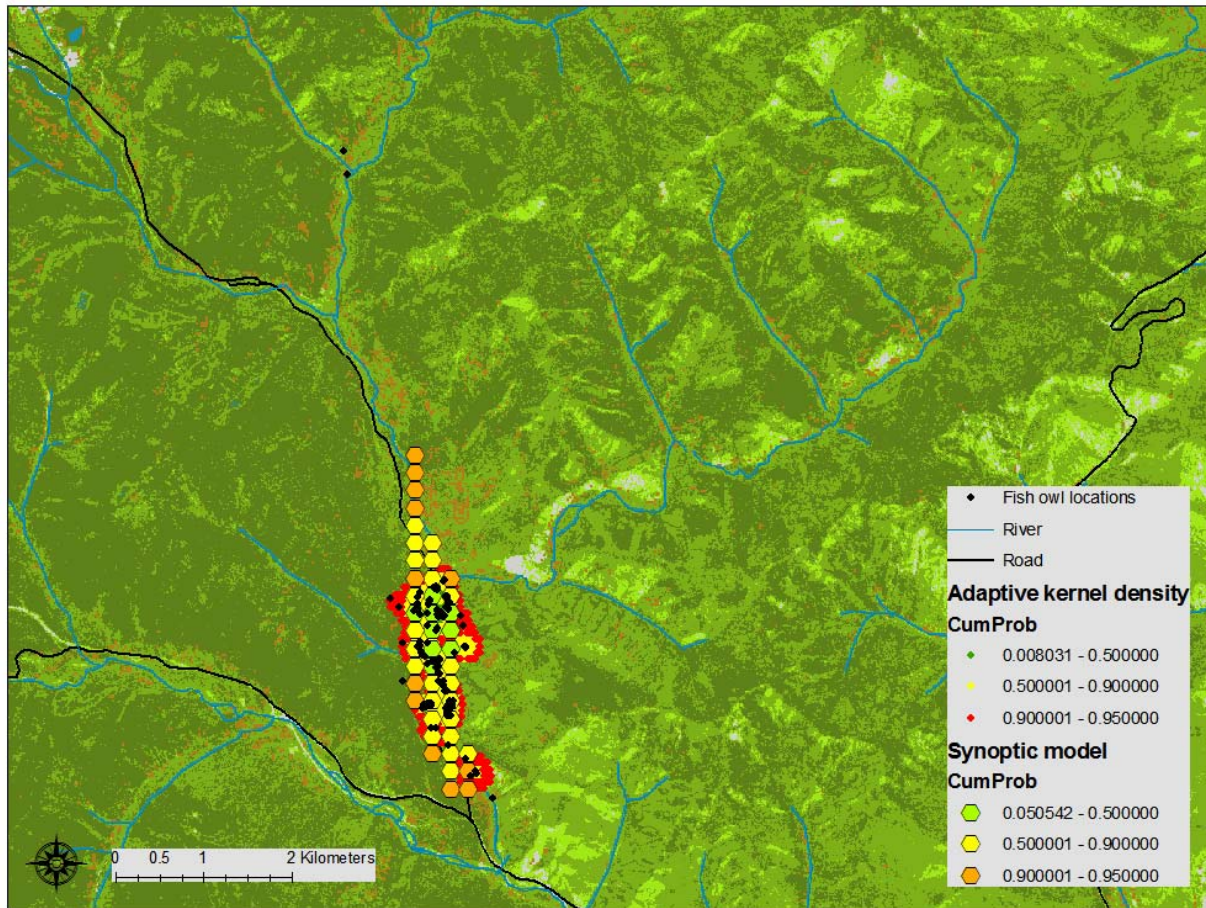
Appendix 1.7.2. Results of model selection for male Blakiston’s fish owl at the Faata River territory, during summer 2009. The model chosen for inference is in bold. Null model (BVN) includes parameters mean of x, mean of y, standard deviation of x, standard deviation of y, and correlation. All models (except BVN) include BVN and NEIGH (neighboring owl territories).

<u>Model</u>	<u>n</u>	<u>K</u>	<u>ΔAIC_C</u>	<u>$\xi(g_j x)$</u>	<u>w</u>
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213+DISTURB	67	12	0.00	1.00	0.91
VALLEY+D_WAT+RO_213+CHAN_213	67	10	5.09	0.08	0.07
VALLEY+D_WAT+RO_213+CHAN_213+RO*DWAT	67	11	7.58	0.02	0.02
VALLEY+D_WAT+RO_213+RO*DWAT	67	10	50.93	0.00	0.00
VALLEY+D_WAT+RO_213	67	9	55.21	0.00	0.00
VALLEY+D_WAT	67	8	60.65	0.00	0.00
VALLEY+CHAN_213+RO_213+DEC_213	67	10	63.14	0.00	0.00
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213	67	11	63.97	0.00	0.00
VALLEY+CHAN_213+RO_213	67	9	65.96	0.00	0.00
VALLEY+CHAN_213	67	8	69.68	0.00	0.00
VALLEY+D_WWAT+RO_213+DEC_213	67	10	117.53	0.00	0.00
VALLEY+D_WWAT+RO_213	67	9	118.23	0.00	0.00
VALLEY+WWAT_213+RO_213	67	9	221.80	0.00	0.00
BVN	67	5	326.20	0.00	0.00

Appendix 1.7.3. Results of model selection for male Blakiston's fish owl at the Faata River territory, during autumn 2009. Although one model was within 2 ΔAIC_C , the inclusion of the interaction term was not well supported (85% confidence interval overlapped 0). The model chosen for inference is in bold. Null model (BVN) includes parameters mean of x, mean of y, standard deviation of x, standard deviation of y, and correlation. All models (except BVN) include BVN and NEIGH (neighboring owl territories).

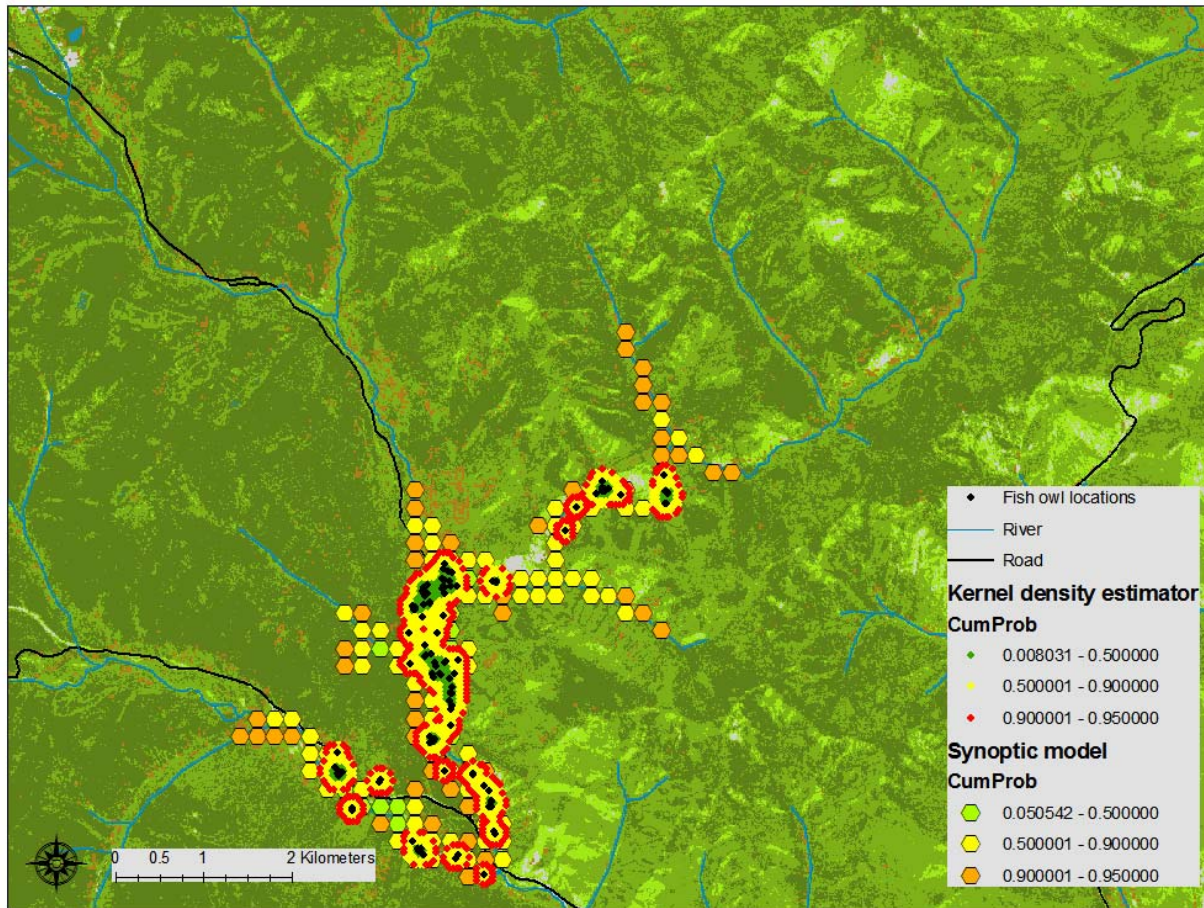
<u>Model</u>	<u>n</u>	<u>K</u>	<u>ΔAIC_C</u>	<u>$f(g_j x)$</u>	<u>w</u>
VALLEY+D_WAT+RO_213+CHAN_213	35	10	0.00	1.00	0.37
VALLEY+D_WAT+RO_213+CHAN_213+RO*DWAT	35	11	0.44	0.80	0.30
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213	35	11	2.52	0.28	0.10
VALLEY+D_WAT+RO_213+DEC_213+OPEN_213+DISTURB	35	12	2.59	0.27	0.10
VALLEY+D_WAT	35	8	3.07	0.22	0.08
VALLEY+D_WAT+RO_213	35	9	4.31	0.12	0.04
VALLEY+D_WAT+RO_213+RO*DWAT	35	10	6.93	0.03	0.01
VALLEY+CHAN_213+RO_213+DEC_213	35	10	15.57	0.00	0.00
VALLEY+CHAN_213	35	8	16.11	0.00	0.00
VALLEY+CHAN_213+RO_213	35	9	17.42	0.00	0.00
VALLEY+D_WWAT+RO_213+DEC_213	35	10	46.10	0.00	0.00
VALLEY+D_WWAT+RO_213	35	9	46.38	0.00	0.00
VALLEY+WWAT_213+RO_213	35	9	54.77	0.00	0.00
BVN	35	5	121.87	0.00	0.00

Appendix 2.1.1. Winter home range of a female Blakiston's fish owl at the Sha-Mi River in Primorye, Russia, 2009. Large hexagons are estimates using the synoptic model, and small colored circles are estimates from a kernel density estimator. Black circles are fish owl GPS locations used to develop the models.

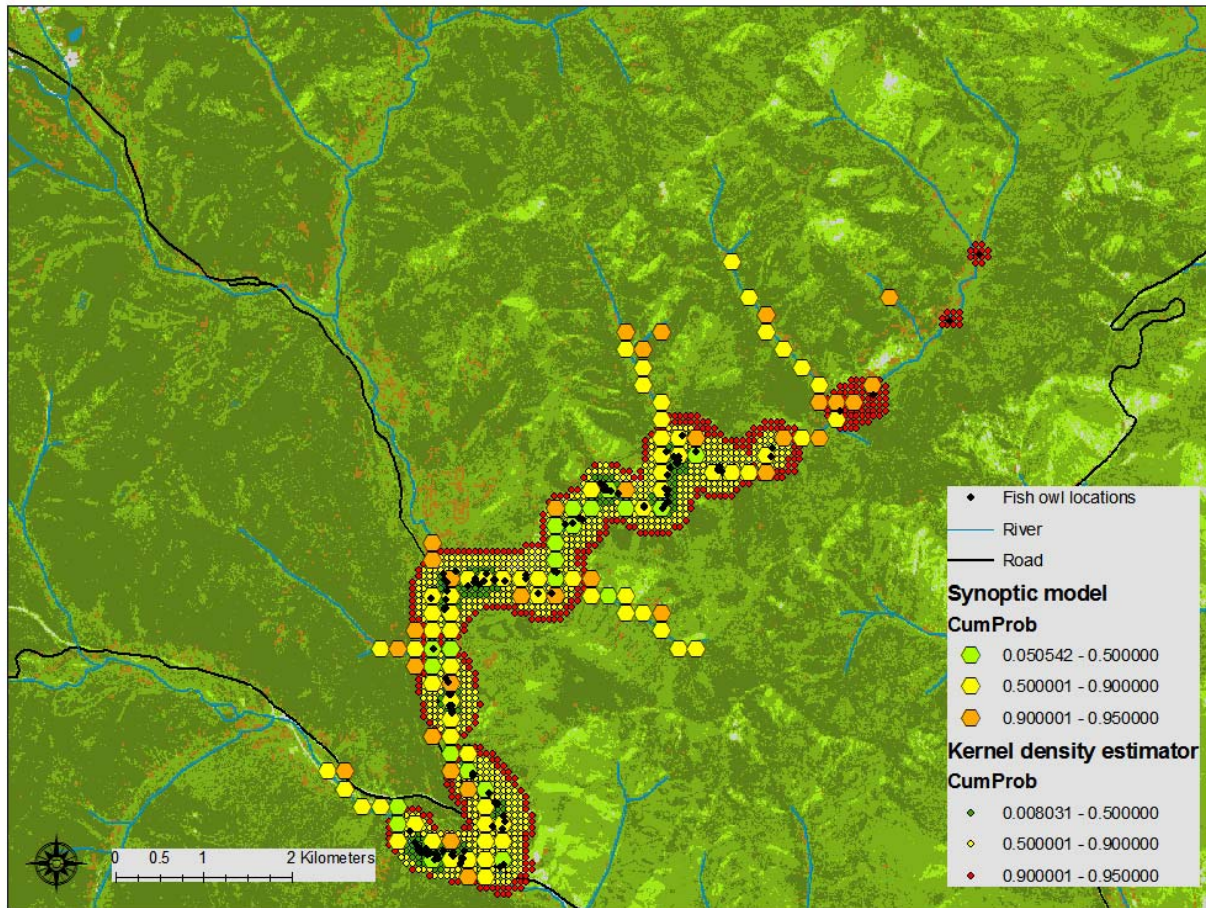


Appendix 2.1.2. Spring home range of a female Blakiston's fish owl at the Sha-Mi River in Primorye, Russia, 2009. Large hexagons are estimates using the synoptic model, and small colored circles are estimates from a kernel density estimator. Black circles are fish owl GPS locations used to develop the models.

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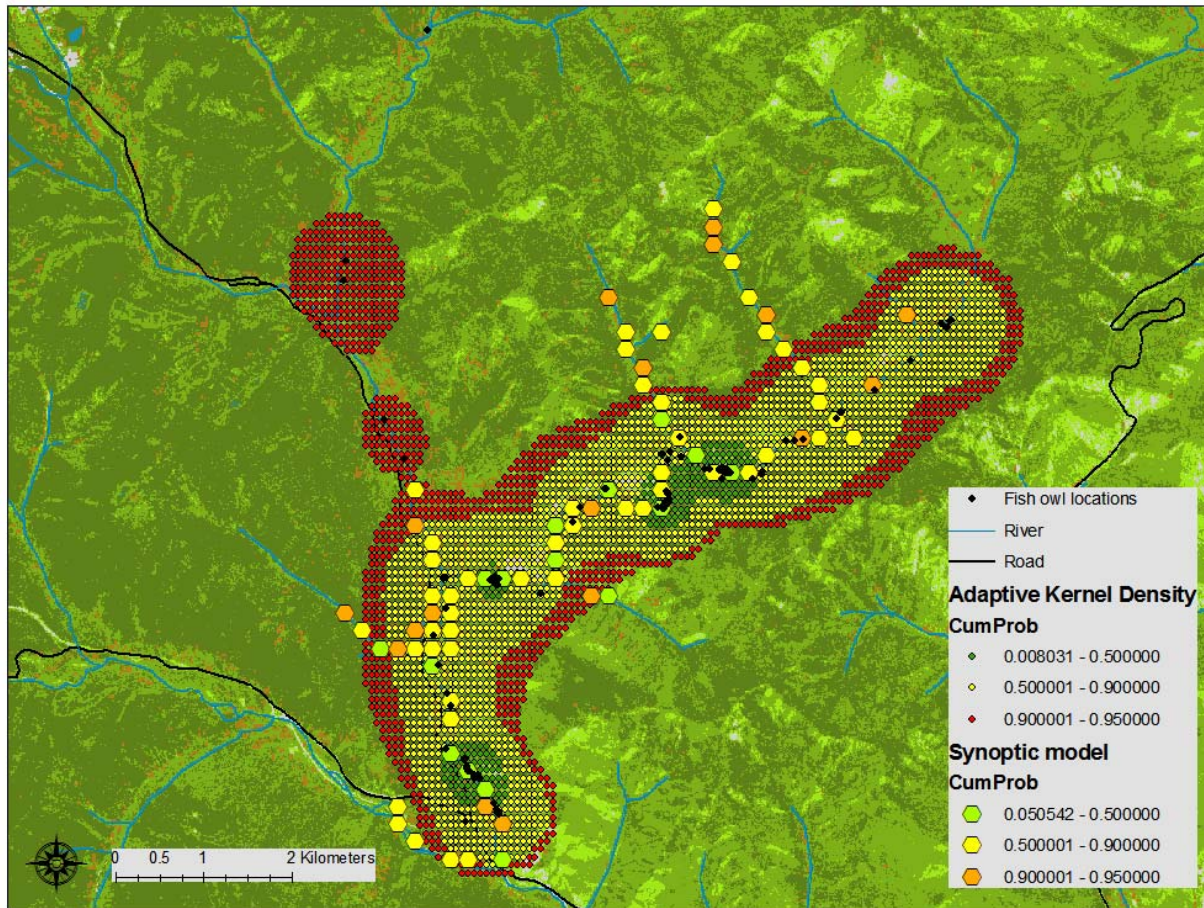


Appendix 2.1.3. Summer home range of a female Blakiston's fish owl at the Sha-Mi River in Primorye, Russia, 2009. Large hexagons are estimates using the synoptic model, and small colored circles are estimates from a kernel density estimator. Black circles are fish owl GPS locations used to develop the models.



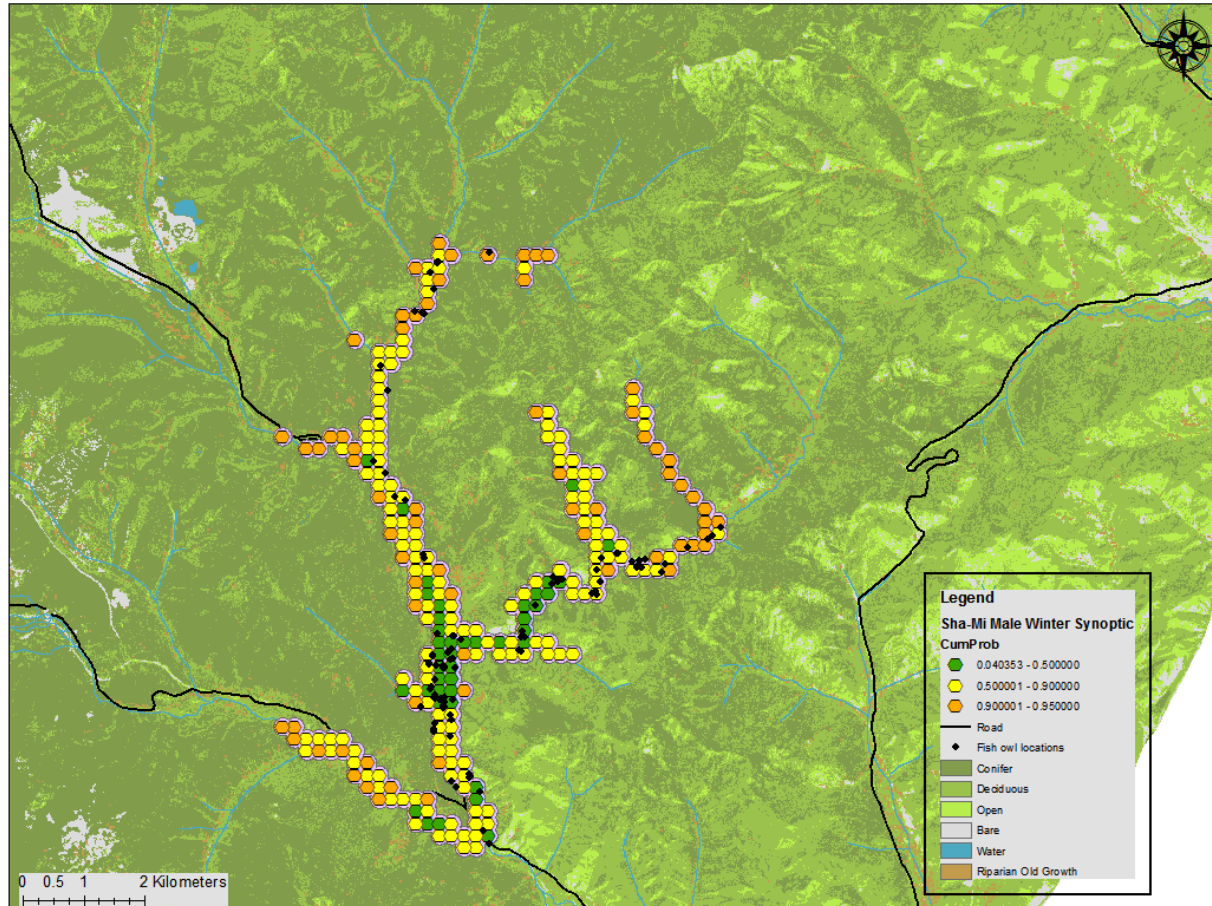
Appendix 2.1.4. Autumn home range of a female Blakiston's fish owl at the Sha-Mi River in Primorye, Russia, 2009. Large hexagons are estimates using the synoptic model, and small colored circles are estimates from a kernel density estimator. Black circles are fish owl GPS locations used to develop the models.

129



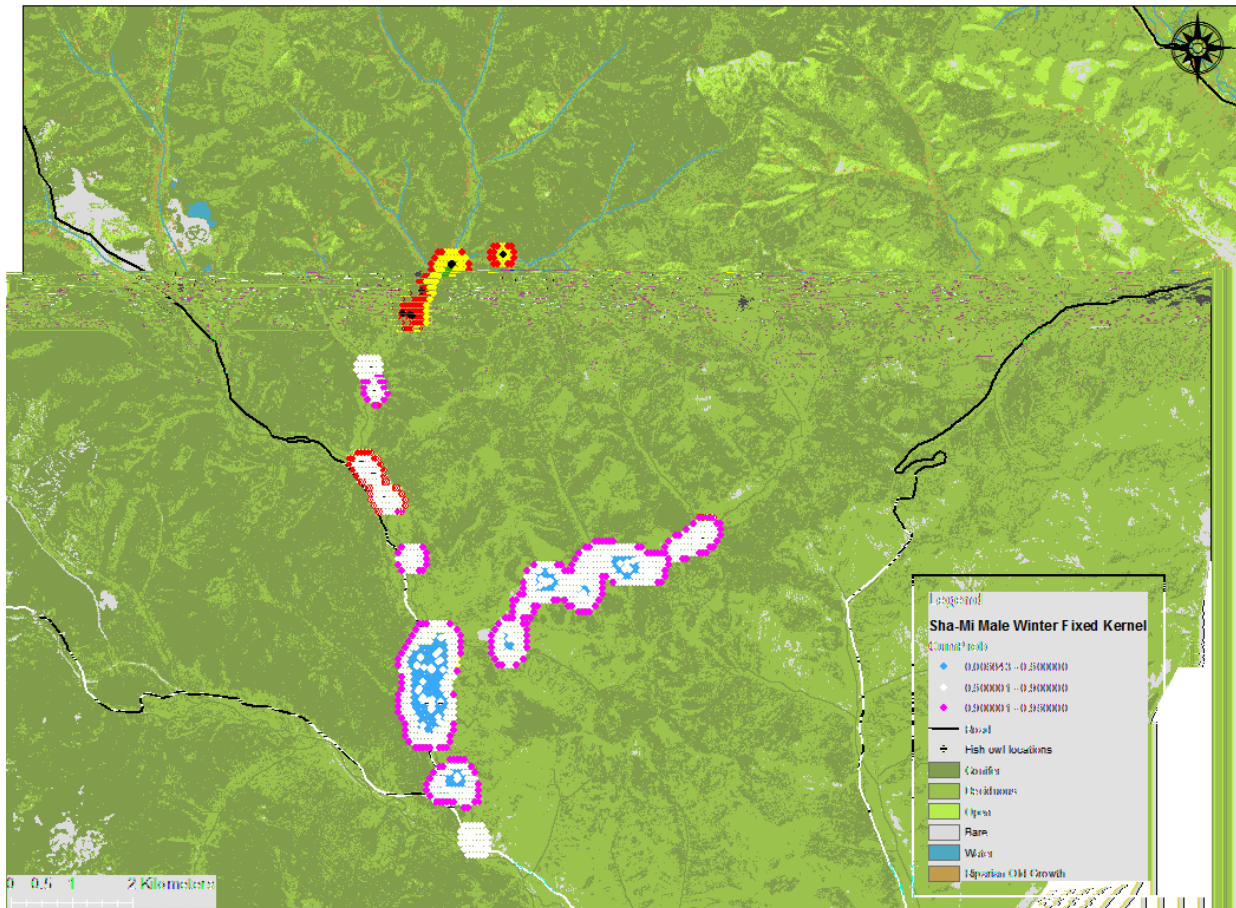
Appendix 2.2.1.1. Winter home range of a male Blakiston's fish owl at the Sha-Mi River in Primorye, Russia, 2009, using the synoptic model. Black circles are fish owl GPS locations used to develop the models.

130



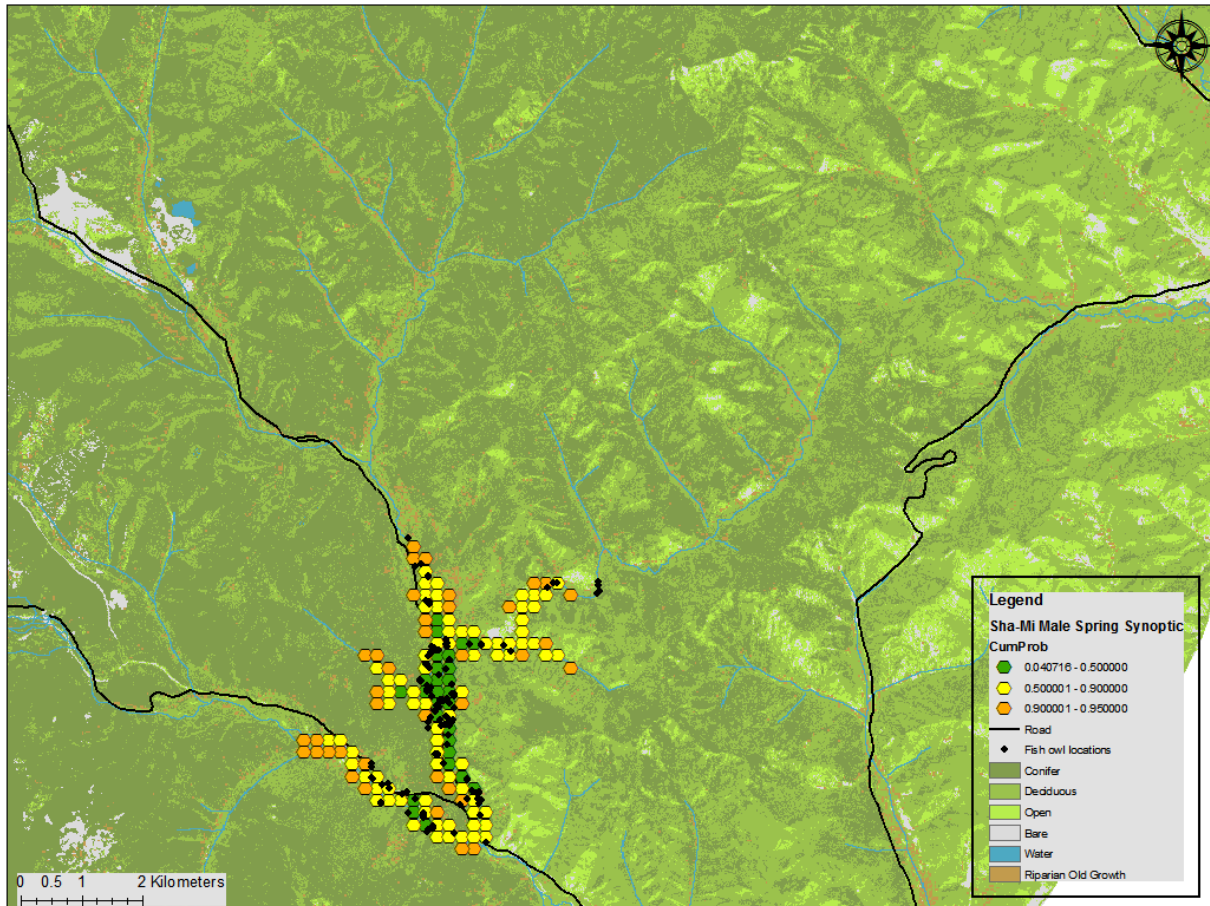
Appendix 2.2.1.2. Winter home range of a male Blakiston's fish owl at the Sha-Mi River in Primorye, Russia, 2009, using a kernel density estimator. Black circles are fish owl GPS locations used to develop the models.

131



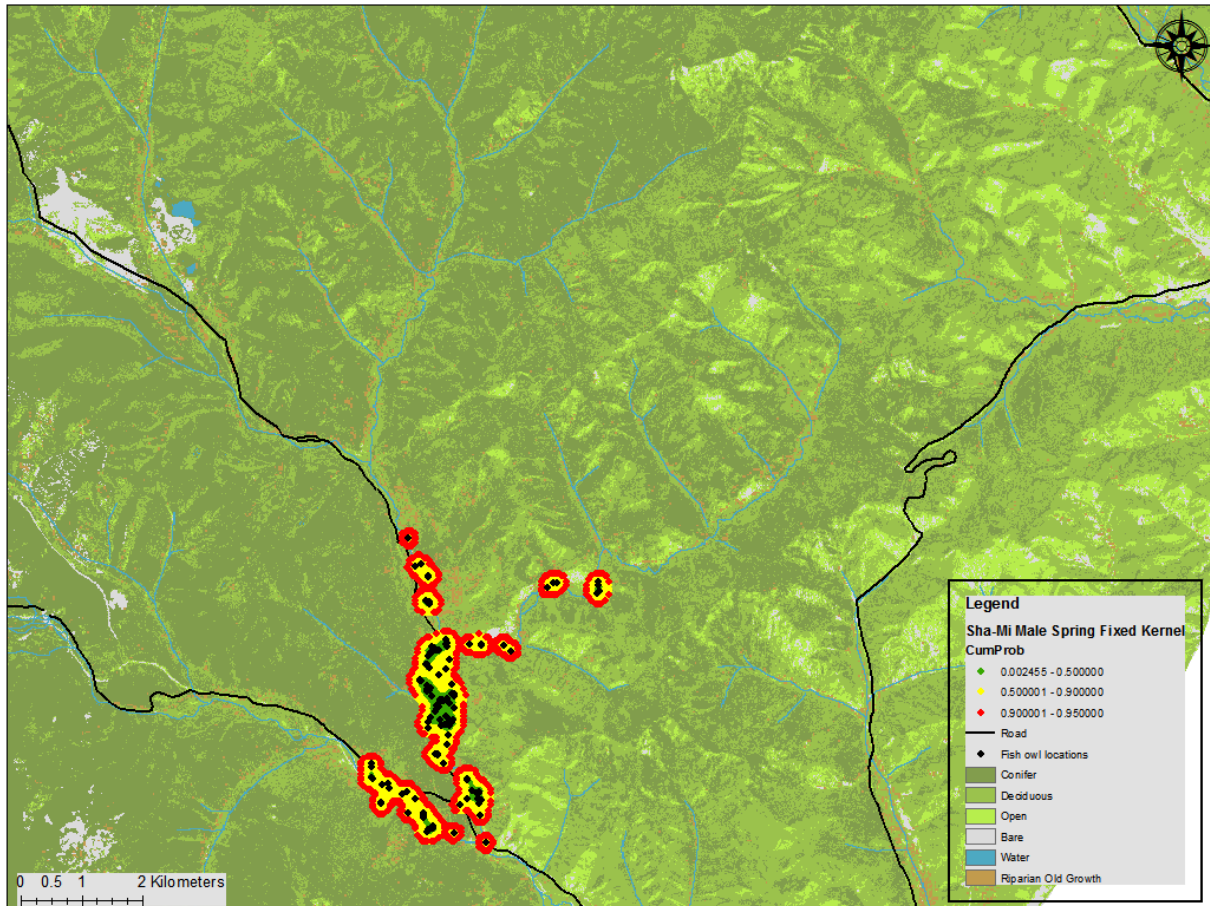
Appendix 2.2.2.1. Spring home range of a male Blakiston's fish owl at the Sha-Mi River in Primorye, Russia, 2009, using the synoptic model. Black circles are fish owl GPS locations used to develop the models.

132



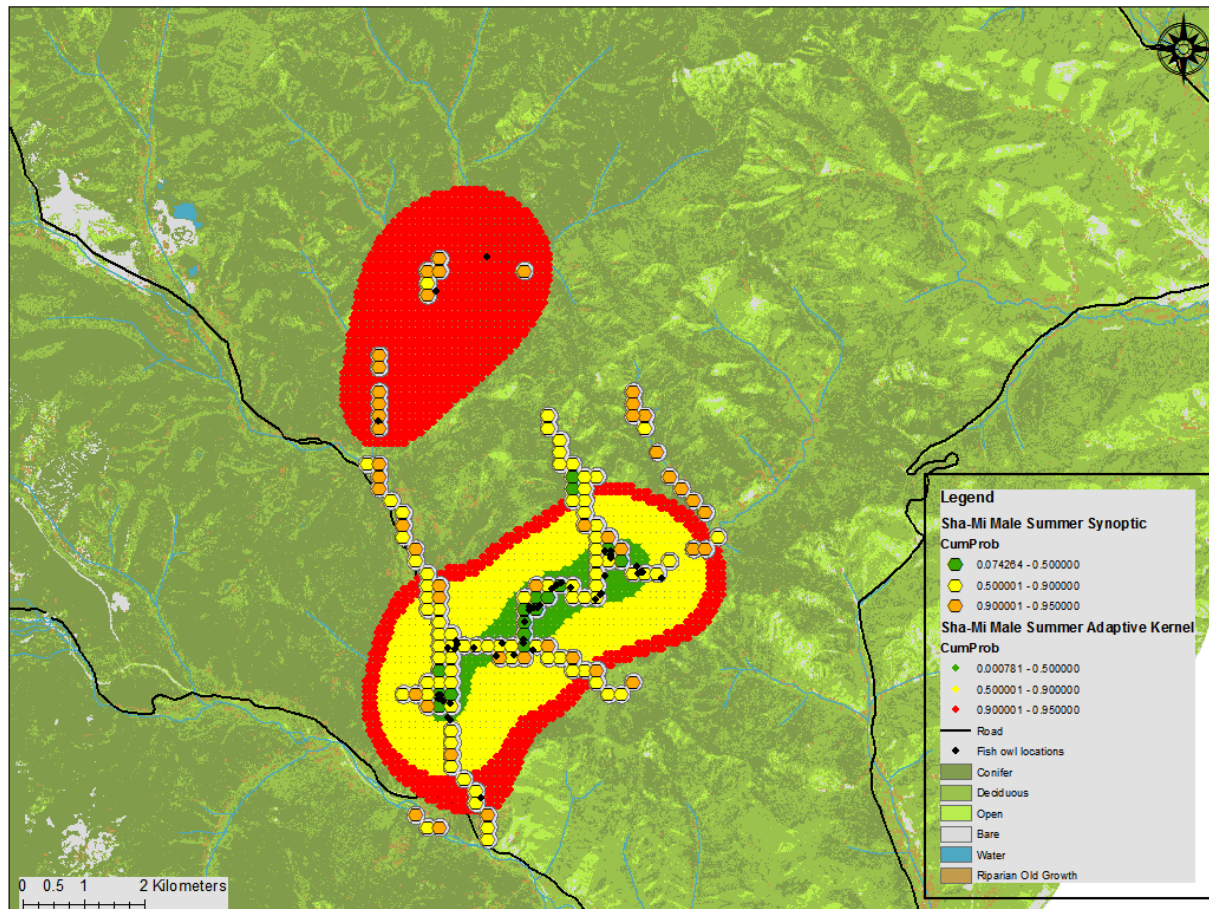
Appendix 2.2.2.2. Spring home range of a male Blakiston's fish owl at the Sha-Mi River in Primorye, Russia, 2009, using a kernel density estimator. Black circles are fish owl GPS locations used to develop the models.

133



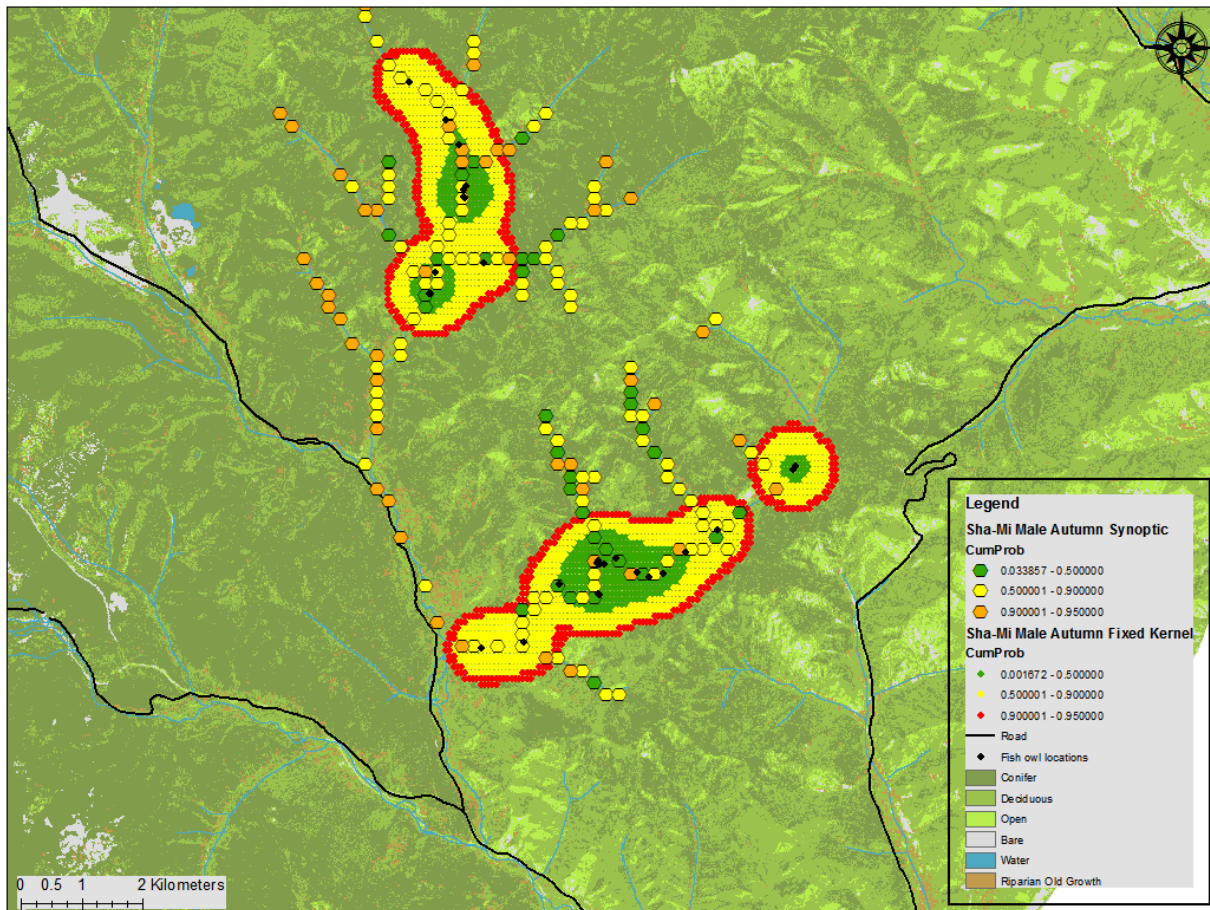
Appendix 2.2.3. Summer home range of a male Blakiston's fish owl at the Sha-Mi River in Primorye, Russia, 2009. Large hexagons are estimates using the synoptic model, and small colored circles are estimates from a kernel density estimator. Black circles are fish owl GPS locations used to develop the models.

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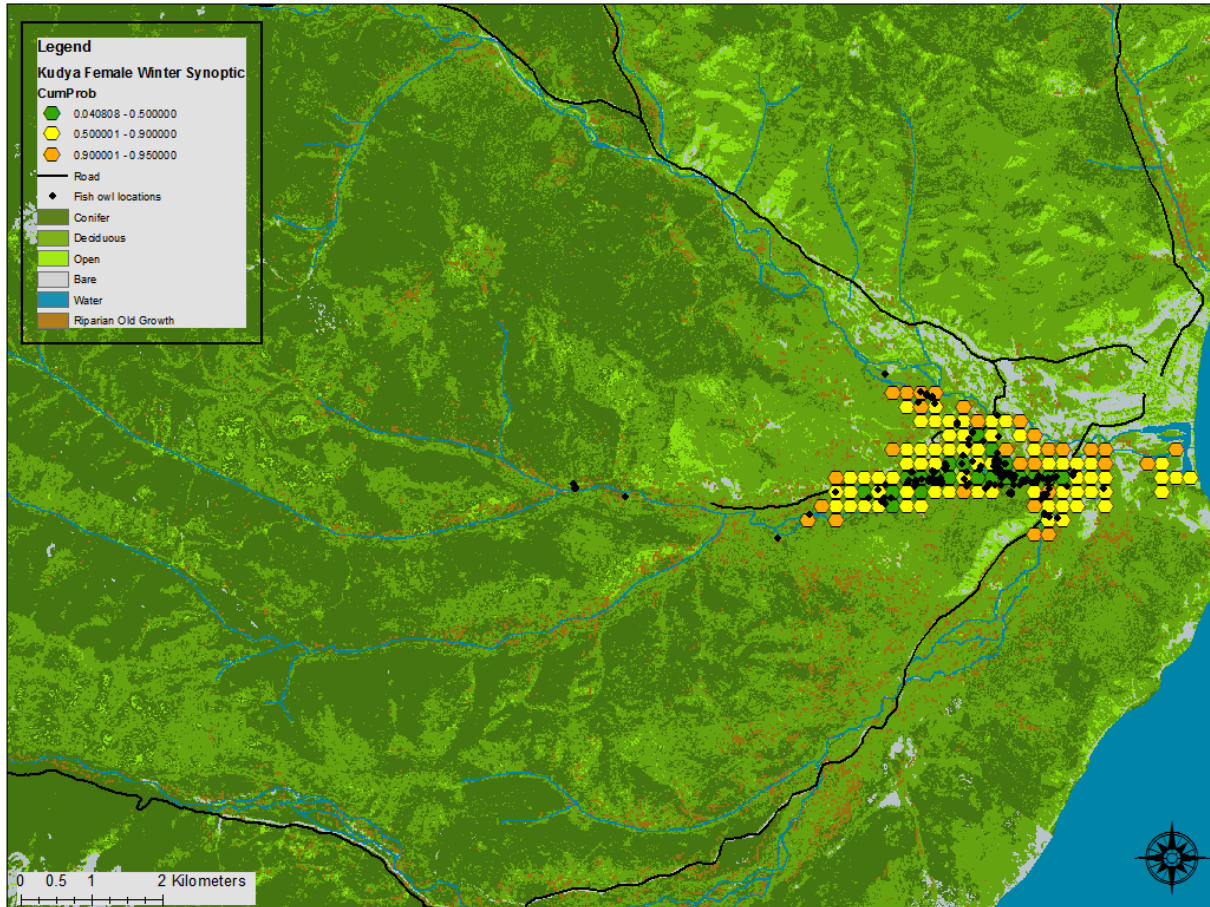


Appendix 2.2.4. Autumn home range of a male Blakiston's fish owl at the Sha-Mi River in Primorye, Russia, 2009. Large hexagons are estimates using the synoptic model, and small colored circles are estimates from a kernel density estimator. Black circles are fish owl GPS locations used to develop the models.

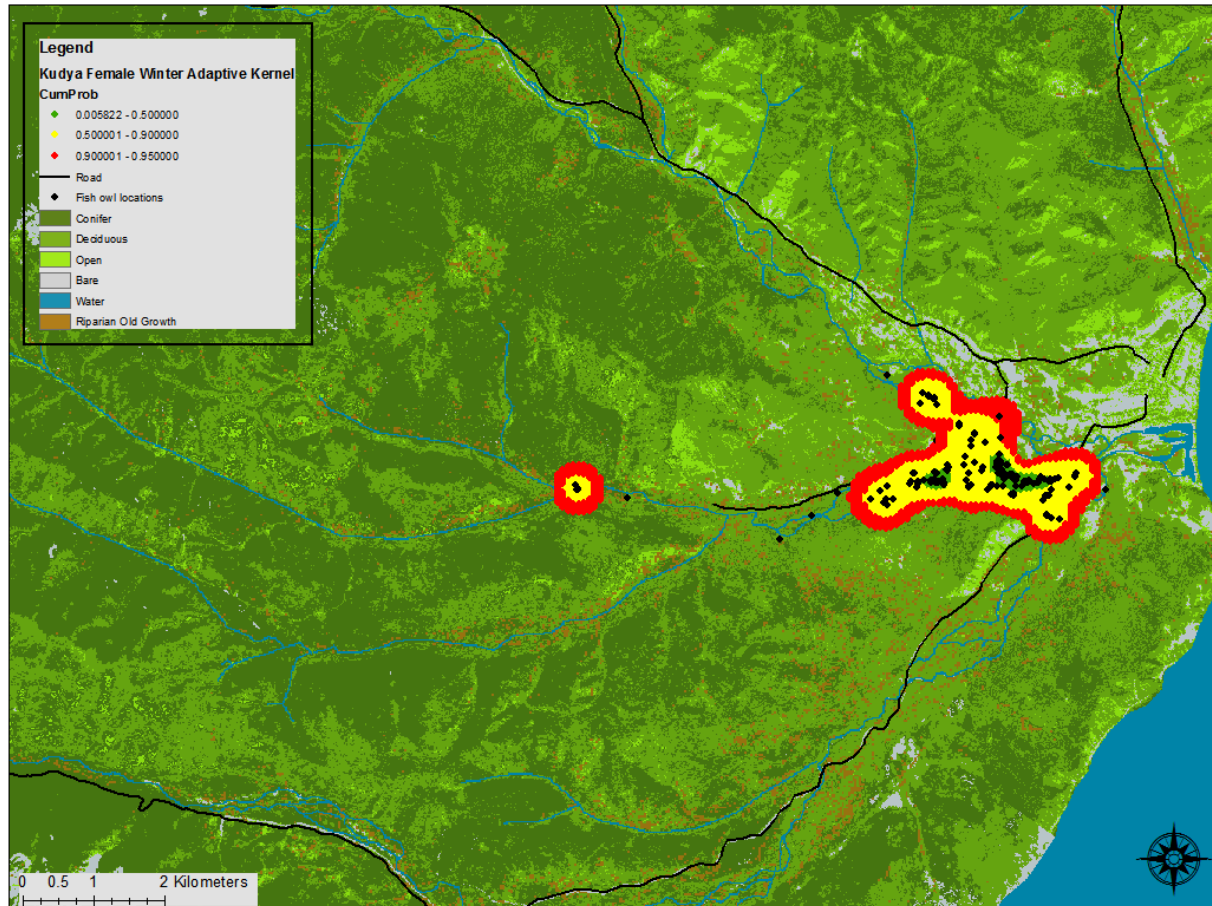
135



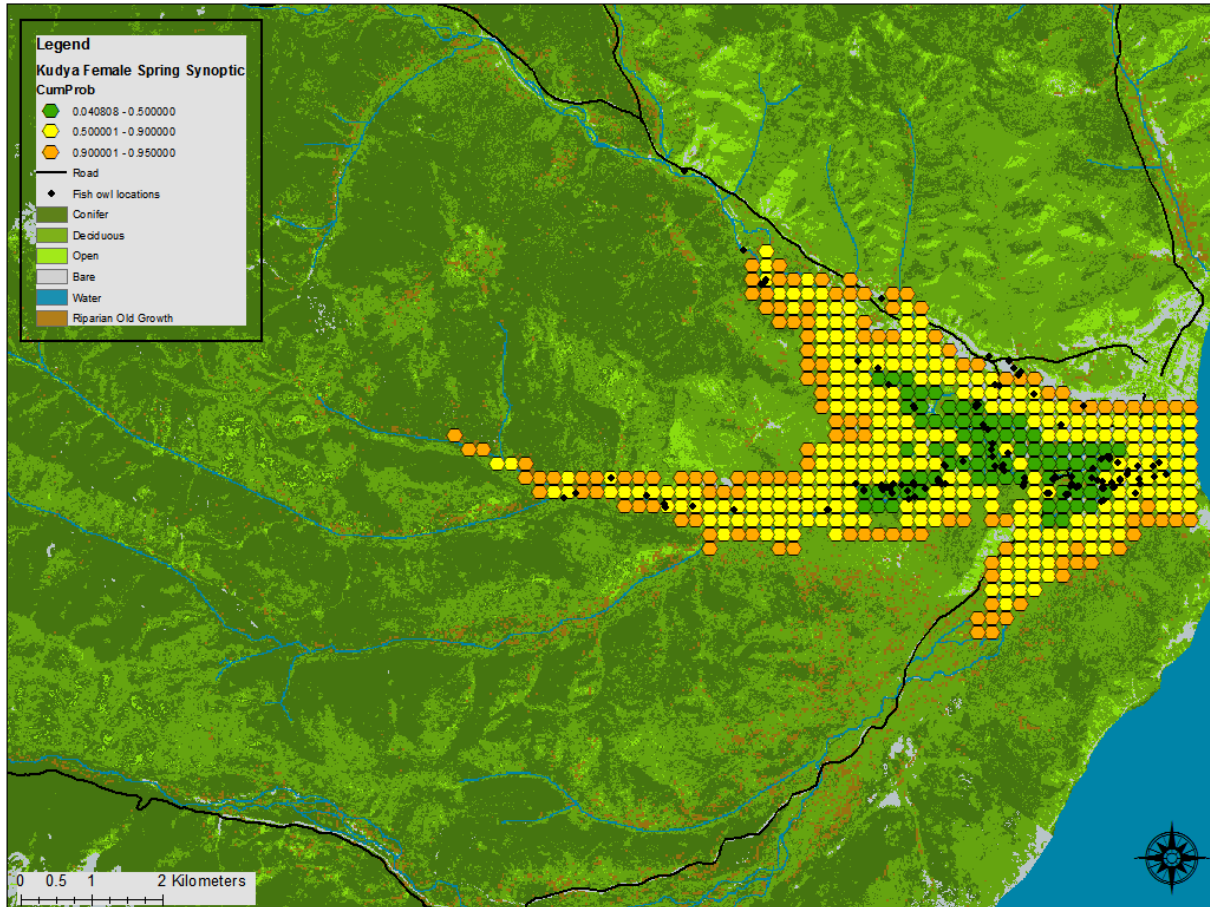
Appendix 2.3.1.1. Winter home range of a female Blakiston's fish owl at the Kudya River in Primorye, Russia, 2009, using the synoptic model. Black circles are fish owl GPS locations used to develop the models.



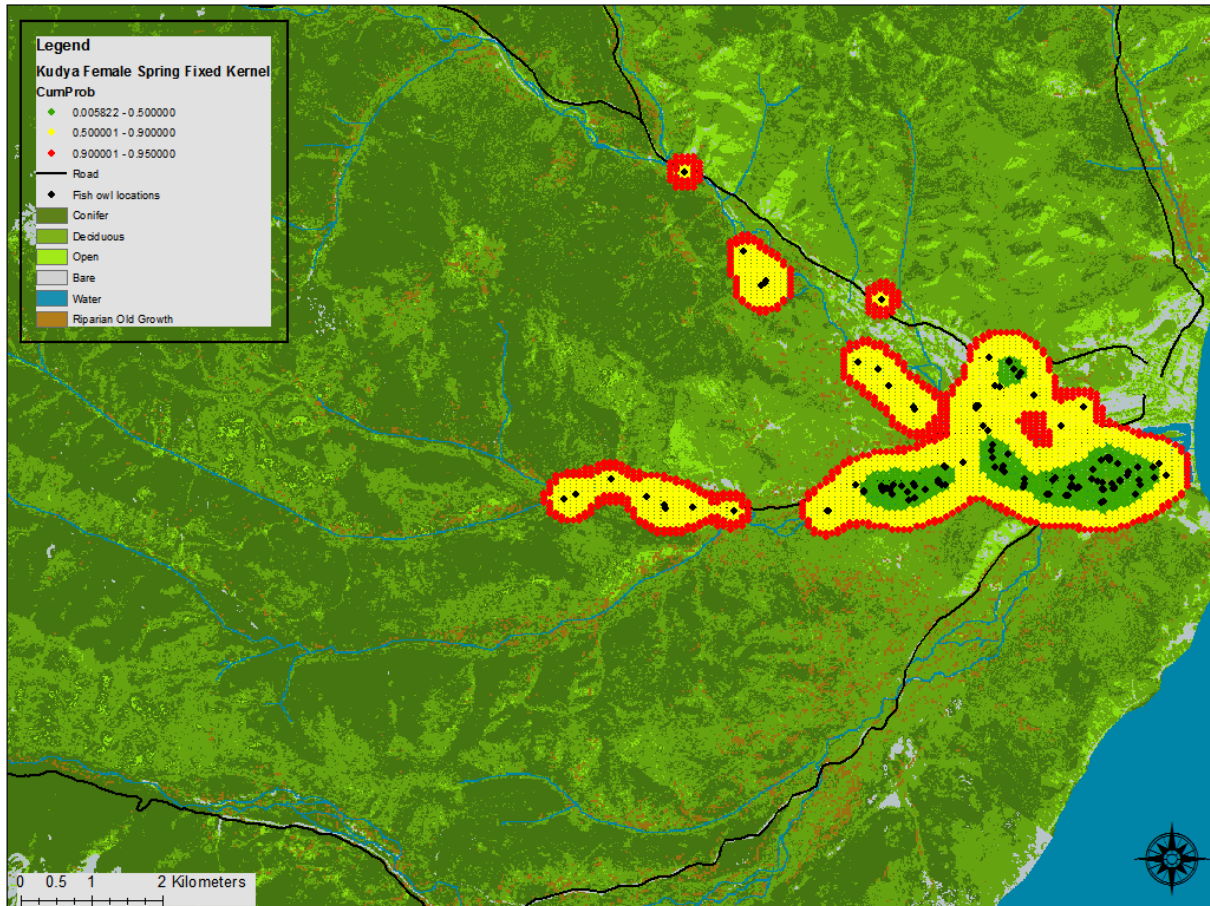
Appendix 2.3.1.2. Winter home range of a female Blakiston's fish owl at the Kudya River in Primorye, Russia, 2009, using a kernel density estimator. Black circles are fish owl GPS locations used to develop the models.



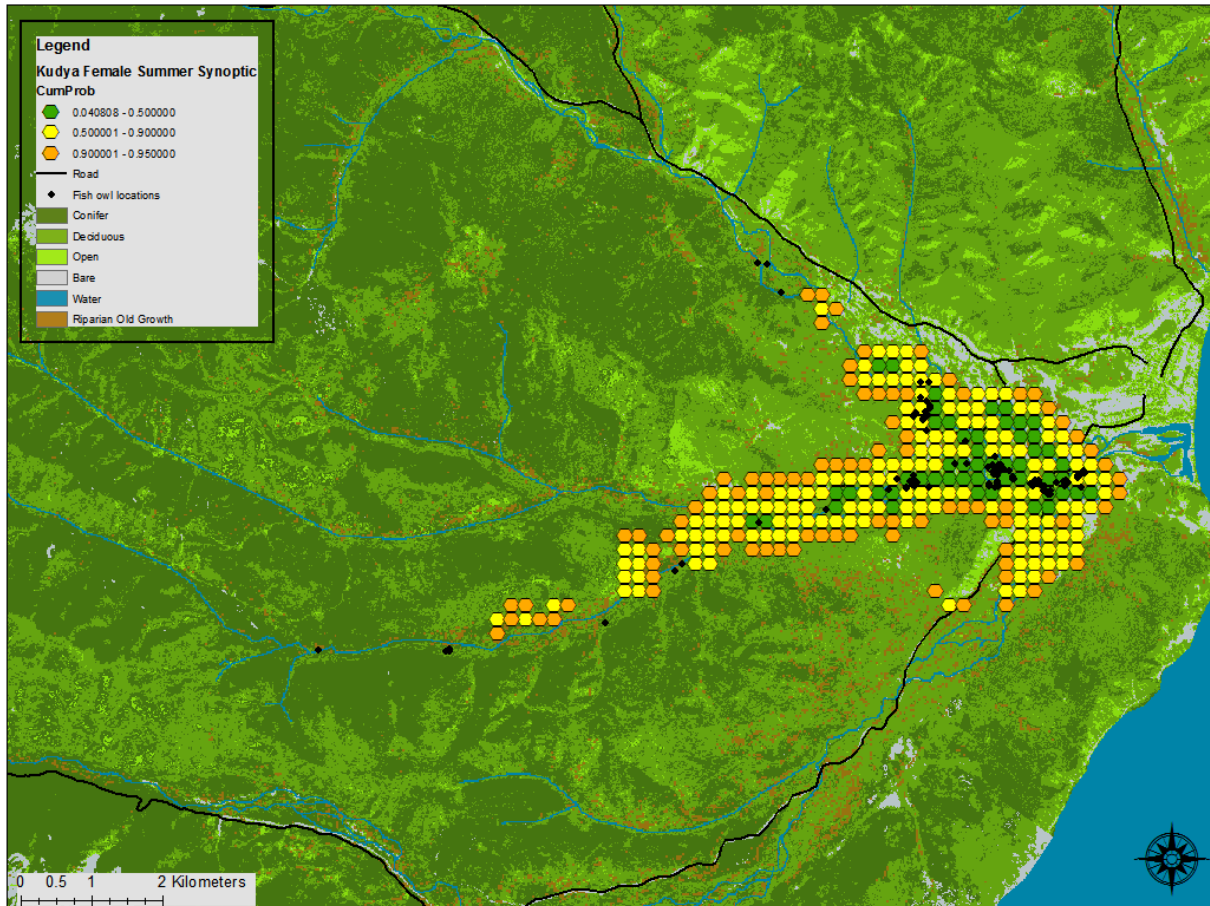
Appendix 2.3.2.1. Spring home range of a female Blakiston's fish owl at the Kudya River in Primorye, Russia, 2009, using the synoptic model. Black circles are fish owl GPS locations used to develop the models.



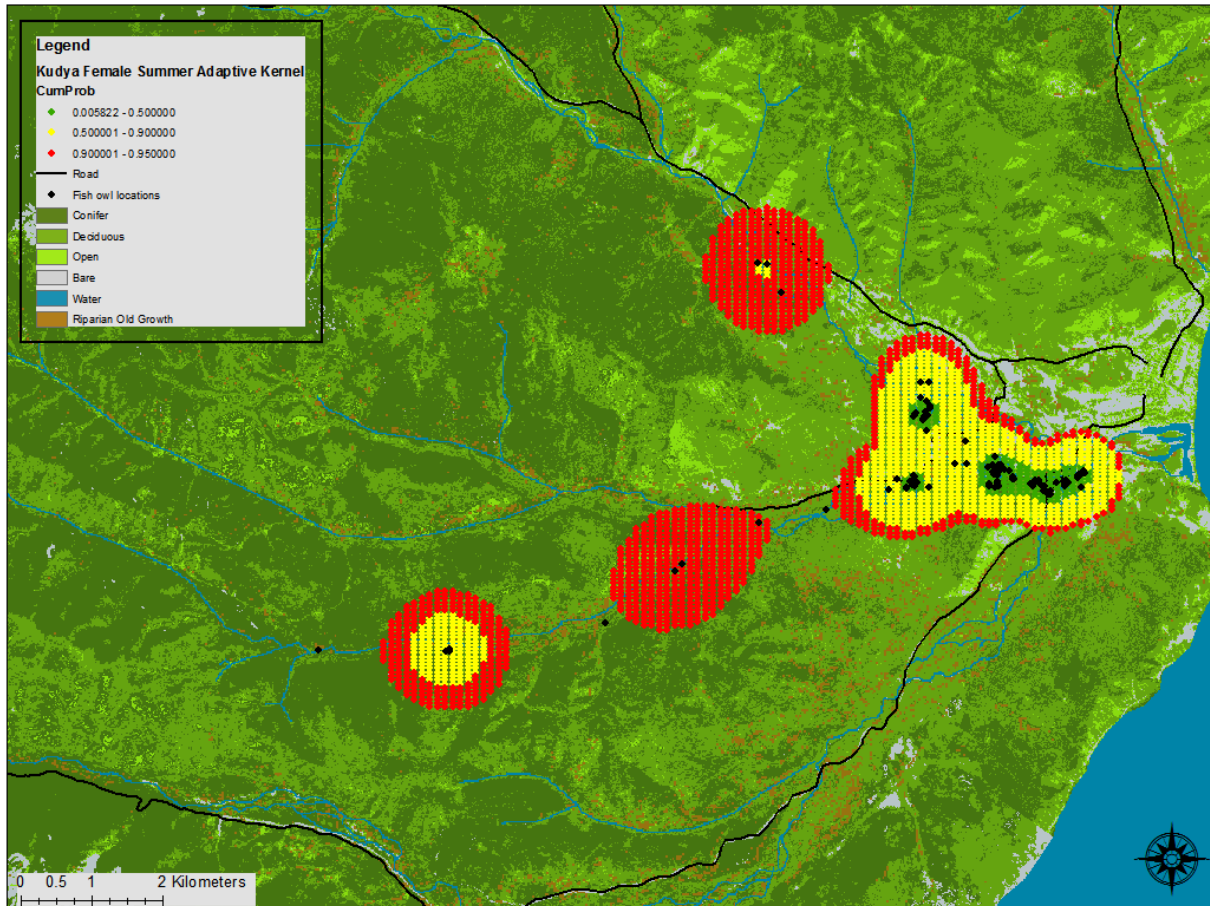
Appendix 2.3.2.2. Spring home range of a female Blakiston's fish owl at the Kudya River in Primorye, Russia, 2009, using a kernel density estimator. Black circles are fish owl GPS locations used to develop the models.



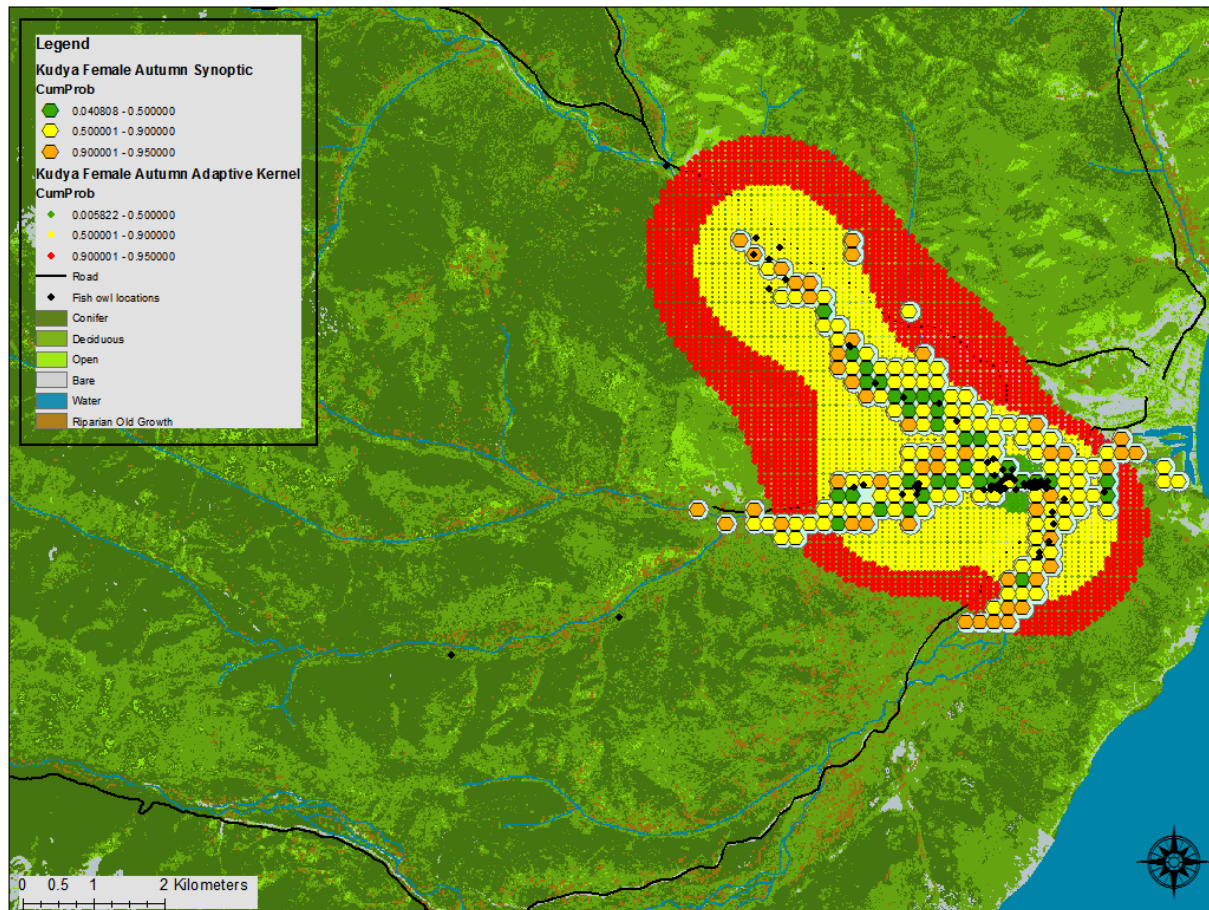
Appendix 2.3.3.1. Summer home range of a female Blakiston's fish owl at the Kudya River in Primorye, Russia, 2009, using the synoptic model. Black circles are fish owl GPS locations used to develop the models.



Appendix 2.3.3.2. Summer home range of a female Blakiston's fish owl at the Kudya River in Primorye, Russia, 2009, using a kernel density estimator. Black circles are fish owl GPS locations used to develop the models.

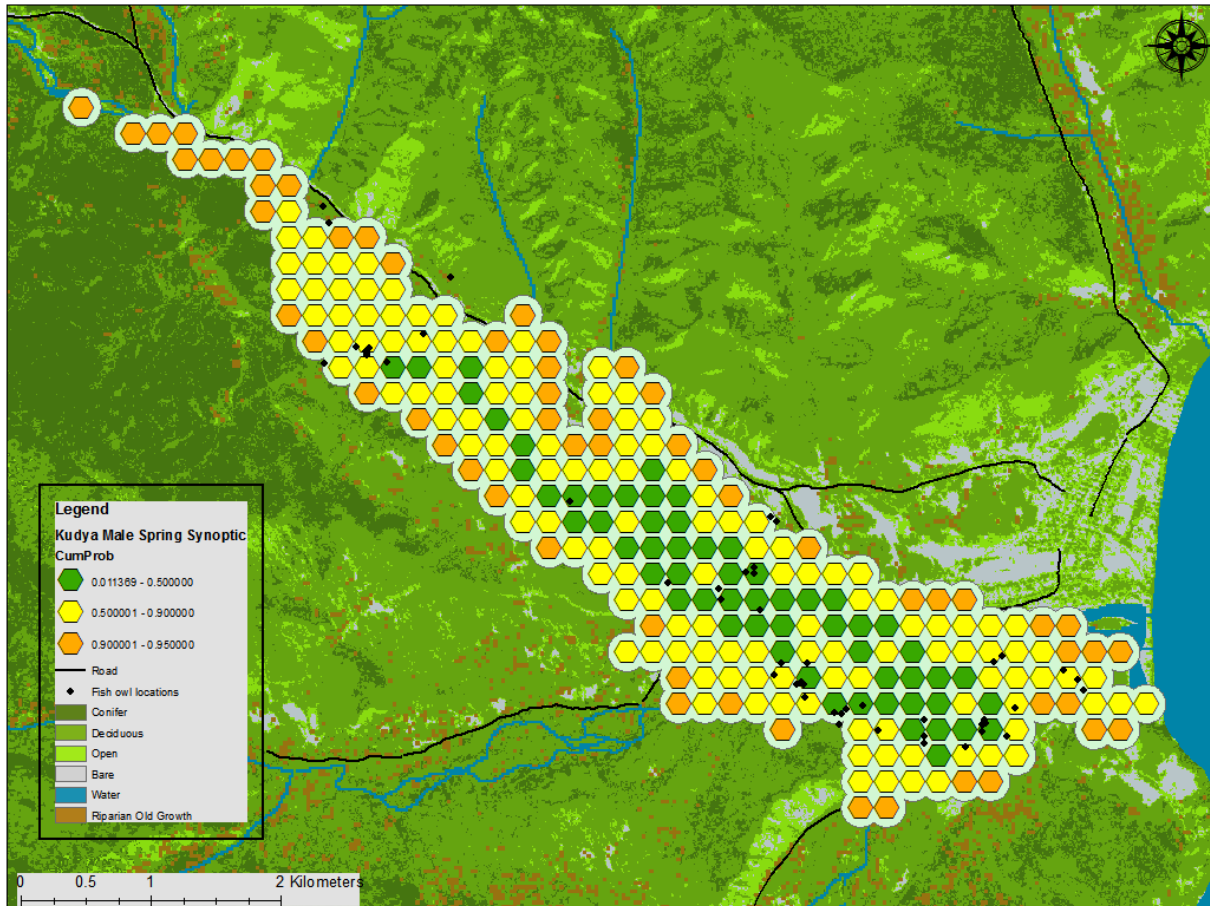


Appendix 2.3.4. Autumn home range of a female Blakiston's fish owl at the Kudya River in Primorye, Russia, 2009. Large hexagons are estimates using the synoptic model, and small colored circles are estimates from a kernel density estimator. Black circles are fish owl GPS locations used to develop the models.



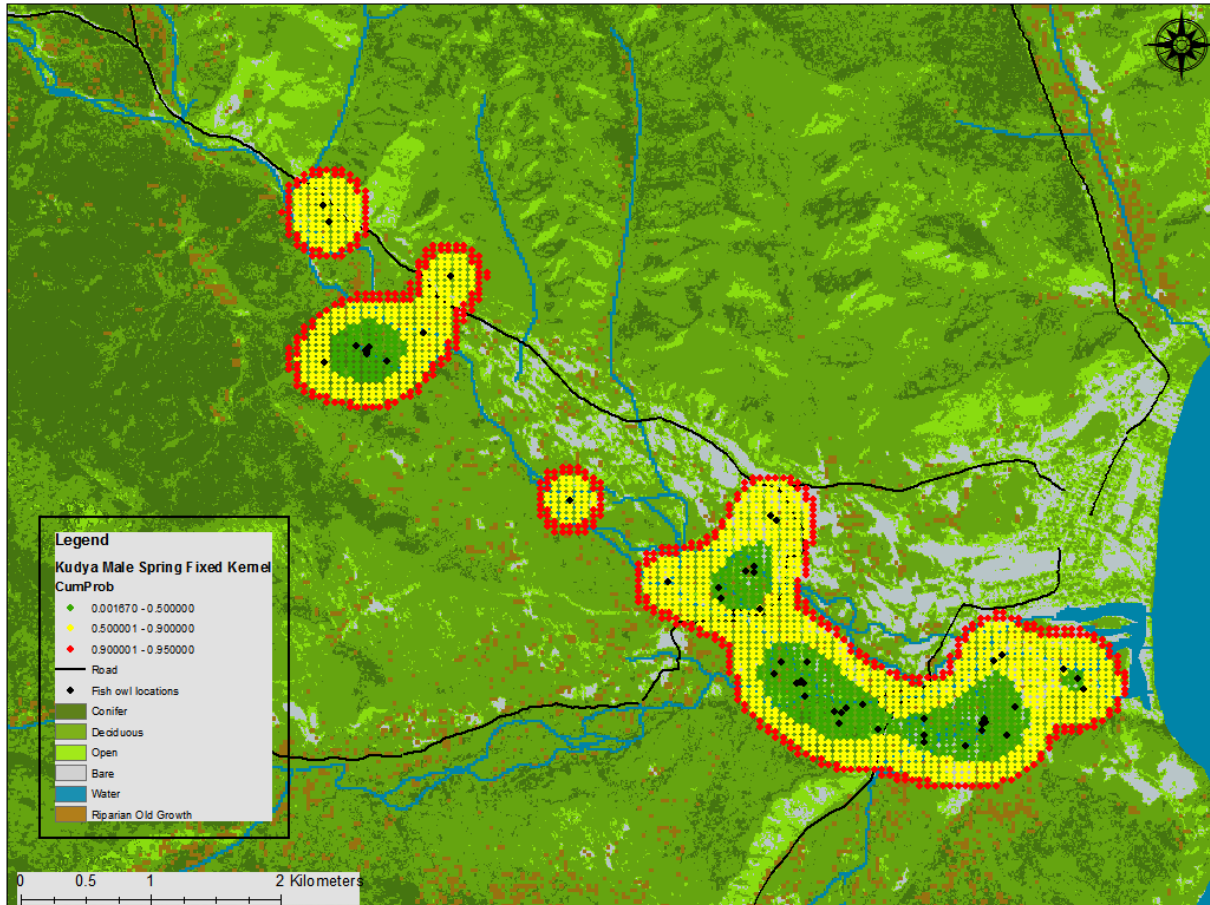
Appendix 2.4.1.1. Spring home range of a male Blakiston's fish owl at the Kudya River in Primorye, Russia, 2009, using the synoptic model. Black circles are fish owl GPS locations used to develop the models.

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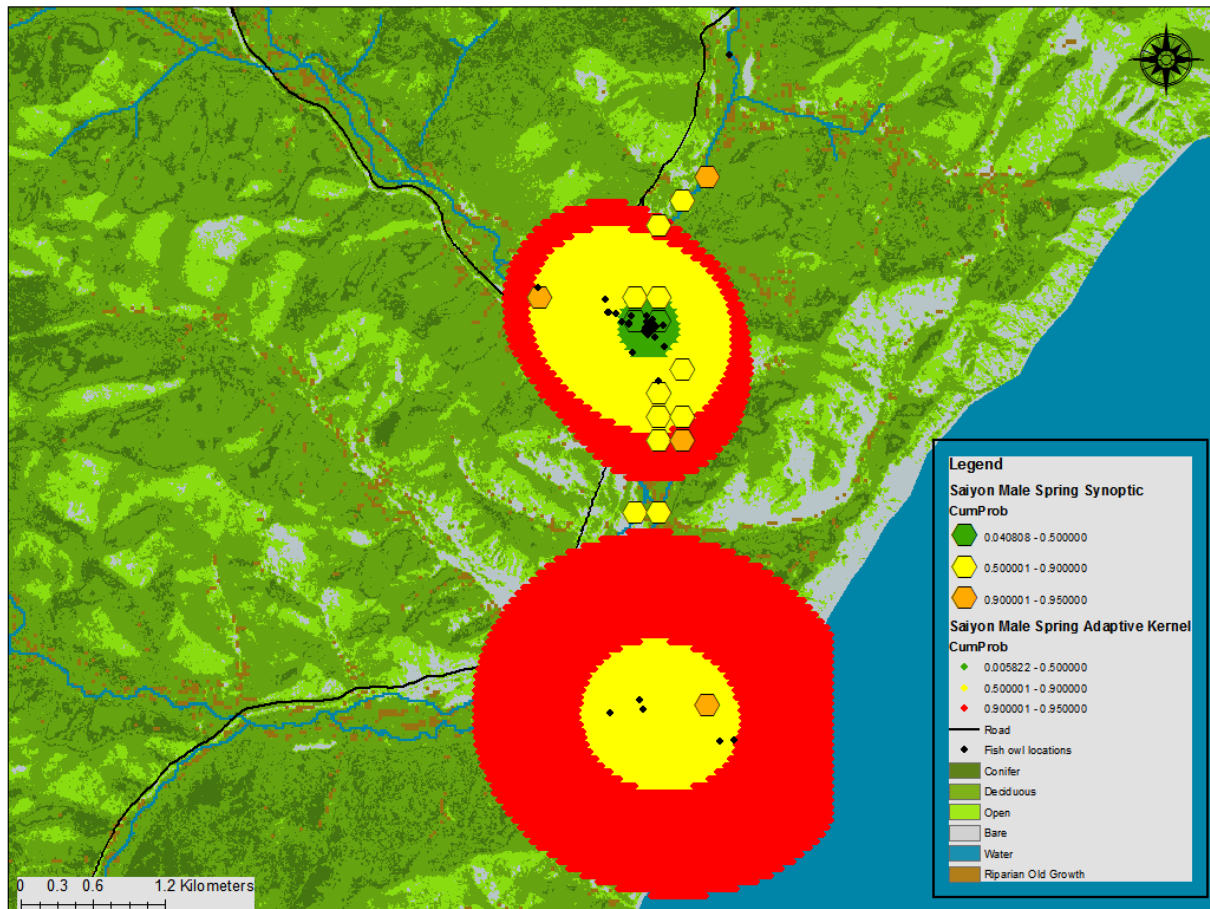
Appendix 2.4.1.2. Spring home range of a male Blakiston's fish owl at the Kudya River in Primorye, Russia, 2009, using a kernel density estimator. Black circles are fish owl GPS locations used to develop the models.

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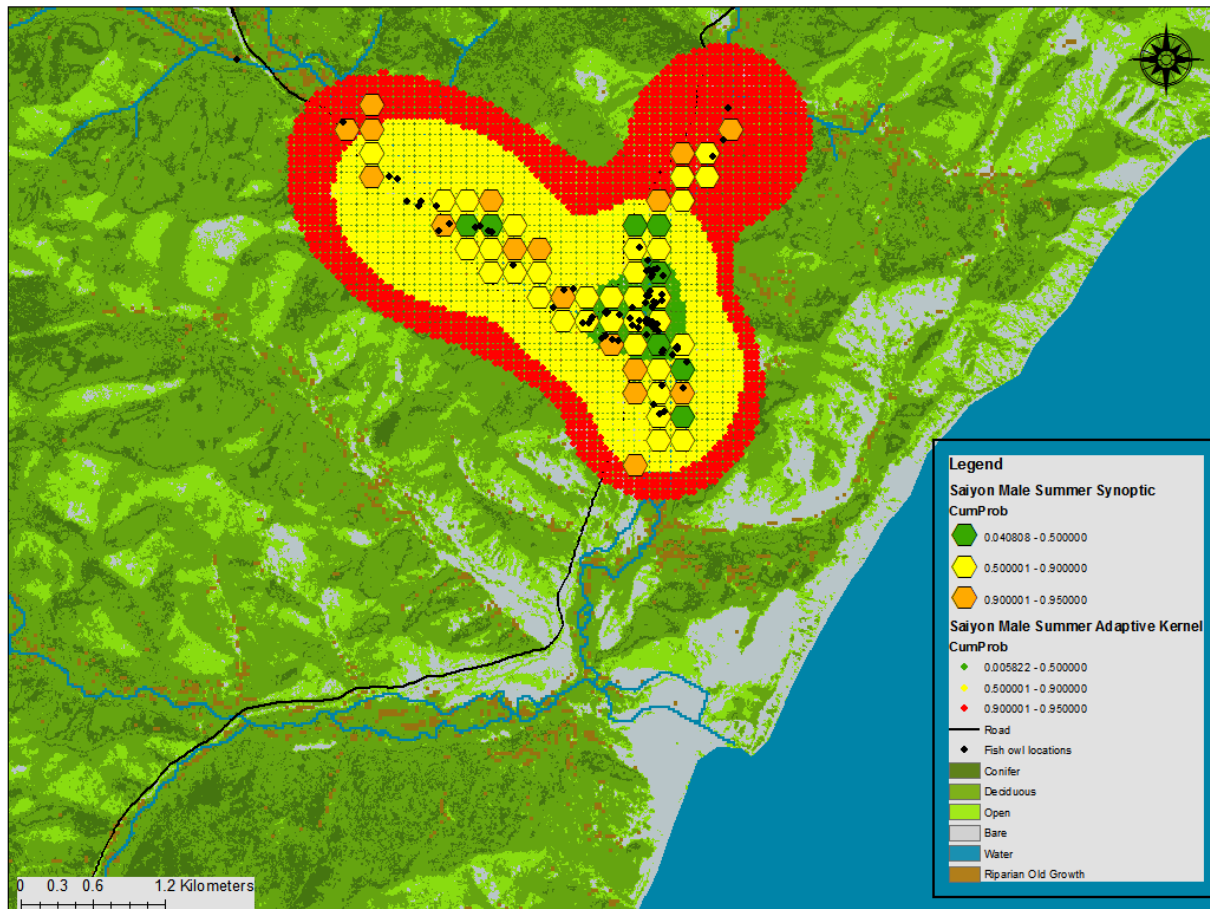
Appendix 2.5.1. Spring home range of a male Blakiston's fish owl at the Saiyon River in Primorye, Russia, 2009. Large hexagons are estimates using the synoptic model, and small colored circles are estimates from a kernel density estimator. Black circles are fish owl GPS locations used to develop the models.

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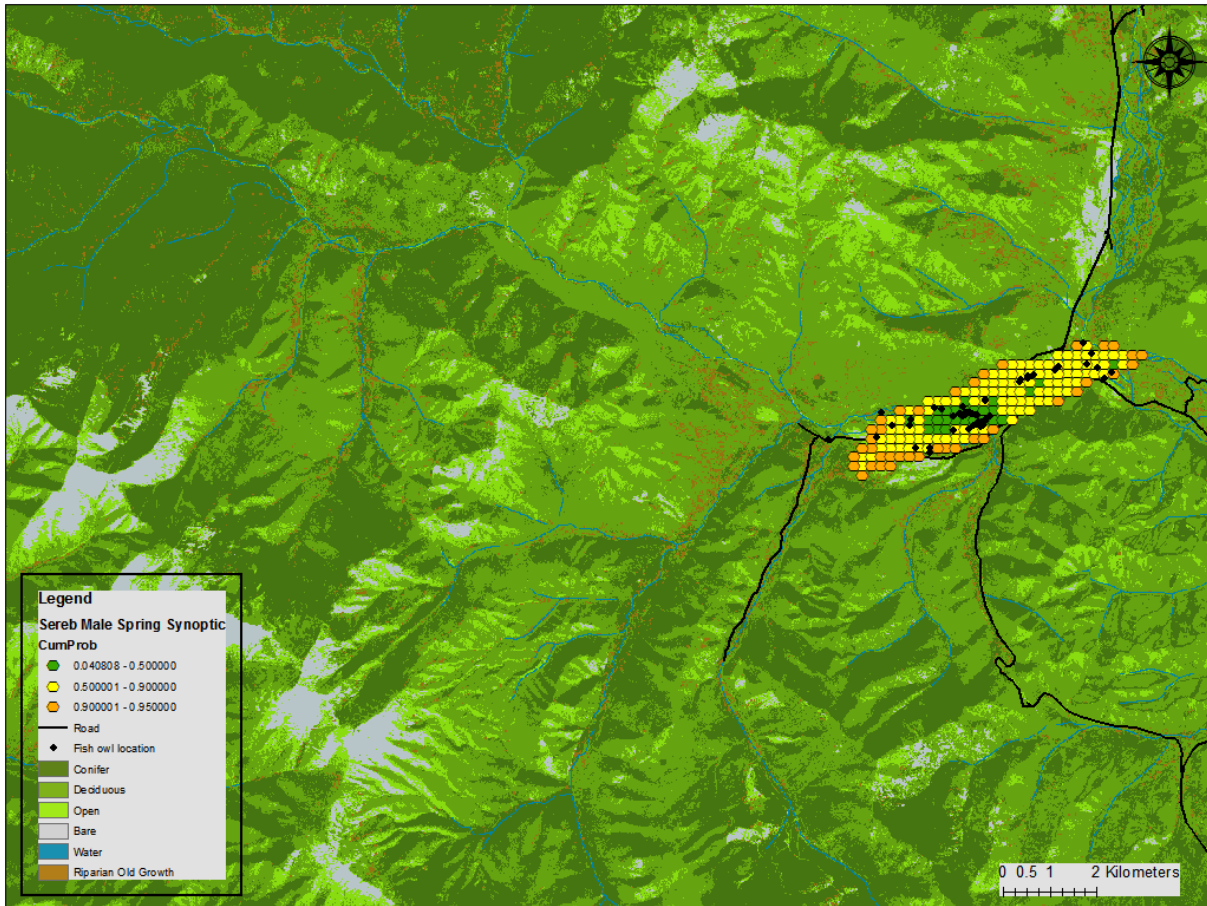
Appendix 2.5.2. Summer home range of a male Blakiston's fish owl at the Saiyon River in Primorye, Russia, 2009. Large hexagons are estimates using the synoptic model, and small colored circles are estimates from a kernel density estimator. Black circles are fish owl GPS locations used to develop the models.

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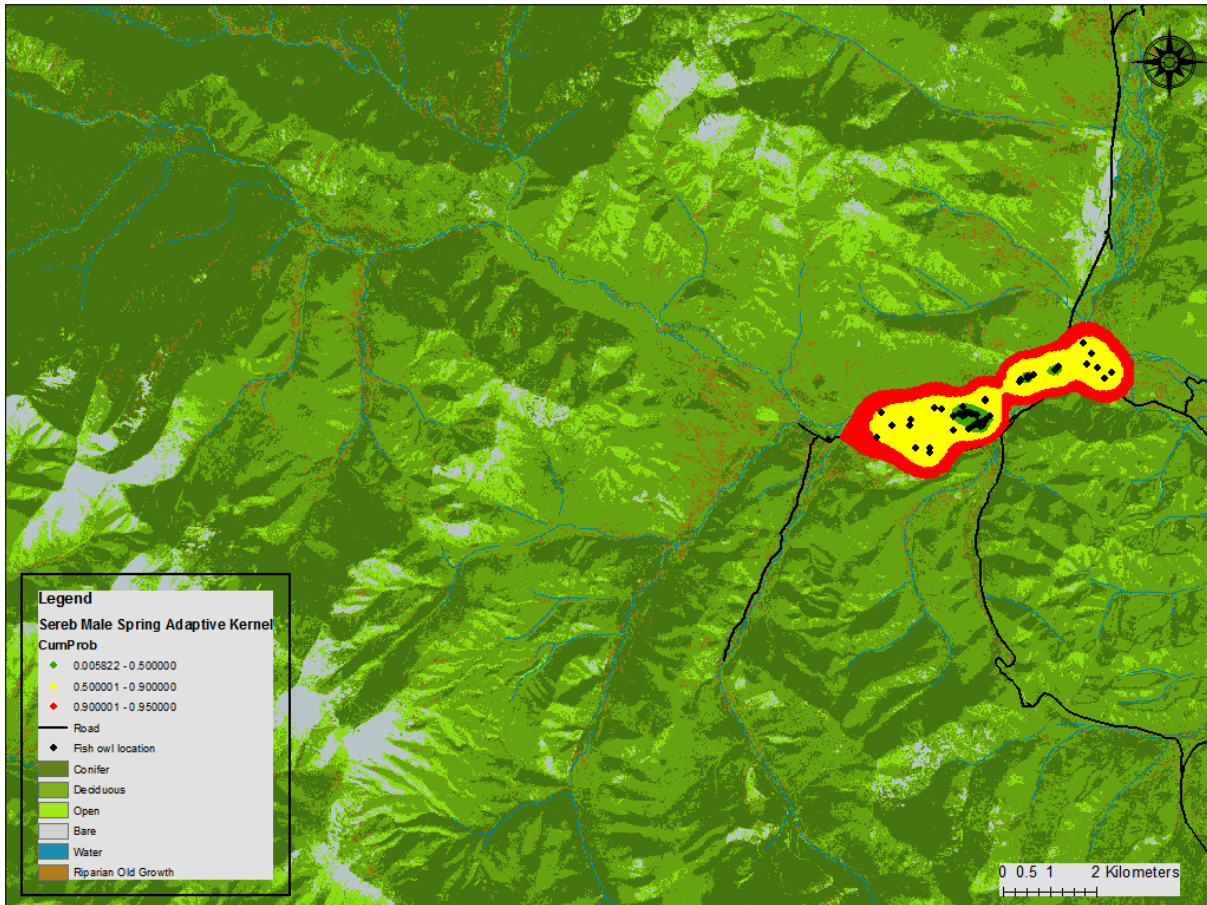
Appendix 2.6.1.1. Spring home range of a male Blakiston's fish owl at the Serebryanka River in Primorye, Russia, 2009, using the synoptic model. Black circles are fish owl GPS locations used to develop the models.

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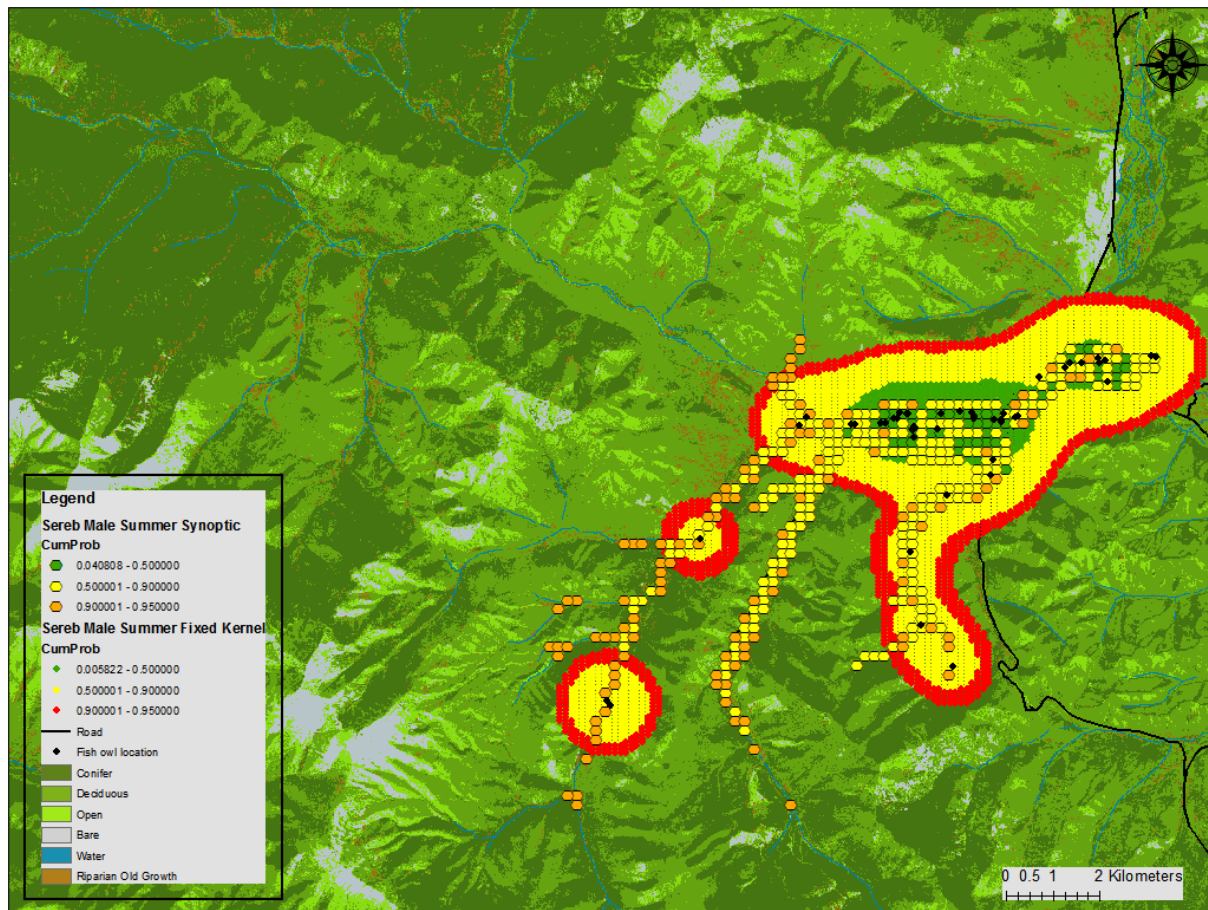
Appendix 2.6.1.2. Spring home range of a male Blakiston's fish owl at the Serebryanka River in Primorye, Russia, 2009, using a kernel density estimator. Black circles are fish owl GPS locations used to develop the models.

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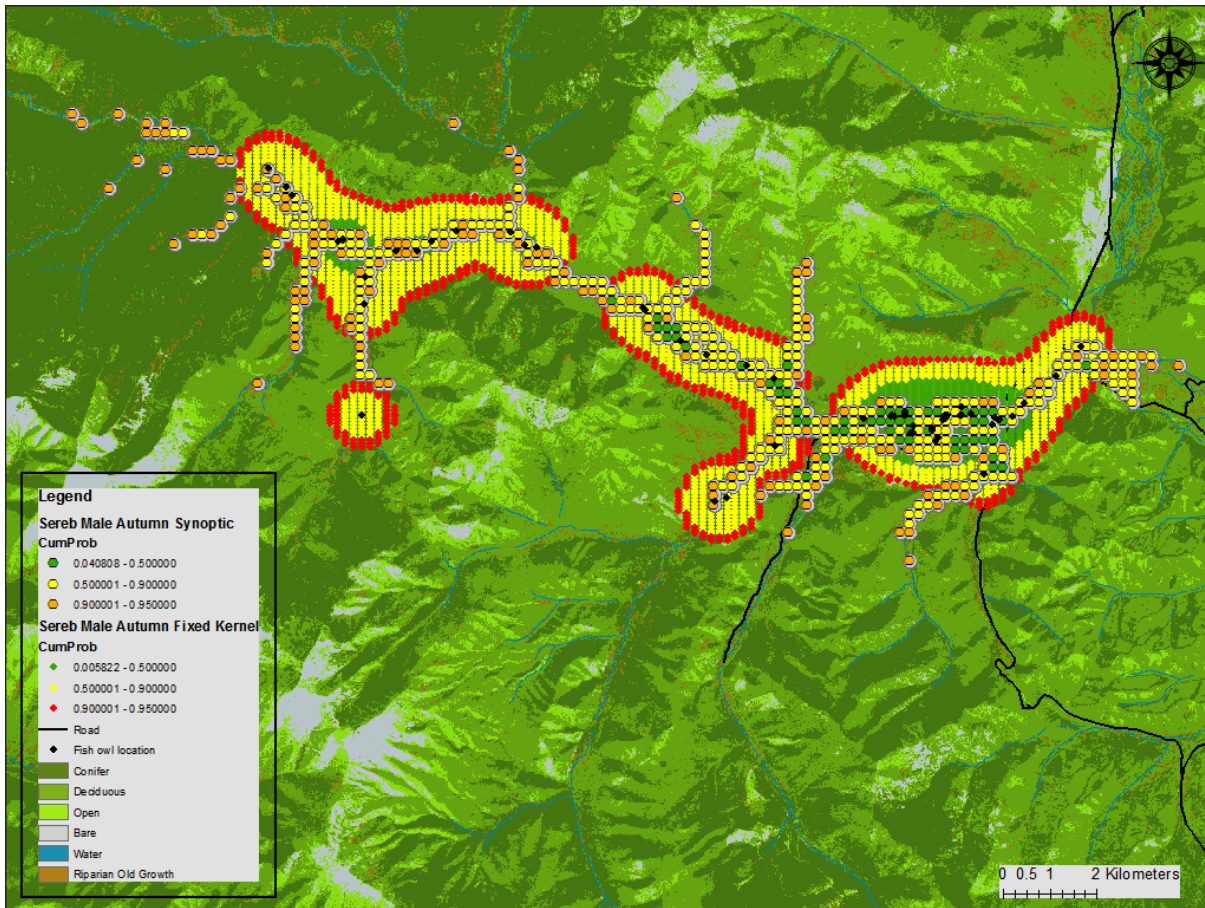
Appendix 2.6.2. Summer home range of a male Blakiston's fish owl at the Serebryanka River in Primorye, Russia, 2009. Large hexagons are estimates using the synoptic model, and small colored circles are estimates from a kernel density estimator. Black circles are fish owl GPS locations used to develop the models.

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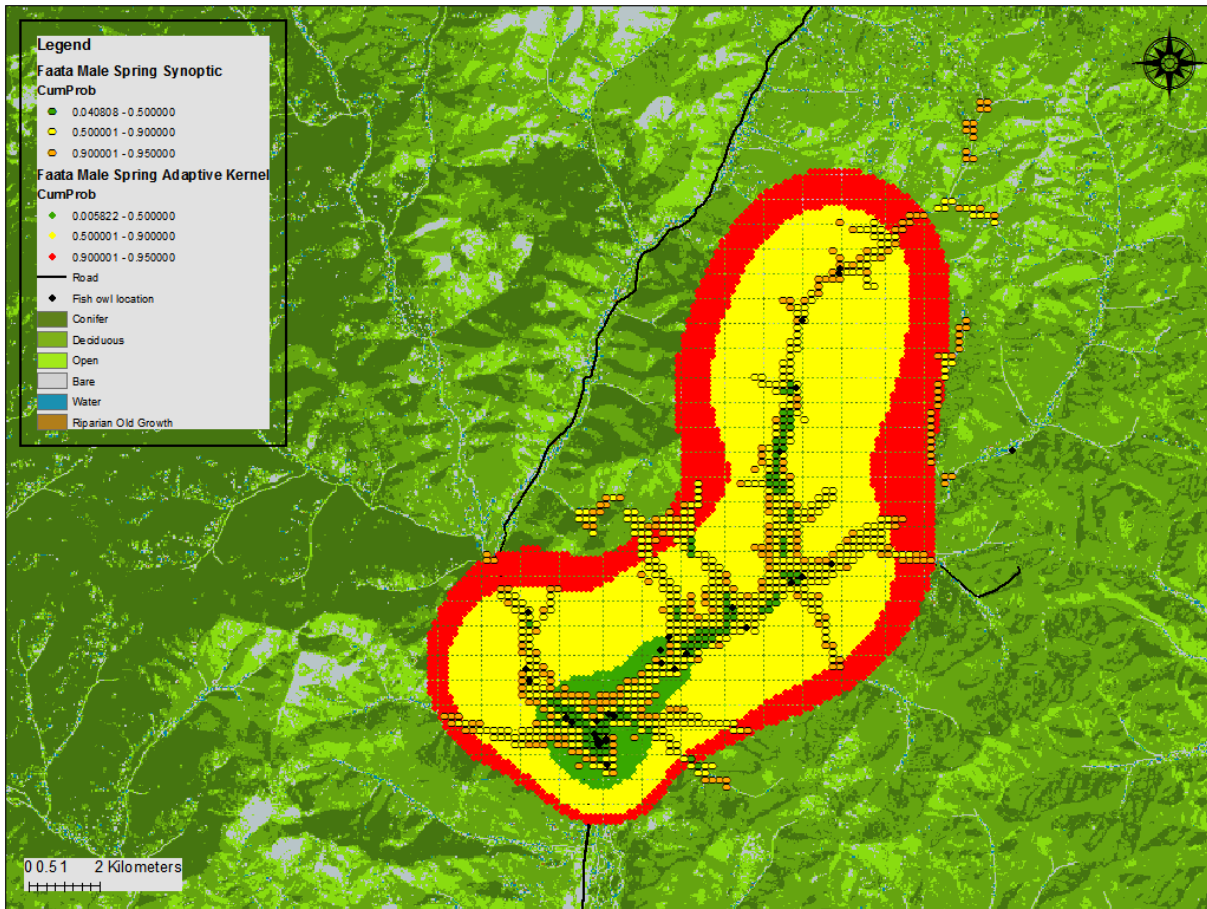


Appendix 2.6.3. Autumn home range of a male Blakiston's fish owl at the Serebryanka River in Primorye, Russia, 2009. Large hexagons are estimates using the synoptic model, and small colored circles are estimates from a kernel density estimator. Black circles are fish owl GPS locations used to develop the models.

150

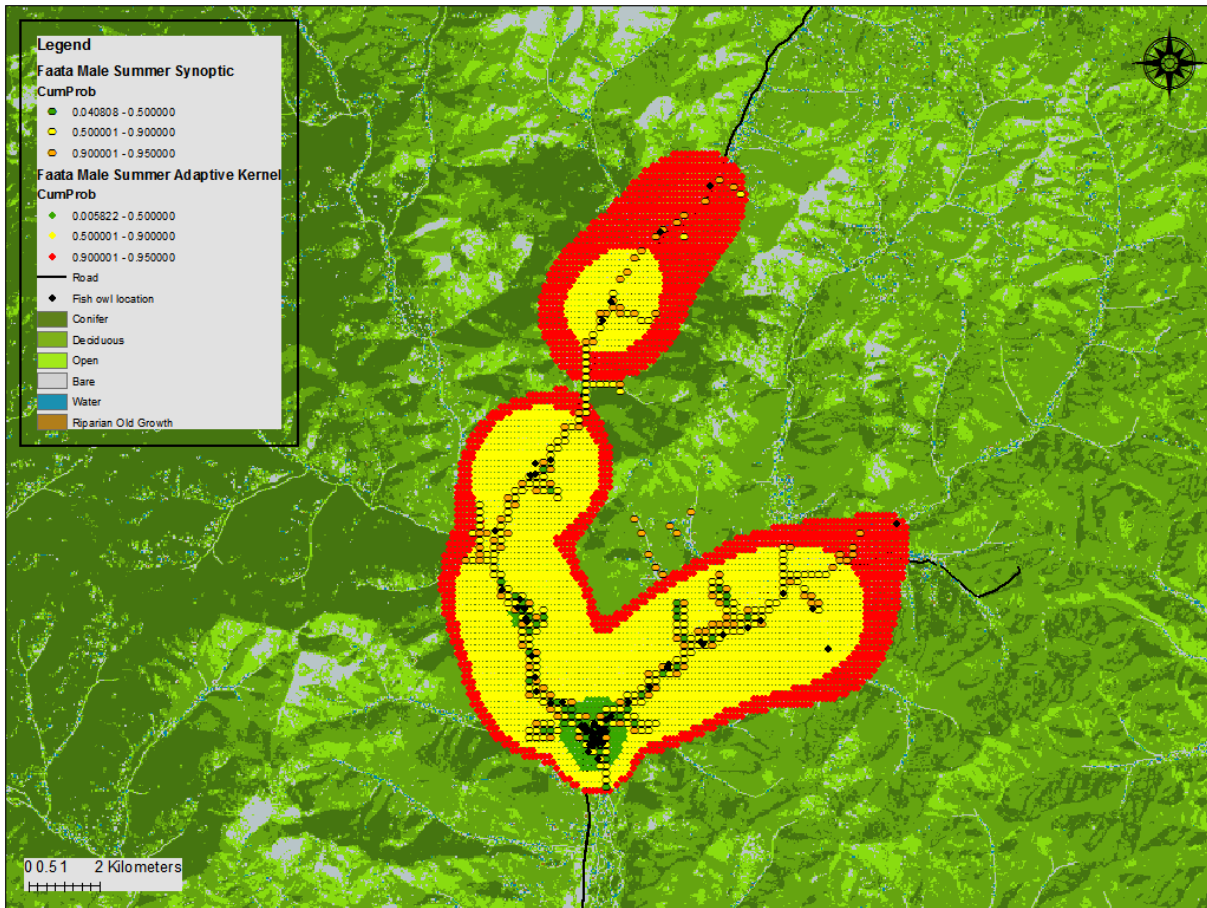


Appendix 2.7.1. Spring home range of a male Blakiston's fish owl at the Faata River in Primorye, Russia, 2009. Large hexagons are estimates using the synoptic model, and small colored circles are estimates from a kernel density estimator. Black circles are fish owl GPS locations used to develop the models.



Appendix 2.7.2. Summer home range of a male Blakiston's fish owl at the Faata River in Primorye, Russia, 2009. Large hexagons are estimates using the synoptic model, and small colored circles are estimates from a kernel density estimator. Black circles are fish owl GPS locations used to develop the models.

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Appendix 2.7.3. Autumn home range of a male Blakiston's fish owl at the Faata River in Primorye, Russia, 2009. Large hexagons are estimates using the synoptic model, and small colored circles are estimates from a kernel density estimator. Black circles are fish owl GPS locations used to develop the models.

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