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ADAPTIVE MANAGEMENT MONITORING OF SPOTTED OWLS

Annual Progress Report – August 2007

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Re: Recovery Permit TE-834385-3

INTRODUCTION

In 1998, we began monitoring responses of Spotted Owls (NSOs) to forest structural conditions that resulted largely from less intensive forestry practices such as thinning and partial harvesting (i.e, a retrospective emphasis). Also, we have collected observations of owl behavioral responses to intermediate silvicultural treatments within core areas of home ranges. This project therefore involves both repeated observational experiments and manipulative experiments in areas that contain relatively continuous managed forests.

We assume habitat selection links Spotted Owl populations with their environments because selection of a habitat reflects the balance of costs and benefits associated with alternative choices. Given that assumption, we emphasize resource selection function (RSF) modeling because those analyses are robust and provide strong conclusions regarding habitat selection. In this progress report, we include additional RSF modeling results from 3 of the 9 study areas. Those results include a draft final report to cooperators from one of the study areas. We also provide initial observations based upon radio-tracking a few Barred Owls in areas occupied by Spotted Owls. A research paper based upon resource selection analyses of California Spotted Owls (CASPO) was printed in the June issue of the Journal of Wildlife Management, the abstract of which is contained herein.

The research products will provide information and tools for the following:

1) identifying high-use areas that could be avoided in hazardous fuels reduction treatments, partial cutting operations, or intensive thinning projects; or conversely, identifying low-use areas where treatments may have minimal effects;
2) identifying optimal habitat conditions in a decision-support framework;
3) identifying the potential for enhancing owl habitats using silvicultural techniques; and
4) helping to promote longterm forest/habitat sustainability.

GOALS

The goals of this study include generating scientific information to:

I. Develop RSF models that provide quantitative support for decisions about silvicultural applications or forest fuels treatments in areas occupied by spotted owls;

II. Promote integrated conservation or recovery of spotted owls across the landscape mosaic of forests managed for commercial and non-commercial values over both the short and long runs;

III. Clarify spotted owl/habitat relationships in certain areas of their geographic range;

IV. Evaluate initial and subsequent spotted owl responses to commercial thinning and to partial harvesting in different parts of the owl's geographic range.

The 1998 Study Plan and subsequent Annual Reports through 2005 provide descriptions of methods, treatments, research design and biological rationale for the project. The primary objectives involve comparisons among owl foraging use of forest stands with and without previous silvicultural treatments and before-vs.-after silvicultural treatments conducted during the study. Based upon the manipulative experiments and evaluations of responses to previous silvicultural applications (i.e., retrospective analyses), we are seeking to satisfy the following study objectives:

1. Estimate home range sizes and configurations;
2. Quantify stand-structural and abiotic factors that influence habitat selection at the landscape, home range and stand levels;
3. Estimate the sizes of core areas; and
4. Identify areas of concentrated use for foraging.

We are examining spotted owl responses to habitat conditions at 3 spatial scales:

1. Habitat use by multiple sub-populations of spotted owls relative to habitat conditions generally available within study areas (sampled landscapes).
2. Habitat use vs. availability within home ranges.
3. Use of individual patches or forest stands before and after silvicultural treatment.

Here, we report progress since August 2006, and include new information that adds to, but does not necessarily replace previously reported information. We caution readers that more data remain to be collected and analyzed, and it is likely that some apparent trends contained herein will be modified with additional analyses. We encourage comments and suggestions for improving this project.

STUDY AREAS

This study employs a repeated, or multiple study-area approach (Johnson 2002), which ultimately may allow data to be combined in meta-analyses for several analysis areas. One analysis area, with 2 study-area replicates (Study areas 1 & 2) is located in Douglas-Fir/Western Hemlock forests west and east of Eugene, Oregon. These two study areas (described in previous interim reports as "clusters") occur on private timberlands and those administered by Oregon Department of Forestry, Bureau of Land Management and U.S. Forest Service. A third study-area replicate in Douglas-fir/Western Hemlock forests was implemented in 2003 on BLM and private timberlands near Coos Bay, Oregon. Results from that area very likely will be combined with information acquired in Study Areas 1 and 2 because of similarity in forests.

A second analysis area with 5 study-area replicates occurs in a zone that extends from the southern Oregon Cascades through the northern Sierra Nevada Mountain Range south of Mt. Shasta, California. This broad area includes Mixed Conifer and Evergreen timberlands administered by the USDA Forest Service (Klamath National Forest) and USDI Bureau of Land Management as well as private timberlands primarily owned by Forest Capital (formerly owned by Boise Cascade Corporation), Fruit Growers Supply Company, Timber Products Company, U.S. Timberlands, and Sierra Pacific Industries. Another analysis area with 1 study area replicate in the range of the NSO was initiated in March 2000 on timberlands administered by the California State Department of Forests and Fire and on private timberlands owned by Mendocino Redwood Company and The Campbell Group in the California Redwood Zone near Ft. Bragg.

Below, we provide additional details from resource selection function analyses for Study Area 4A at Yreka, California, Area 4B at Medford, Oregon, and Study Area 7 near Ft. Bragg, California. The analyses presented herein identify trends in the data for these 3 Study Areas, but readers should recognize that additional analyses will be undertaken as additional information arrives. Analyses based upon data collected at Study Area 6 link CASPO habitat selection with forest vegetation conditions and abiotic or planimetric covariates such as distance from nest sites, elevation, topography and distance from streams (Irwin et al. 2007). Analyses of spotted owl before-after use of areas treated via partial harvesting within home ranges is scheduled for later in 2007 or early 2008.

SUMMARY OF TELEMETRY DATABASE

In previous reports we summarized the number of birds monitored, telemetry points recorded and cumulative home range estimates for individual study areas. Estimates of cumulative home range sizes, based upon the FK methods, 95%MMCP and the 100%MCP for 9 study areas were provided in the 2006 annual report. New research indicates that the 90% fixed kernel estimator is the most reliable estimator for comparing among studies that may have different sampling intensities (Borger et al. 2006), so final reports will include those values. We use the MMCP as the template for availability in use/availability analyses. We have monitored **232 spotted owls and 18 Barred Owls at 111 owl territories** during the course of the project. From Spring 1998 through 1 June 2007, **field crews and mapped 33,057 locations** of the telemetered birds. That number excludes limited data for a few owls that were radio-tracked in Study Area 3, which was initiated but not developed because of insufficient federal funding. The total also excludes data for a few owls that died or for which transmitters failed shortly after capture and were not replaced by new adults.

Home range sizes--. In Table 1 we list site-specific home range sizes for study areas at Klamath Falls and Coos Bay, Oregon, based upon 50-, 75-, and 90% fixed kernel (FK) home range algorithms, as well as the 95% modified minimum convex polygon (MMCP) home range algorithm. Smoothing parameters, or bandwidths, were chosen arbitrarily to minimize outlying "island" polygons and maximize inclusion of telemetry data. Final analyses for purposes of publication are likely to differ.

Core areas are defined as those areas used disproportionately within home ranges. Previous experience indicates that spotted owls may spend some 60-80% of their time in core areas that comprise only 20-25% of their annual home ranges. Thus, core areas are likely to be included in the ranges of areas that are described by the 50% and 75% fixed kernel and adaptive kernel probability distributions. In previous reports we noted that those values have ranged from 48 acres (50% FK) to 1839 acres (75% FK). For Study Area 9, the 50% kernel averaged 670 acres, which is slightly larger than the 50% FK (range = 48-548 acres) core-area estimate for 15 Northern Spotted Owls at the Elliott State Forest, Oregon (~215 acres) and for 9 Northern Spotted Owls in northwestern Oregon (~250 acres) from Glenn et al. (2004). Core-area estimates, using the 50% FK, for Study Area 10 at Coos Bay averaged 417 acres. Overall, the 50%-75% FK home range estimates support our original prediction, based upon energetics and body mass, that core areas are likely to lie within a range of 500-1000 acres.

Table 1. Home range sizes (acres) of Northern Spotted Owls in study area 9 (Klamath Falls, Oregon) and study area 10 (Coos Bay, Oregon), as estimated via 95% minimum convex polygon (MCP) and 90-, 75- and 50% fixed kernel (FK) algorithms. SP is the smoothing parameter or bandwidth.

	Telem Pts	Site	95MCP (Ac)	90FK (Ac)	75FK (Ac)	50FK (Ac)	SP
AREA 9							
	246	A	16228	9069	4814	1822	600
	602	B	4640	532	270	113	600
	412	C	8856	4189	1224	55	600
	414	E	8963	3177	1512	568	600
	52	F	7119	3684	1119	506	600
	415	G	5842	1645	857	420	200
	449	H	6870	1799	770	268	400
	450	I	9651	4082	2111	1060	600
	412	J	12067	9668	4674	1857	600
	158	K	1703	1474	694	217	250
	76	M	7167	5498	1866	554	600
Average			**8100**	**4074**	**1810**	**676**	
AREA 10							
	311	A	2941	2935	1413	596	600
	207	B	3788	2522	1128	530	600
	490	C	1467	1282	720	212	200
	421	D	4533	2704	1400	656	600
	455	E	3152	2821	1384	593	600
	173	F	5307	5807	2764	871	600
	375	G	3818	3741	1797	636	600
	73	H	1261	746	169	54	200
	118	I	2362	924	450	206	250
	225	J	3705	810	229	104	400
	108	K	1814	1335	518	134	200
Average			**3104**	**2330**	**1088**	**417**	

Research Article

Modeling Foraging Habitat of California Spotted Owls

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ABSTRACT--We linked radiotelemetry data from California spotted owls (*Strix occidentalis occidentalis*) with forest inventory data from mixed coniferous forests managed primarily via partial timber harvest practices. We estimated a discrete-choice resource selection function (RSF) based upon 21 choice sets from the forest inventories and nocturnal telemetry locations of radiotagged adult spotted owls occupying 17 home ranges. Nocturnal foraging was strongly associated with forests close to nests and small streams. The combined basal areas of Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), and red fir (*Abies magnifica*) and basal area of hardwoods > or = 20 cm diameter at breast height were positively and unimodally correlated to foraging habitat selection by owls, whereas the relative probability of selection decreased with increasing basal area of ponderosa pine (*Pinus ponderosa*). Opportunistically collected diurnal data indicated that owls roosted in forest stands that contained greater tree densities than those used for foraging. Topographic position, habitat heterogeneity, tree species composition, and forest density also influenced foraging site selection. Because our results indicated that forests can be too dense as well as too open, the study suggests that judiciously applied silvicultural prescriptions may maintain or improve owl foraging habitat. By linking the RSF with forest inventory data and forest-growth models specific to the region of our study, forest managers can forecast potential consequences of silvicultural options on spotted owl foraging habitat at the level of individuals or that of a population.

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KEY WORDS: California spotted owl, discrete-choice model, foraging, managed forests, radiotelemetry, resource selection function (RSF), Strix occidentalis occidentalis.

BARRED OWL ACTIVITIES

NOTE: After this project began, various cooperators developed an abiding interest in learning about relationships between Barred Owls and Spotted Owls. There was interest in the possibility that we would be able to expand or extend our current work to included Barred Owls. Therefore, beginning in 2005, we radio-tagged adult Barred Owls at two of our study areas--Klamath Falls and Coos Bay. These initial efforts were intended to be pilot projects to help with local management needs and identify potential questions that might subsequently be answered in more-detailed research. Since then, we have developed 3 new research studies on Barred Owls, 2 of which are associated with the study areas in this project, and initiated pilot efforts in the Redwood Parks region of Northern California. Abbreviated study plans for the two study areas within the current project are inserted below:

Spotted Owl Distributions and Barred Owl Resource Selection:

A Study Plan (Revised 4 January 2007—Abbreviated version Aug 2007)

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INTRODUCTION

The USDI Bureau of Land Management (BLM) and USDA Forest Service are beginning to revise their land and resource management plans for Pacific Northwest forests. Both agencies need updated scientific information to develop forest management alternatives that will support recovery of threatened Northern Spotted Owls (*Strix occidentalis caurina*), hereafter NSO. Likely, such planning will be hampered by the potential that forest management may exacerbate competitive interactions between NSOs and Barred Owls (hereafter, BAOW). The 2004 USDI Fish and Wildlife Service status review for NSOs, an expert scientist panel evaluation of the status of NSOs (Courtney et al. 2004), and a meta-analysis on trends in demography of NSO populations (Anthony et al. 2006) all identified the

BAOW as a primary threat to NSOs. These evaluations emphasize a critical need to understand how alternative silvicultural practices (e.g., variable-density thinning, partial harvesting, forest restoration activities) might influence interactions between the 2 species.

Specifically, there is an urgent need to determine how habitat changes from anticipated extensive thinning programs will affect NSOs directly and indirectly via influencing interactions with Barred Owls (*Strix varia*). One possibility for estimating how such habitat changes are likely to influence interactions between the two species involves evaluating how each species responds to variation in habitat and environmental conditions in the same area. If such an evaluation were available, decision-support tools could be constructed that can forecast potential short- and longterm effects of thinning. Recent (Irwin et al. 2000, Irwin et al. 2007) and ongoing NCASI studies of Spotted Owl home range and habitat selection provide an opportunity to make such an assessment by gathering similar information on BAOWs. Herein, we describe plans for a 2-year study with two goals that will: a) map BAOW and NSO distributions and estimate crude densities; and b) characterize habitat selection by Barred Owls via resource selection function modeling. Both studies will be conducted near Springfield, Oregon in an area of extensive young and intermediate-aged forests (Irwin et al. 2000) that are representative of millions of acres of Douglas-fir/Western Hemlock forests that are likely candidates for thinning or forest restoration.

The most hopeful outcome of this project would include differentiating the habitat-niche of BAOWs from NSOs in such a way that careful forest management could tip the balance of conditions to favor NSOs. For example, Irwin et al. (2007) and ongoing analyses suggest that, among other influences, forest stands with basal areas of approximately 150-250 square feet/acre provide optimal foraging habitat for NSOs. If the research determines that BAOWs exploit denser conditions, then reducing tree densities via thinning might be expected to improve habitat quality for NSOs but not BAOWs. Of course, the opposite may be true: because BAOWs are slightly larger than NSOs, BAOWs might respond rapidly to forest thinnings. It is also possible that thinning in certain topographical situation (e.g., near riparian zones vs. ridges) will have differential effects on each species.

BACKGROUND INFORMATION

The Barred Owl apparently began dispersing westward from the eastern United States around the turn of the 20th century. Currently, the geographic range of the BAOW extends as far south as Marin County in California, just north of San Francisco. Field observations, while primarily incidental to ongoing research and monitoring of NSOs, strongly suggest that BAOW increases coincided with declines in populations of NSOs (Anthony et al. 2006).

Since 1989 NCASI field crews have detected a steady increase in BAOWs in the Springfield, Oregon study area. In surveys using voiced NSO calls (i.e., "hoots") to which at least one of the 2 species responded, the percentage of BAOWs responding increased from 3% of responses from 1989-1991 to 24 % from 2002-2006 During the same time period, the ratio of NSO detections to BAOW detections decreased from 44:1 to 3:1 respectively. In 2005, an estimated 35 % of all ***Strix*** owls that were detected in the area were BAOWs. Concomitantly, the number of sites found occupied by NSO pairs declined by 61%, from 54 to 21 since 1989.

Observations suggest that NSOs may be retreating to heterogeneous habitats in "matrix" forests, where suitable habitat is less abundant and/or the landscape may be less favorable for maintaining populations. These observations place a premium upon a detailed understanding of habitat-niche requirement of each species, to determine if judicious forest management might be capable of shifting environmental conditions to favor NSOs. We plan to build on previous observations and research by initiating a project with 2 inter-related studies in an area where Spotted Owl populations and habitat selection have been monitored since 1990.

Recent research efforts have revealed that details of forest structure, topography, basal area, tree species density and composition, and understory vegetation matter to spotted owls (Haufler and Irwin 1993; Irwin et al. 2000; Irwin et al. 2004; Irwin et al. 2007). Irwin (1998) pointed out that attributes of the physical environment (e.g., soil types, topography or landform, elevation, primary productivity) influence habitat quality for birds in general, and Haufler and Irwin (1993), Irwin (1994), Irwin et al. (2004) and Zabel et al. (2003) presented evidence that topography, aspect, and slope influence how NSOs use their habitats. Both Zabel et al. (2003) and Hicks et al. (2004) found that site index, a long-used indicator of productivity in forest management, was correlated with NSO habitat selection. Those studies suggest that, given that a forested stand contains appropriate vegetative structures (e.g., large trees, snags, hardwoods, coarse woody debris, understory shrubs), its overall quality depends upon *where* it is located, such as on the toe of a steep, north-facing slope or near the top of a gentle, south-facing slope. As in real estate sales, location matters greatly to spotted owls. Our study aims to determine how the same or different factors can be used to predict nocturnal habitat selection (i.e., hunting for prey) by Barred Owls and compare them to those for the NSO.

STUDY AREA

The study area lies on the western slope of the Oregon Cascades on BLM and private timberlands within or near the Eugene BLM Upper Willamette Resource Area, which contains the BLM's former McKenzie Resource Area. The forests are comprised predominantly of 25-80 year-old trees. The study area lies mostly within Lane County east of Interstate Highway 5, and west of a north-south line through Vida, Oregon. The study area encompasses approximately 20 townships (720 $miles^2$ or 460,000 acres). The BLM administers some 75,000-100,000 acres, private timberlands occupy an estimated 200,000 acres, and the remainder includes agricultural, residential, or small wood-lot owners. BLM lands in the area are managed under Matrix, AMA, Unmapped-LSRs (i.e., NSO core areas) and Riparian Reserve land allocations.

We selected the study area for several reasons. First, the study area is representative of several million acres of relatively young westside Douglas-fir/Western Hemlock forests that are likely to be manipulated by intermediate silviculture to reach various objectives over the next few decades. Second, we wanted to avoid potential interference with existing NSO demography study areas or other study areas. Third, there is a wealth of background information from the study area on NSOs in matrix/AMA forests. For example, NSO densities in the study area have been monitored intensively from 1990-1996 and were consistently partially or fully monitored (i.e., 3 or 6 visits per year) from 1997-2006 Fourth, NSOs in the area were monitored via radio-telemetry for several years. For example, extant data allow a comparison of NSO home range sizes in the presence of low (circa 1990-1992) and high (1998-2003) densities of BAOWs.

Furthermore, the study area contains a large number of individually-identifiable, leg-banded NSOs for comparison to previous distributions. Spotted owls have been banded and re-observed continuously in the area since 1990 and ≥ 80% of the adults are banded at known NSO nesting sites on private timberlands and BLM lands and some U.S. Forest Service lands. In addition, the proposed study area may represent a prime location for federal agencies to conduct a subsequent BAOW removal study or other research that cannot be conducted within existing NSO demographic study areas.

As described above, recent and ongoing research studies have demonstrated that details of forest structure, coarse woody debris, topography, basal area, tree species composition, understory vegetation, and tree density matter to NSOs. Ongoing habitat-inventory plot sampling, expected to be completed in the study area in 2007, will provide valuable data for documenting the influences of those details on NSO habitat selection by 20 birds, as well as for those BAOWs that use the same areas in the study proposed herein. Over the next few years, we should be able to evaluate of NSO initial responses to actual thinning within core areas by combining information at Springfield with that from 2 other study areas in Western Oregon (a total of more than 25 NSO home ranges). Funding has been approved for collection of additional forest habitat data for application to both species. Those efforts have resulted in an accurate, extensive, and detailed geo-referenced habitat database. To our knowledge, no similar detailed habitat database exists. Yet, such data are necessary for developing predictive resource selection function (RSF) models. These RSF models can be used as decision-support tools for forecasting the potential short- and longterm effects of forest thinning on both NSOs and BAOWs.

Despite checkerboard land ownership, the study area has been continuously surveyed for NSOs because of NCASI's ability to include private timberlands' data in survey/monitoring (mostly Weyerhaeuser Company and Cascade Timber Consultant lands). The forests also meet other requirements of the project that are limited within the NSO's range in Oregon. For example, the area has an extensive road system that provides adequate year-round access for accurate telemetry monitoring. Because NCASI is an independent, not-for-profit research organization supported by the forest products industry, its scientists can facilitate collegial research in areas of mixed ownership.

***History of Studies*--.** NCASI staff biologists have extensive familiarity with Eugene BLM forests and intermingled private timberlands and NSO sites as a result of conducting NSO surveys, monitoring, and telemetry studies since 1990. The following describes those activities:

1990-1992: Telemetry study of home range and habitat use at 12 owl sites (Irwin et al. 2000).

1992-1996: Demographic surveys that included monitoring circa 50 NSO sites and general surveys of habitat without NSO sites.

1997-2006: Nest-site surveys and partial monitoring on many of the NSO sites in the 1992-1996 effort.

1998-2003: Telemetry study of 11 additional NSO sites on the Eugene BLM within study area.

1990-1992, 1998-2003: Habitat-inventory plot data collected within known NSO home ranges and nest stands (analysis to be completed in 2007) – including 23 sites on the Eugene BLM.

I. DENSITY AND DISTRIBUTIONS OF BAOWs and NSOs

The primary goal of this study is to compare the current abundance (crude density, i.e., numbers/area surveyed) and distributions of NSOs and BAOWs with data collected in the same area from 1990-2005. In conducting intensive "blanket" surveys, we will document trends in populations of each species, and determine the occupancy status of historic NSO sites and current locations of leg-banded individuals that have not been located for several years because we only monitored previously-occupied or "known" sites. We also will determine if banded NSOs have moved to new nest sites in an apparent avoidance response to BAOWs by estimating the percentage of BAOW site centers or nesting locations that are former NSO nest-site locations or site centers. Specific objectives include the following:

1. Intensively survey and monitor NSOs and BAOWs on approximately 250,000 acres, including up to 60 previously-occupied NSO nesting sites and an estimated 20 BAOW nesting sites for two years (2007-2008).
2. Use accepted survey protocol to broadcast NSO calls by voice and recordings. Barred Owl calls would not be used in general surveys or monitoring NSO. Barred Owl calls may be used to determine BAOW nesting status and to capture individuals if such actions are deemed to not interfere with local spotted owl behavior. We recognize that this protocol may underestimate BAOW densities, because their responses would be incidental to seeking NSO responses. However, doing it this way provides an assessment of BAOW population trend.
3. For both NSOs and BAOWs, identify previously banded birds, and capture and attach color bands and uniquely numbered USFWS metal bands to unbanded individuals to the extent possible (BAOWs are more difficult to capture than NSOs).
4. Extract and store blood-droplet samples from brachial veins from all captured BAOWs for future DNA fingerprinting and for identifying blood parasites and presence of West Nile Virus (as funding allows).
5. Conduct standardized follow-up site visits to confirm occupancy, pair, nesting, and reproductive status for all NSO's found. Geo-reference all nest trees and measure habitat conditions at nest sites for all NSO's and attempt to locate BAOW nest sites for the BAOW's that are radio-tagged.
6. Provide regurgitated pellets to a cooperating investigator for comparison of diets of both species, emphasizing BAOWs at sites where BAOW's are radio-tagged (diet analysis was previously conducted for NSOs).

II. BARRED OWL NIGHTIME RESOURCE SELECTION

The second goal for this study is to quantify responses by BAOWs to variation in forest stand density, tree species composition, abundance of coarse woody debris, understory vegetation, and tree size-class distribution in a young and intermediate-aged forest landscape. Specifically, we will estimate a resource selection function (RSF) using data from detailed forest inventories and from nocturnal locations of radio-tagged BAOWs. RSFs (Manly et al. 2002) provide an optimal means of linking BAOW foraging behavior with their habitat and environmental conditions because RSFs combine multiple and interacting influences.

We will construct discrete-choice RSF models (McCracken et al. 1998; Cooper and Millspaugh 1999; Manly et al. 2002), which are appropriate for examining resource selection at the population level when available resources are measured uniquely for each individual. That is, each choice set is considered unique. Discrete-choice models also possess the advantage of accounting directly for habitat changes during a study, such as from wildfires or timber harvesting. Most importantly, the models provide the capability to forecast in advance the likely outcomes of alternative forest plans. This can happen because, unlike previous habitat-selection models that determined preference, neutrality or avoidance of seral stages or cover types, discrete-choice models estimate the relative probability of use of a forest stand with specified characteristics, such as basal area, tree density-by-size class, elevation, distance from roads, etc. Discrete-choice models have been applied to NSOs (McDonald et al. 2006) and to California Spotted Owls (Irwin et al. 2007). Currently, NCASI is building discrete-choice RSFs for Northern Spotted Owls in 6 study areas in western Oregon and northern California, which will allow for comparisons to RSFs for BAOWs.

We will radio-track BAOWs at night when they hunt most extensively. Foraging choices and other nocturnal behaviors such as territory maintenance should influence lifetime reproductive performance and survival (Newton 1979). We will therefore retrospectively identify the combinations of vegetative and physical environmental factors that comprise BAOW foraging habitat. Our primary goal involves estimating a RSF that will: a) include forest stand details so as to forecast short-term consequences of applications of commercial thinning; b) can be linked with forest-growth and other models to forecast longterm effects as forests grow. We hope, but cannot predict in advance, that the results might promote development of silvicultural prescriptions that may support conservation of NSOs. This study will also add to the growing database on BAOW food items.

Specific objectives include the following:

1. Capture and radio-tag 8-10 pairs of Barred Owls, emphasizing locations in close proximity to those where NSOs were radio-tracked from 1998-2003. Technically, it would be better if both the study area and the BAOWs were randomly selected; however, we are able to economize and capitalize upon previous work by being selective.
2. Measure detailed habitat conditions in BAOW home ranges, using variable-radius plots.
3. Using data from Objectives 1 and 2, develop a discrete-choice resource selection function for BAOWs and compare model variables and their coefficients with a similar RSF to be developed in 2007 for NSOs in the same area.
4. Prepare a habitat capability map for BAOW and compare it to a similar map for NSOs in the same area.
5. Compare fixed-kernel home range sizes of NSOs and BAOWs occupying the same area.

We will radio-track BAOWs beginning in February 2007 through December 2008 or January 2009 using standard methods described by Carey et al. (1989), Guetterman et al. (1991), and Millspaugh and Marzluff (2001). BAOWs will be located and captured using accepted procedures and animal-welfare protocol (Forsman 1983). Briefly, that will involve locating owls by imitating their calls or NSO calls, enticing them with pet-store mice (*Mus musculus*) or artificial decoys, and capturing them via mist nets in early breeding season or spring. We will attach backpack harness transmitters with a mass of 11.5g. These transmitters are expected to function for 2 years, although it is possible that some may need to be replaced during the study.

We will map the locations of each BAOW 2-3 nights per week each year to provide a reasonably large, spatially independent sample (Guetterman et al. 1991). This protocol should translate into some 100-200 telemetry points for each bird over the course of the study. Spatial correlation conceivably could influence standard errors of the RSF model, but not their estimated coefficients (McDonald et al. 2006). However, we anticipate that spatial correlation will be unimportant because BAOWs, stronger fliers than NSOs, should be capable of traversing much of their comparatively small home ranges within a 24-hr period. We will rotate the order of tracking each bird weekly to ensure a range in nocturnal (i.e., 1 hr after sunset to 1 hr before sunrise) sampling times. Most likely, we will also record diurnal locations (i.e., roosting sites) on an opportunistic basis. Locations will be obtained via hand-held, 3-element Yagi directional antennae (Wildlife Materials, Inc., Carbondale, IL or Telonics, Mesa, AZ). We will use methods similar to those of Glenn et al. (2004) and Irwin et al. (2007), in which we will triangulate BAOW positions from 3 strongest-signal azimuths recorded within a 10-minute period from geo-referenced receiving stations along access roads. Much of the geo-referencing has already been done in the recent NSO telemetry study. The extensive road system will mitigate many of the well-known radio-tracking problems by allowing field personnel to acquire most transmitter signals <200 m from the BAOWs.

Nocturnal BAOW positions will be mapped in the field and recorded on 1:24,000 topographic maps. If a triangulation polygon is >2 ha, the location will be discarded and another sample will be taken, most often the same night. We have previously assessed the accuracy of our telemetry system in the study area by placing transmitters at geo-referenced locations unknown to radio-tracking crews. Average distance to the estimated locations from the true locations was about 80m. We will assign habitat values to telemetry and random locations that are ≤100m from inventory plots and within 95% minimum convex polygon (MCP) home-ranges (Hayne 1949, Harvey and Barbour 1965). Fixed kernel and MCP home ranges will be estimated via program BIOTASS (Ecological Software Solutions, Urnasch, Switzerland). We will choose the smoothing parameter, or bandwidth, for fixed-kernel home ranges following Horne and Garton (2006), probably via the least-squares cross-validation method. In areas where BAOW home ranges intersect NSO home ranges from the previous study, we will estimate home-range overlap via utilization distributions (Fieberg and Kochanny 2005).

Estimating Discrete-Choice RSF Models--. We will estimate coefficients for the discrete-choice model by modifying a stratified Cox proportional hazards model, as described by Manly et al. (2002:208). The discrete-choice model is a special case of logistic regression such that the probability of a BAOW selecting the jth unit of land (e.g., a stand with specific habitat characteristics) from the ith choice set (i.e., 95% MCP home range of an individual BAOW) is proportional to an exponential function of the form: $w_{ij} = \exp(\beta_1 X_{1ij} + \beta_2 X_{2ij} + \ldots + \beta_p X_{pij})$, where the β-values are coefficients to be estimated and $X_{ij} \ldots X_{pij}$ are values of p-covariates that characterize independent vegetative and abiotic conditions measured in the stands within individual BAOW home ranges. To do so, we will compare habitat conditions assigned to telemetry points with those assigned to approximately 2-3 times as many randomly available points in each home range. For planimetric variables (e.g., elevation, distance to roads or streams) we will use a GIS to measure from the geometric centers of telemetry-error polygons and from random coordinate points. We will model male and female BAOWs separately because their foraging habitat-choices are anticipated to be independent, as they are assumed to be with NSOs (Glenn et al. 2004). We do not anticipate modeling separately new birds that may replace those that die or emigrate, because we assume their foraging choices would be independent of previous occupants.

By Spring 2007, we should have acquired forest inventory data for many BAOW home ranges, including such stand-density metrics as basal area by species or species group, quadratic mean diameter, overstory canopy cover, total tree density, and tree density by diameter class (West 1983, Long 1985, Lilieholm et al. 1993). Each measure provides a slightly different perspective of variation in stand density. We will also include physical environmental covariates (elevation, slope, aspect, distance from roads and streams) because we anticipate significant foraging in association with nesting locations and in riparian areas. It is likely that additional sampling will be required because the BAOW home ranges are unlikely to coincide completely with NSO home ranges that have been mapped. If so, additional funding may be required to support the necessary fieldwork.

The above-described covariates will be entered into plausible *a priori* nested models that represent multiple hypotheses to account for variation in habitat selection patterns across the BAOW population. We will use an information-theoretic process that includes Schwarz' (1978) Bayesian information criterion (BIC) to select the most parsimonious models, following Shono (2005) and McDonald et al. (2006). Differences in BIC values of ≥2 are generally considered to indicate that models are statistically distinguishable (Shono 2005). Quantifying the statistical effects of habitat and environmental factors should be useful in predicting responses by BAOWs to various silvicultural treatments that modify stand structure and composition (Irwin et al. 2007). Information on physical site descriptions could help in determining if it matters to BAOWs where silvicultural treatments occur (e.g., ridges vs. lower parts of slopes near riparian zones). Nocturnal habitat selection by BAOWs might vary between nesting and non-nesting seasons, so we will test for a seasonal effect via t-tests that compare coefficients of covariates in the final RSF model when re-estimated for nesting (1 Feb-30 Sept) and non-nesting (1 Oct-31 Jan) seasons. We will test predictive capabilities of the final model via a process similar to the k-fold cross validation described in Boyce et al. (2002). Briefly, that will involve iteratively excluding each choice set, re-estimating the final model from the remaining choice sets, and predicting telemetry locations of the excluded BAOW choice set. To do so, we will regress the observed number of telemetry locations in the excluded choice sets against the sample-size adjusted predicted number of telemetry locations in each of 20 equal-sized bins of relative probabilities, scaled to 1.0. Following Howlin et al. (2004), we can conclude that a model has good predictive abilities if the slope of the regression is >0.0 and not statistically different from 1.0; moderate if the slope is >0.0 but the 95% CI does not contain 1.0; and poor if the slope is not different from 0.0.

This telemetry study may be enhanced by 2 similar collaborative efforts that are in the planning stages for evaluating BAOW habitat relationships in different ecological settings, one in southwestern Washington and 1 in the redwood zone in northwestern California. If those studies are indeed initiated, similarities in objectives and methods would provide opportunities for combining datasets for answering additional questions, such as variation in home-range size in BAOWs. This study also complements somewhat similar work by Drs. Robert J. Anthony (Oregon State University) and Eric E. Forsman (USFS), who have proposed a comprehensive study in the Oregon Coast Ranges (*"Competitive Interactions and Resource Partitioning Between Northern Spotted*

Owls and Barred Owls in Western Oregon"). Their work will examine home range sizes, home range overlap, diets, resource partitioning, behavioral interactions, and survival rates of both owl species. Our project does not duplicate their efforts, yet there are certain field objectives and methods that may provide an opportunity to combine certain datasets in such a way that enhances the overall value of the several projects (e.g., for survival analysis).

III. PROGRESS TO DATE

Field crews captured and radio-tagged 13 Barred Owls at 11 sites in the Springfield study area, and have detected many additional Barred Owls. The radio-tagged Barred Owls have been triangulated regularly, and home range size estimates and distribution maps will be available by next year's report. Surveys for Spotted Owls in that study area have identified 17 sites that remain to be occupied. There are now 5 pairs and 12 single Spotted Owls in an area that in 1990 the area contained 54 sites that were occupied by 40 or more pairs of Spotted owls.

Spotted Owl Responses to Barred Owl Calls:

A Study Plan, 2 January 2007 (Abbreviated August 2007)

Larry L. Irwin, National Council for Air & Stream Improvement, Stevensville, MT

Dennis Rock, National Council for Air & Stream Improvement, Amboy, WA

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INTRODUCTION

Land and resource management planning for USDI Bureau of Land Management (BLM) and USDA Forest Service (USFS) Pacific Northwest forests may be hampered by the potential that forest management may exacerbate competitive interactions between Northern Spotted Owls (NSOs) and Barred Owls (BAOWs). The 2004 USDI Fish and Wildlife Service status review for NSOs, an expert scientist panel evaluation of the status of NSOs (Courtney et al. 2004), a meta-analysis on trends in demography of NSO populations (Anthony et al. 2006), and discussions associated with development of a Recovery Plan each identified the BAOW as a primary threat to NSOs. Here, we describe an opportunity to acquire useful information on NSO behavioral responses to imitated BAOW calls in NSO territories.

STUDY AREA

Our study area lies on the eastern slope of the Oregon Cascades on BLM, USFS and private timberlands within or near the Klamath Falls BLM District. BLM lands in the area are managed under Matrix, Unmapped LSRs (i.e., NSO core areas) and Riparian Reserve land allocations. We selected the study area to take advantage of an ongoing study of NSO habitat selection in the area. NCASI initiated one of its Adaptive Management Study modules there in cooperation with the BLM, USFS, USFWS and two private timber companies. Since 2002 NCASI crews monitored approximately 23 NSOs via radio telemetry. During those activities NCASI radio-tagged 2 Barred Owls at two different sites, and have monitored them the past two years. The Adaptive Management study there ended on March 1, 2007, at which point there were 7 NSOs still wearing tailmount radio-tags. These transmitters should continue emitting signals through summer 2007, providing a unique opportunity to acquire useful information with little cost. Specifically, we propose to conduct an experiment involving NSO responses to simulated Barred Owl calls within NSO territories.

OBJECTIVE AND METHODS

The primary objective of this case study is to quantify behavioral responses of NSOs, primarily movements and vocalizations, to simulated BAOW calls. We propose to broadcast BAOW calls 2-3 times each month within home ranges of individual NSOs that are radio-tagged. After triangulating NSO positions, we will listen for ten minutes and then we broadcast BAOW calls for 10 minutes within 100-400m of the NSO. After that, we will listen for and record NSO vocal responses for 10 minutes, resulting in a total of 30 minutes for each trial, after which we will triangulate and record the final position of the radio-tagged bird

Telemetry triangulations will allow field personnel to locate the NSOs in advance of calling and/or listening. We will call and/or listen from a distance of 100- 400m from the NSOs, assuming that we will be able to detect their vocalizations within that range. Individual owls that are monitored on any given night will be triangulated again 2 hours later, at which time the procedure will be repeated. This will allows us to acquire 2 potential vocal responses per trial and also document rate and direction of movement. Subsequently, the same birds are visited 3 days later, and we will reverse the process with NSO voiced-calls, and repeat the procedures stated above. This process will continue throughout the summer, or until the tail-mount radios are molted or their batteries quit functioning. Statistical analyses will involve paired t-tests of differences in numbers of vocalizations and movement distances (and direction) of treatment birds vs. control birds.

PROGRESS AND PRELIMINARY OBSERVATIONS

To date, we have conducted over 50 call-response trials at 4 separate Spotted Owls sites involving 7 radio-tagged NSOs in the Klmath Falls study area. Because the project was initiated in June of this year, we have no initial analyses of information to report. Anecdotal observations suggest, however, that male NSOs may at least occasionally move toward the imitated Barred Owl without vocalizing. At this point, we are uncertain how often such behavior occurs, how far the birds move, or if they respond to imitated NSO calls in the same manner.

FUTURE BARRED OWL ACTIVITIES

Another area where there is strong interest among resource professionals in conducting research on Barred Owls occurs near Eureka, California, on forests owned by Green Diamond Timber Company and lands within Redwood National Parks. Currently, a pilot effort has been mounted in which Redwood National Parks is monitoring a few radio-tagged Barred Owls. If sufficient finances can be acquired for a research study, the primary objectives would be similar to those in the study near Eugene, Oregon. However, we would hope to be able to track Barred Owls before and after extensive forest thinnings that apparently are being planned within the Redwood National Park system.

We may also extend the NSO-response-to-Barred Owl-calls project by implementing it at Coos Bay in 2008. We expect to re-capture those NSOs that moulted in 2007 in late summer and fall, replace their current backpack transmitters with tailmounted transmitter. If financing can be arranged, we would then have a large sample of birds for monitoring NSO responses to Barred Owl calls.

Below, we report new analyses for resource selection by NSOs at Study Area 4A near Yreka, California and at the adjacent Study Area 4B near Medford, OR. For this report, we developed discrete-choice models based upon 7,389 telemetry data locations and 20,188 randomly selected locations within home ranges of 44 spotted owls (18 owls at Yreka, 4A and 26 at Medford, 4B). These sample sizes may change slightly after data are filtered and analyzed in more detail. Both areas are within the Mixed Conifer zone dominated that by Douglas-fir and White fir stands. Randomly selected stands at Yreka (Study Area 4A) averaged 180 square feet of basal area per acre, whereas those at Medford were generally less dense, averaging 134 square feet of basal area per acre. However, the Medford study area contained more large trees (greater than or equal to 24 inches DBH) per acre on average (10.4 vs. 7.5).

Study Area 4A--. A discrete-choice RSF model for Study Area 4A at Yreka indicated that the same abiotic or planimetric variables as for CASPOs influenced NSOs. Spotted Owls spent more of their time foraging near nest sites or site centers and at lower elevations. The relative probability of use of a forest stand initially increased to a maximum level and then decreased with additional increase in basal area (i.e., hump-backed pattern) of Douglas-fir. A similar pattern was also observed for CASPOs near Chico, except that in 4A, the relative probability of use of a stand for foraging decreased with increases in basal area of white fir. Incense cedar basal area had a positive but unimodal influence on probability of foraging in a stand in that study area (hump-backed pattern), although it was not a strong covariate.

Study Area 4B--. To date, we have computed coefficients for approximately 35 discrete-choice models for Northern Spotted Owls at Medford. The top models for that area consistently demonstrated that planimetric variables were strong influences on foraging habitat selection by NSOs, as we observed by the Yreka study area and for CSOs at Chico, California. These planimetric variables include distance to nest (unimodal relation) and distance to streams (unimodal). Distance to nearest roads also had an influence in the model, via a unimodal pattern. As in Study Area 4A, basal area of Douglas-fir had a unimodal influence on foraging habitat selection, as did incense cedar basal area and basal area of hardwoods. We graphed the relation with Douglas-fir in Figure 1.

Because of similarities in study areas 4A and 4B and because of similarities in preliminary RSF models, we combined the data. The top model (to date) contained the following variables: distance to nest site, distance to road, distance to water, elevation, basal areas of Douglas-fir, white fir, incense cedar, and ponderosa pine. The pattern was unimodal for distances to nest sites and water, and negatively unimodal for distance to roads. There was a unimodal relation between relative probability of foraging and basal area of Douglas-fir and Ponderosa pine. Relations with white fir and incense cedar were linear and negative. This model appeared to have a high degree of strength, and has the form:

Relative Probability of Foraging = EXP(1.3e-4*DISTNEST –3.69e-8*DISTNEST^2 –9.05e-4*DISTROAD + 8.73e-8*DISTROAD^2 –5.19e-4*DISTWATER – 3.17e-8*DISTWATER^2 +2.34e-3*ELEVFEET – 205E07*ELEVFEET^2 + 6.67e-4*BASLD-FIR –4.29e-7*BASALD-FIR^2 –4.80e-4*BASALWFIR –5.28e04*BASALCEDAR +1.91e-6*BASALPINE –6.28e-6*BASALPINE^2).

The modeled relationship with basal area of Douglas-fir is shown in Figure 3.

DISCUSSION

Irwin et al. (2007) found a unimodal or "hump-backed" relation between California Spotted Owl habitat selection and combined basal areas of Douglas-fir, white fir and red fir. Their analyses suggested that, among other things, forest stands with basal areas of approximately 160-240 square feet/acre provide optimal foraging habitat for California spotted owls. Habitat quality is expected to decline at forest densities significantly above or below that range. Thus, there can be too many as well as too few trees. If the foregoing is true across much of the range of the owl, then reducing hazardous fuel densities by thinning and partial harvesting should improve habitat conditions over the long run, at least, and perhaps the short run as well (Verner et al. 1992). Preliminary analyses for NSOs in Mixed Coniferous forests at Yreka and Medford suggested similar relationships, although the optimal basal areas may be higher. Those data also suggested that white fir may have a depressing effect on the probability of a forest stand being used by NSOs for foraging. Hardwoods also are important, most likely through the relation between hardwood mast and fruit crops and abundance of bushy-tailed and dusky-footed woodrats. Overall, the data suggest there may be options for reducing fuel loads in a way that is not detrimental to spotted owls, and may actually improve foraging habitats.

The view that reducing fuel loads could improve owl habitat is also supported by data in Irwin et al. (2004), who found that forest stands dominated by young grand fir trees 13-19 cm in dbh had negative effects on owl reproduction and occupancy in Mixed Coniferous forests along the eastern slope of the Washington Cascades. There, abandonment of some 45 owl sites was correlated with the abundance of small, shade-tolerant grand fir trees that were slowly replacing Douglas-firs, which probably provide better conditions for the owl's prey or provide better protection against inclement weather and predators than grand fir trees.

In fact, Irwin et al. (2004) presented evidence that maintaining habitat quality for owls in Mixed Coniferous forests in their Washington study area may actually require some form of partial harvesting, owing to increasing risks of fire and successional changes in forest density and composition. Their analyses suggest that advancing succession toward a true-fir climax in "fire-adapted" forests, where climatic climax grand fir trees replace seral Douglas-fir trees, reduces habitat quality for NSO. This probably occurs via very high tree densities that reduce understory vegetation production, and thereby, densities of the owl's prey. Such a view suggests that **continuous cover forestry**, which has become common approach throughout Europe for maintaining biological diversity (Pommerening 2002), could become a useful paradigm for maintaining high-quality habitat for spotted owls, at least in fire-prone forests.

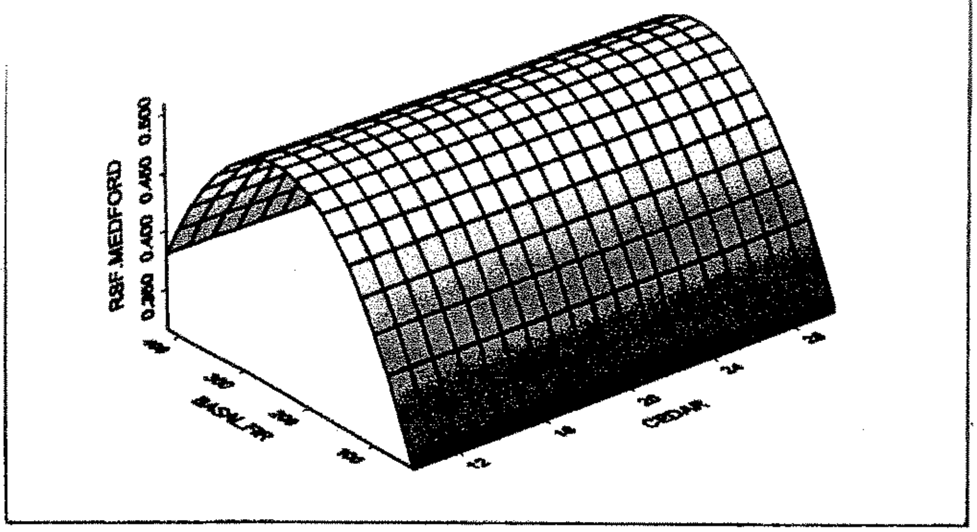

Figure 1. Graphic display of "best" Resource Selection Function for Study Area 4B at Medford, including combined basal areas of species of fir trees and Incense Cedar, while holding other model variables constant.

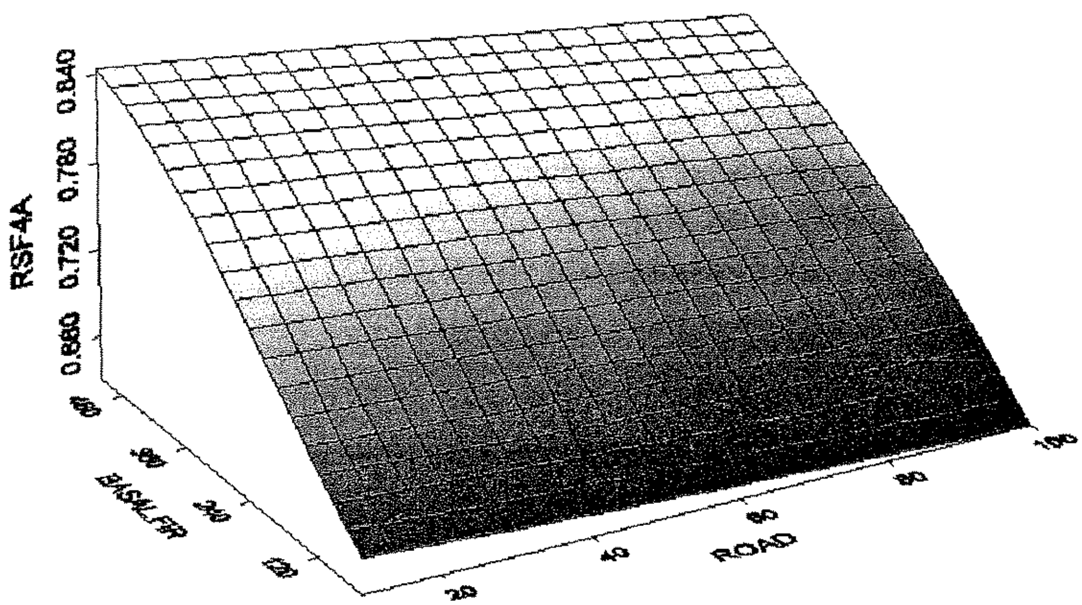

Figure 2. Influence of basal area of Douglas-fir and roads on relative probability of a stand being used for foraging (Y-axis) by northern spotted owls in combined study areas 4A and 4B.

SPOTTED OWL HABITAT SELECTION AND HOME RANGE IN CALIFORNIA COASTAL FORESTS[1]

[1] Habitat modeling reported herein could change with final analyses that incorporate habitat changes due to thinning during the study period. Likewise, home range size estimates may change and should also be considered preliminary.

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Draft Summary Report – June 2007

INTRODUCTION

Many landowners from northern California through Washington are expected to achieve certain forest management objectives via intermediate silvicultural treatments such as commercial thinning or partial harvesting. The objectives often are aimed at maintaining specific habitat-structural elements (e.g., large trees, snags, coarse woody debris) while promoting growth of large trees to account for the needs of the threatened northern spotted owl (*Strix occidentalis caurina*). However, such intermediate treatments could create short-term negative influences on northern spotted owls (Irwin and Thomas 2002). As a result, federal policy documents encourage a long-term view to identify possible future benefits of forest treatments that may create short-term impacts (U.S. Dept. Interior/U.S. Dept. Commerce 2002a, 2002b). In the case of northern spotted owls, new decision-support tools are needed for assessing risks associated with silvicultural treatments over short- and long term planning horizons.

In coastal redwood and Douglas-fir forests in California only McDonald et al. (2005) provided a habitat selection model that could help guide such comparative risk assessments. Their model included proportions of forest-age classes, and other spotted owl studies also compared spotted owl use among seral-stages or age classes or examined nest sites (e.g., Blakesley et al. 1992, Thome et al. 1997, Hunter et al. 1994). And Franklin et al. 2000 noted that a heterogeneous mix of forest stages resulted in greater overall population performance among spotted owls. Yet, thinning, partial harvesting practices or hazardous fuels reduction programs do not change seral forest stages. Instead, they modify stand density, vegetation composition, and/or tree size-class distributions. Moreover, seral-stage based habitat models, which are generally constructed from even-aged forestry concepts, have never provided satisfactory reliability for predicting wildlife population responses, at any scale (Short and Hestbeck 1995, Irwin 1998, DeGraaf 2002).

Therefore, we wanted to take an additional step by constructing a habitat selection model that would include stand-structural details such as basal area, snag density, abundance of coarse woody debris, tree density by size class, and species composition. These factors can be controlled by silviculturists, so an understanding of their relative effects on habitat selection is needed to construct a risk-assessment tool that can account for both short and long term effects.

Long term research programs that integrate wildlife biologists, foresters and land managers within an active adaptive management experimental framework are required to understand complex ecological processes in the context of sustainable resource management (Irwin and Wigey 1993, DeStefano 2002). Our 5-year project includes an integrated research program that involves both retrospective examinations and manipulative experiments to acquire much-needed information. We analyzed the data within a modern information-theoretic framework technical approach (Burnham and Anderson 1998). We monitored responses of northern spotted owls to existing conditions (i.e, a retrospective emphasis), and we also collected observations of owl behavioral responses to silvicultural thinnings that occurred within core areas of owl home ranges. Core areas are defined as those areas used disproportionately within home ranges. The project therefore involved both repeated observational experiments and manipulative experiments. Here, we summarize the extent of resource selection modeling results from a study near Ft. Bragg, California. We have yet to acquire details associated with forest thinning within core areas of owl home ranges, so results of spotted owl behavioral responses to that form of forest management will be reported at a later date.

GOALS

The general goals of our study included the following:

1. Develop a resource selection function (RSF) that can provide quantitative support for decisions over both the short and long runs regarding silvicultural applications in areas occupied by northern spotted owls;

2. Promote integrated conservation of northern spotted owls across the landscape mosaic of forests managed for commercial and non-commercial values; and

3. Evaluate northern spotted owl responses to commercial thinning or partial harvesting.

Here, we summarize telemetry data acquired from March 2000 through March 2005, along with habitat inventory information gathered subsequent to radio-tracking in 2005. The study was conducted under the appropriate California state research permit and a U.S. Fish and Wildlife Service Permit, TE-834385-3. Specific objectives included the following:

5. Estimate home range sizes and configurations;
6. Quantify stand-structural and abiotic factors that influence owl habitat selection at the home range and stand levels;
7. Estimate the sizes of core areas; and
8. Identify areas of concentrated use within home ranges that owls use for foraging.

BACKGROUND INFORMATION

Millions of acres of second-growth forests less than 60 years old exist in the Pacific Northwest and northern California (DeBell et al. 1997, Hayes et al. 1997). Many such stem-exclusion stage (Oliver and Larson 1990) forests are densely stocked. Such forests may provide current or future foraging habitat for spotted owls following thinning, partial harvesting or by virtue of legacy structures from previous stands or their proximity to riparian zones where owls forage extensively. For example, McDonald and McDonald (2002) identified an interaction in which young, pole-sized trees positively influenced use by spotted owls for foraging where such stands occurred in lower elevations near small streams. Moderate, variable-density thinning to a relative density of 0.35-0.45, commonly prescribed for increasing tree growth in the Douglas-fir/Western Hemlock (DF/WH) zone, appears to maintain or improve habitat quality for most species of small mammals (Carey et al. 1999) that are prey for spotted owls.

Thinning creates forest stands with more-open canopies, which immediately stimulates the development of herbaceous understory plants (Suzuki and Hayes 2003), including plants used by prey of spotted owls (Block et al. 2005). Relatively shortly after the herbaceous layer responds, the understory shrub layer may or may not also respond. Abundance of some species of small mammals is associated with shrub cover in forest stands (Carey and Johnson 1995, Hayes et al. 1995). Suzuki and Hayes (2003) found that, overall, thinning did not have substantial detrimental effects of any of 12 small mammal species they studied in coastal

DF/WH forests. In fact, the total number of small mammals was higher in previously thinned than in unthinned stands. Reproductive performance of deer mice (*Peromyscus maniculatus*), an important prey item for spotted owls, improved in the short term following thinning. Wilson and Carey (2000) found that deer mice and creeping voles (*Microtus oregoni*) were more abundant in thinned DF/WH stands than in unthinned stands, even though the unthinned stands were managed to retain large-diameter trees, downed wood and snags.

Moreover, Ransome and Sullivan (2002) found that commercial thinning had no negative short-term effects on population dynamics of northern flying squirrels (*Glaucomys sabrinus*) in 60-70 year old coastal DF/WH forests in British Columbia. Their study occurred immediately after thinning and before any large changes in understory vegetation development and changes in stand characteristics (increased diameters, thicker crowns, increased tree growth, etc.). But there may be a great deal of variation, as Carey (2000) found that a 70-year old unthinned stand contained more flying squirrels than similarly aged stands that had been commercially thinned twice. However, the unthinned stand in Carey's study had numerous residual large snags and remnant live trees, which were absent or few in the thinned stands. Overall, these results support a view that proactive thinning and legacy retention may promote owl use of managed stands. Yet, the only published study to date that reported direct response by spotted owls to thinning was a case study of 1 radio-tagged male spotted owl in northwestern Oregon (Meiman et al. 2004). There, the owl apparently avoided recently thinned stands. However, other owls in that study area frequently used stands that had been thinned in the past (Anthony et al. 2000). Perhaps there is a lag period before thinned stands result in benefits to spotted owls.

Wilson and Carey (2000) noted that forests managed via thinning had 50% more individual small mammals and 70% more small mammal biomass than forests managed with legacies of coarse woody debris and large snags. While neither thinning nor legacy retention is necessarily likely to support the same small mammal communities typical of late-successional forests (Wilson and Carey 2000), young DF/WH forests that have been so managed should be considered to contribute to spotted owl habitat at least until forest crowns close and begin crowding out the understory again. Across a dynamic landscape, stands thinned at varying times could conceivably provide suitable foraging habitats more or less continuously. Juxtaposition of thinned stands relative to existing old-growth stands could be a key to effectiveness.

Less information seems available on animal response to thinned stands in coastal redwood and mixed redwood and Douglas-fir forests. However, there may be more latitude for managing these forests to benefit spotted owls because of the presence of bushy-tailed and dusky-footed woodrats (*Neotoma cinerea* and *N. fuscipes).* Bushy-tailed woodrats were 5 times more abundant in Mixed Coniferous forests than in DF/WH forests (Carey et al 1992). Densities of woodrats in streamside zones in mixed forests were 4 times greater than those in DF/WH forests. Although dusky-footed woodrats in Carey's et al. (1992) study were often absent from patches of young forest, they were 2-3 times more abundant in young, stem-exclusion stage Mixed Coniferous forests and streamside forests than in upland old forests. Carey and Peeler (1995) concluded that, where dusky-footed woodrats are abundant, owls should preferentially use units of young forest near their core areas.

Working in northwestern California, Ward et al. (1998) found that spotted owls selected edges between late-successional forests and young forests where dusky footed woodrats were more abundant. Franklin et al. (2000) subsequently confirmed the importance of young, "brushy-stage" clearcuts when they found that the length of linear forest edge was correlated with owl reproductive success and survival in northwestern California. Similar results have been reported for western Oregon's Mixed Conifer forests near Roseburg (Olson et al. 2005) but not in others (Dugger et al. 2005). Apparently, spotted owls frequently select foraging habitat according to the distribution of woodrats, which the owls apparently acquire near the ecotones between late and early seral (15-40 year) forests (Sakai and Noon 1997). Sisco (1990) recorded foraging use *within* shelterwood-harvested units in winter, as opposed to use only along edges, by 2 radio-tagged owls (24.1% and 19% of telemetry locations) in the Six Rivers National Forest, California. In such forests, the optimal environment apparently includes a moderately heterogeneous landscape with older forest patches, which confer greater survival, interspersed with young, brushy-stage forest patches, which confer greater reproductive success (Franklin et al. 2000).

Irwin et al. (2007) found a unimodal or "hump-backed" relation between California spotted owl (*Strix occidentalis occidentalis*) habitat selection and combined basal areas of Douglas-fir, white fir and red fir. Their analyses suggest that, among other things, forest stands with basal areas of approximately 160-240 square feet/acre provide optimal foraging habitat for spotted owls. Habitat quality for foraging by California spotted owls is therefore expected to decline at forest densities significantly above or below that range. Thus, there may be a range of basal areas that provide optimal conditions above which there can be too many trees. If the foregoing is true in the coastal redwood and mixed redwood and Douglas-fir forests, then thinnings and partial harvesting of dense stands have potential to improve habitat conditions for spotted owls over the long run, at least, and perhaps the short run as well (Verner et al. 1992).

RSF MODELS CLARIFY HABITAT RELATIONS

A primary objective of this project involves developing a resource selection function, or RSF, that summarizes factors that influence foraging habitat selection by spotted owls. For the analyses presented here, we estimated log-linear models using coefficients from discrete-choice RSF models (Manly et al. 2002, McDonald et al. 2006) within which data for all owls within a study area are evaluated as "choice sets" to identify a common set of factors. We assume that habitat selection links spotted owl populations with their environments because selection of a habitat affects the balance of costs and benefits associated with alternative choices (Partridge 1978, Rosenzweig 1991). Ultimately, demonstration of viability requires linking owl population dynamics with habitat conditions, summed across owl territories at the landscape scale (Boyce et al. 1994, Boyce et al. 2005).

To our knowledge, only Irwin et al. (2007) and this study have developed RSF models for spotted owls that include structural variability and vegetation composition within forest stands. Previous telemetry studies of habitat relationships among spotted owls generally compared owl use of forest habitat conditions on the basis of categorical descriptions of forest successional stages (e.g., clearcut, plantation, pole, young, mature, old) or age classes. In developing logistic regression models for spotted owls in western Oregon, Glenn et al. (2004) found that such seral stages accounted for only a modest amount of the variation in habitat selection. Discrete-choice models differ in that they can estimate the relative probability of use of a specific forest stand, given its location, topographic position, vegetation composition, and structural details. This is truly a great advantage for relative risk assessments, and it is unquestionably more satisfying than previous models that used broad vegetation classes. Our goal was to identify the combinations of vegetative and physical environmental factors that comprise nocturnal foraging habitat, because food acquisition is a primary influence of population performance in birds of prey (Newton 1976). Therefore, we wanted to develop a RSF that could:

1) Include forest stand details so as to forecast initial consequences of applications of partial harvesting;
2) Forecast long term effects when the RSF model is linked with forest-growth and other models;
3) Promote silvicultural prescriptions that may support conservation of spotted owls in managed forests; and
4) Clarify vegetative and abiotic influences on spotted owl habitat selection.

This report contains preliminary information on habitat selection and home range size. Information on habitat conditions after several areas were thinned within core areas of owl home ranges was unavailable, which precluded more detailed analyses. That information will be provided at a later date.

STUDY AREA

This study was part of a larger program that employed a repeated, or multiple study-area approach (Johnson 2002), in which we radio-tracked spotted owls in 9 study areas (Figure 1). The Ft. Bragg study area, shown as Study 7 in Figure 1, was implemented on the Jackson Demonstration State Forest, which is administered by the California State Department of Forests and Fire, and on adjacent private timberlands, most of which were owned by Mendocino Redwood Company and The Campbell Group. The forests occur within the California Redwood Zone. The area is dominated by coastal redwood (*Sequoia sempervirens*) and mixed redwood and Douglas-fir (*Pseudotsuga menziesii*) forests, with some mixed Douglas-fir and oak woodlands (Zinke 1988). Many of the redwood and Douglas-fir stands contained evergreen hardwood components such as tanoak (*Lithocarpus densiflorus*), madrone (*Arbutus menziesii*), California bay (*Umbellaria californica*), as well as other species such as red alder (*Alnus rubra*) and California black oak (*Quercus kelloggii*). Many of the original old-growth forests in the study area were completely logged after the turn of the 20th century, so current forests are a mixture of recent clearcuts, scattered select cuts, second- and third-growth stands. Remnant old-growth trees or small (3-5 acre) patches of old-growth forest remain in some places, but there are no large old-growth groves. The climate is dominated by a maritime system that creates cool summers and mild, wet winters with high humidity and fog as common features. Elevations range from sea level to about 800m, with the mountainous areas characterized by steep slopes.

METHODS

We radio-tracked spotted owls from March 2000 through March 2005 using standard methods described by Carey et al. (1989), Guetterman et al. (1991), and Millspaugh and Marzluff (2001). We located and captured spotted owls using accepted procedures and animal-welfare protocol (Forsman 1983). Briefly, that involved locating owls by imitating their calls, enticing them with pet-store mice (*Mus musculus*), and capturing them via noose poles or by hand in early breeding season or summer. We attached backpack-harness transmitters of 7.5- to 8.0g mass because there were concerns about the possible effects of previously-used 19- to 24g backpack-mounted transmitters on owl reproduction and perhaps survival (Paton et al. 1991 and Foster et al. 1992). The smaller transmitter packages that we used apparently do not negatively influence spotted owl reproductive success (Irwin et al. 2000) or survival (Loehle et al. 2005). We recaptured radio-tagged owls and fitted them with new transmitters annually. We monitored all birds for nesting attempts and reproductive success.

We mapped the locations of each owl 2-3 nights per week yearlong to provide a reasonably large, temporally independent sample (Guetterman et al. 1991). Although weak spatial correlation could influence standard errors but not estimated coefficients (McDonald et al. 2006), we concluded that spatial correlation was nil because spotted owls are capable of traversing much of their home ranges within a 24-hour period (Forsman et al. 1984). We rotated the order of tracking weekly to ensure a range in nocturnal (i.e., 1 hour after sunset to 1 hour before sunrise) sampling times for each bird. We recorded diurnal locations opportunistically. We obtained locations via hand-held, 3-element Yagi directional antennae. We acquired receivers from Wildlife Materials, Inc., Carbondale, IL and Telonics, Mesa, AZ. We used methods similar to those of Glenn et al. (2004), in which we triangulated owl positions from 3 strongest-signal azimuths recorded within a 10-minute period from geo-referenced receiving stations along access roads. The extensive road system helped mitigate many of the well-known radio-tracking problems by allowing field personnel to acquire most transmitter signals <200 m from owls. We mapped locations in the field and recorded them on 1:24,000 topographic maps. If a triangulation polygon was >2 ha, we discarded the location and recorded another sample, usually the same night. We assessed the accuracy of our telemetry system by placing transmitters at geo-referenced locations unknown to radio-tracking crews. Average distance to the estimated locations from the true locations across the project 84m (SD = 16.1 m).

We obtained habitat-inventory data from Jackson Demonstration State Forest, who inventoried their forests in 2005, and we inventoried associated private timberlands in 2005. After iteratively finding little variation in RSF coefficients from initial analyses of a few habitat variables at 60 m, 80 m, 100 m, and 120 m from geo-referenced, variable-radius inventory plots (40 BAF prism), we assigned habitat values that were ≤120 m from telemetry and random locations and within 95% minimum convex polygon (MCP) home-ranges (Hayne 1949, Harvey and Barbour 1965). We estimated 50%, 75%, and 90% fixed kernel home ranges via program BIOTASS (Ecological Software Solutions, Urnasch, Switzerland). We used the default smoothing parameter for bandwidth. Home ranges and locations of inventory plots on Jackson Demonstration State Forest are shown in Figure 2.

RSF MODELS

We estimated discrete-choice RSF models to predict foraging habitat selection by spotted owls based upon the sets of forest vegetative features and physical environmental covariates available within individual home ranges. The choice of a template for estimating resource availability is not standardized; we chose the 95% MCP, which assumes that a small proportion of telemetry points may be outliers and the remainder capture the areas actually traversed during normal behaviors for foraging, sheltering and nesting. Discrete-choice RSF models (McCracken et al. 1998, Cooper and Millspaugh 1999, Manly et al. 2002) are appropriate for examining resource selection at the population level when available resources are measured uniquely for each individual. That is, each choice set of used and random points is distinct. Discrete-choice models therefore avoid the additional step estimating individual-based models and then averaging coefficients across all animals to arrive at a population-level model (e.g., Glenn et al. 2004). Discrete-choice models also provide the capability of accounting for habitat changes during a study, such as from wildfires or timber harvesting.

We acquired a single random sample of available choices within each choice set. Classic discrete choice models assume that when a choice is made from each of several sets of units, a new random sample of available units is taken (Manly et al. 2002). However, McDonald et al. (2006) showed that a simplified discrete-choice model based upon a single random sample of available units yields valid results. We estimated coefficients for the discrete-choice model by modifying a stratified Cox proportional hazards model in S-PLUS (Mathsoft 1999), following Manly et al. (2002).

The discrete-choice model is a special case of logistic regression such that the probability of selecting the jth unit from the ith choice set is proportional to an exponential function of the form: $w_{ij} = \exp(\beta_1 X_{1ij} + \beta_2 X_{2ij} + \ldots + \beta_p X_{pij})$, where the β-values are coefficients to be estimated, and $X_{ij} \ldots X_{pij}$ are values of p-covariates that characterize independent vegetative and abiotic conditions measured on the jth units of the ith choice sets (i.e., individual owl home ranges). To do so, we compared habitat conditions assigned to telemetry points with those assigned to ~ 2 times as many randomly available points in each choice set, following Irwin et al. (2007). For planimetric variables (e.g., elevation, distance to streams) we measured from the geometric centers of telemetry-error polygons and from random coordinate points. We modeled male and female owls separately, although we could not be assured that their foraging habitat-choices were necessarily independent (Glenn et al. 2004). In several cases, we estimated separate models for new birds that replaced those that died or emigrated, because we assumed their foraging choices would be independent of previous occupants. In a few cases, we had insufficient data to estimate home ranges for replacement owls, so their telemetry points were added with those of previous occupants of the same sex, again assuming their locations would be independent.

We acquired forest inventory data for stand-density metrics (Table 1) including basal area by species or species group, quadratic mean diameter, overstory canopy cover, total tree density, and tree density by diameter class (West 1982, Long 1985, Lilieholm et al. 1993). Each measure provides a slightly different perspective of variation in stand density. We included physical environmental covariates (distance to nest, elevation, slope, aspect, distance from roads and streams) because we anticipated significant foraging in association with nesting locations, which often are found near lower portions of slopes (Courtney et al. 2004).

We used biological knowledge and local experience to identify covariates for plausible *a priori* nested models that represented multiple hypotheses that might account for variation in habitat selection patterns, following Glenn et al. (2004). We used Schwarz' (1978) Bayesian information criterion (BIC) for selecting the most parsimonious models, following Shono (2005) and McDonald et al. (2006). Differences in BIC values of ≥2 are generally considered to indicate that models are statistically distinguishable (Shono 2005). The literature indicates that nocturnal habitat selection by spotted owls would be associated with convoluted topography, areas in productive vegetation types along riparian zones, specific vegetation composition, forest stands near nest sites, tree density, and forest structures believed to influence populations of the owl's prey (Thomas et al. 1990, Verner et al. 1992, Haufler and Irwin 1993, Courtney et al. 2004, Glenn et al. 2004, Irwin et al. 2007). Quantifying the effects of such factors should be useful in predicting responses by owls to various silvicultural treatments that modify stand structure and composition (Verner et al. 1992). Information on physical site descriptions and interactions (McDonald and McDonald 2002) could help in determining if it matters to owls where silvicultural treatments occur (e.g., ridges vs. valley bottoms).

Plant communities or tree species relatively near streams should contain a greater abundance of prey via a greater expression of understory vegetation (Carey et al. 1992). We presumed that elevation would be a factor because of a shift in vegetation composition at higher elevations that may disfavor woodrats. Forests in lower elevations exhibit greater prey biomass, at least in southwestern Oregon (Carey et al. 1992). Woodrat populations likely are influenced by mast- or fruit-producing hardwoods such as oaks (Atsatt and Ingram 1983), so we included basal areas of various hardwood species. Woodrats also are strongly associated with riparian zones (Anthony et al. 2003), and Haufler and Irwin (1993), Irwin et al. (2000), Glenn et al. (2004), and Irwin (2007) observed that spotted owls frequently used riparian zones for foraging. Therefore, we postulated that distance from streams would be an important correlate.

In addition, we hypothesized that basal area of specific tree species such as redwoods or Douglas-fir would influence owl foraging behavior because of the presence of arboreal or semi-arboreal small mammals such as red tree voles or flying squirrels, which also are important prey species (Carey 1991). Further, spotted owls nest most frequently in Douglas-fir trees (Buchanan et al. 1993, Hershey et al. 1998). Spotted owls are considered central-place foragers (Carey and Peeler 1995, Rosenberg and McKelvey 1999), so we hypothesized that distance to nest sites would be an important influence (McDonald and McDonald 2002, Glenn et al. 2004), at least in years when nesting occurs. Also coarse woody debris is also known to be important to foraging spotted owls (Irwin et al. 2000). We acquired data on densities of large snags and downed wood, but that information is not presented herein. We will integrate those data at a later date. We did not examine landscape-pattern metrics, such as indices of forest fragmentation because we were sampling within-stand characteristics. Also, we did not measure landscape-pattern metrics because Meyer et al. (1998) were unable to detect effects of fragmentation indices except size of old-forest patches on territory selection or occupancy by northern spotted owls in western Oregon.

There are enormous possible combinations of variables in models that could include >20 covariates, their non-linear transforms, and possible interactions. To guard against a "fishing expedition" in which some spurious variables might be identified, we limited the number of models that we examined by proceeding in stages and by employing BIC to optimize the number of covariates that could be supported by the data. The order of including truly independent variables doesn't affect the outcome (Irwin et al. 2007), so we arbitrarily initiated the modeling process by identifying the 5 top models that included up to 6 continuous planimetric or physical environmental covariates, including their quadratic, cubic, and natural-log transforms. Aspect was modeled by trigonometric functions (Stage 1976).

We then selected the 5 top models among those that included the several habitat factors, also including their linear and non-linear transforms. We considered basal area, total tree density, and quadratic mean diameter in separate models because they were correlated. We subsequently added the density of small- and large trees (see Table 1 for habitat variables examined) to the models that contained stand-density measures because Irwin et al. (2004) found a negative correlation between small-diameter trees and reproduction and site occupancy of northern spotted owls in mixed coniferous forests in Washington and because numerous studies demonstrated a close association between northern spotted owls and large trees (Thomas et al. 1990). After that, we constructed 25 models that integrated the best 5 models with planimetric variables with the top 5 habitat-only models. We selected the top several models among those combinations for further consideration.

We sub-divided total basal into component basal areas and densities of specific hardwood and coniferous species to represent variation in composition. In the final analyses, we will consider several extra models that include suspected interactions between planimetric variables and vegetation covariates, because McDonald and McDonald (2002) found that use of tree-size classes by a northern spotted owl pair in western Oregon varied with elevation. Finally, we will examine whether habitat selection might vary between nesting and non-nesting seasons. Call et al. (1992) found that California spotted owls used different habitats in those seasons. Testing for a seasonal effect will involve using t-tests to compare coefficients of covariates in the final RSF model when re-estimated for nesting (1 Feb-30 Sept) and non-nesting (1 Oct-31 Jan) seasons.

Model validation.—For final analyses, we plan to test predictive capabilities of the best model (or models) using a process similar to the k-fold cross validation described in Boyce et al. (2002). That will involve iteratively excluding each choice set, re-estimating the final model from the remaining choice sets, and predicting telemetry locations of the excluded choice set. To do so, we will regress the observed number of telemetry locations in the excluded choice sets against the sample-size adjusted predicted number of telemetry locations in each of 20 equal-sized bins of relative probabilities, scaled to 1.0 by dividing by the largest value.

Following Howlin et al. (2004), we can conclude that a model had good predictive abilities if the slope of the regression is >0.0 and not statistically different from 1.0; moderate if the slope is >0.0 but the 95% confidence interval does not contain 1.0; and poor if the slope is not different from 0.0.

RESULTS

TELEMETRY DATABASE

We captured and radio-tagged 25 northern spotted owls, beginning in March 2000. We tallied 4,197 telemetry locations on those owls through February 2005, and recorded inventory information from an associated 7,323 variable-radius plots. Excluding some owls with limited telemetry locations, using 95% MCP home ranges, and our requirement of a random point or owl telemetry point being within 120m from habitat plots (based upon telemetry error and iterative analyses) reduced the number of telemetry and random points that we were used for RSF analyses to 3,822 telemetry points and 6,247 random locations within owl home ranges. We detected one barred owl (*Strix varia*) during the study. At the request of JDSF personnel, we captured that bird, and attached a tail-mount radio transmitter to it so that JDSF could follow it. However, we have no knowledge about its movements. The following description of owl site locations provides details regarding fate and reproductive success of several owls, the replacements for which were captured and radio-tagged, or describes why certain sites were dropped from further work:

South Fork Noyo River--. This was the first territory where we captured spotted owls. It is located on Campbell/Hawthorne ownership, and includes adjacent residential parcels. Both owls at the site were captured and fitted with radio-transmitters in spring of 2000. The pair attempted nesting but failed that year. The female was found dead on 31 July 2000. The carcass was decomposed, so the cause of death was undetermined. The male was also found dead on 17 October 2000 within days of dying. It appeared that he had starved as a result of a broken leg, which would have made foraging extremely difficult, if not impossible. That site was not occupied until 2001. In the intervening period, the landowner implemented a series of clearcuts near the site center. Those activities were beyond the scope of the study, so we decided not to capture the replacement owls at that site and the site was dropped.

Dead Man's Trestle--. This territory is within the Jackson State Demonstration Forest. We began with capturing and fitting a radio-transmitter on the male on 6 April 2000. The female there was captured and radio-tagged on 30 April 2000. The pair nested and fledged 2 owlets that year. The pair nested again in 2001 and fledged 2 more young. In fall 2001 the female disappeared and was never relocated again. On 27 February 2002 a subadult female was found roosting in the site center with the male. We captured and radio-tagged her, but she was found dead on 22 April. The carcass was sent to the forensics lab in Davis, who reported that parasites contributed strongly to its death. The report did not attribute the mortality to the radio transmitter. We captured yet another female there on 11 November 2003. The pair nested in 2004 and fledged 1 young. The female's radio stopped transmitting in summer 2004, and we were unable to re-capture her and replace the transmitter. The pair attempted nesting in 2005, but failed to produce young.

Sointula Gulch--. This territory is on the ownership of Campbell/Hawthorne, and the birds use adjacent timberlands owned by Mendocino Redwood Company and individual private owner. The male was captured and radioed on 6 April 2000, and the female was radio-tagged on 1 May 2000. That year, the pair nested and fledged 2 owlets. The pair attempted to nest again in 2004, but the nest failed. The male's radio-transmitter signal disappeared in the fall 2004. We suspect a new male may have occupied the territory in 2005.

Elk Creek 3--. This territory is located on Mendocino Redwood Company lands. We initiated work there on 2 May 2000, but after only a few months of telemetry we re-captured the birds and removed their radios because a planned timber operation in the territory would have conflicted with the objectives of the study. Company personnel apparently did not understand the requirements of the study until later.

North Fork James Creek--. This territory center is located in a small patch of old forest in Jackson State Demonstration Forest, and the birds have foraged on adjacent Mendocino Redwood Company lands and those owned by Coastal Ridge Forests. Work there began by capturing and radio-tagging the male in May 2000. The pair nested and fledged 2 young that year. In 2001 the pair again nested, fledging 2 young. That year, the female was captured and fitted with a transmitter. The pair made another nesting attempt in 2004, but that failed. The pair nested in 2005 and fledged 1 young.

Caspar Creek--. This territory is located on Jackson State Demonstration Forest. We captured the male there on 31 May 2000, and we captured and radio-tagged the female on 14 June 2001. The pair nested in 2002 and fledged 1 young. The original male was replaced in 2004 by a 2001 fledgling from Dead Man's Trestle. The replacement male was fitted with a transmitter on 4 August 2004. We recaptured the original male and removed his radio on 14 May 2004. At that time he had become a "floater", yet was observed within 50 meters of the 2004 nest tree at Dead Man's Trestle. The new pair attempted to nest in 2005, in the same tree as used in 2002, but failed. We detected a barred owl at the edge of this site.

Peterson Gulch--. This territory is located on Jackson State Demonstration Forest. We began work there by radio-tagging the male on 7 August 2000. The pair was observed with 2 fledged young on 30 June 2000, but the nest tree was not found. The pair nested again in 2001 and fledged 1 young. We captured and radio-tagged the female on 11 June 2001. The pair attempted a nest in 2004, but failed to produce young. They nested in 2005 in the same tree as in 2004 and fledged 2 young.

South Fork Big River--. This territory is located on timberlands owned by Mendocino Redwood Company. We captured and radioed the pair on 12 July 2000. They were originally observed with 2 fledglings near their site center, but that nest tree location is not known. The same owls at this site had been radio-tracked in the early 1990s as part of a larger telemetry study in the area. In fact, the most telemetry locations in that study were recorded at this site. The pair nested in 2002 and fledged 1 young. The 2002 nest tree was a large--diameter redwood with a large side cavity. In 2004, the pair attempted to nest using an old raptor nest atop a small diameter (<7") tan oak. There were numerous problems with the radios in 2004 and no signals were recorded the late summer/fall. In a walk-in visit to the site center in spring 2005 we found a single unbanded female. We do not know what happened to the original pair.

Bowman Gulch--. This territory is located on Mendocino Redwood Company timberlands. We captured and radio-tagged the female 28 July 2000, at which time she was found with 1 fledgling. We did not locate the nest tree. We did not observed the male at this site, although he vocalized on several walk-in, follow-up visits on the female. The female's radio quit transmitting that fall. Extensive searches in the area did not detect any additional signals or identify either member of the pair. We did not detect any owls there during follow-up surveys of the area in 2001, so we dropped the site from the study.

North Fork Camp--. This territory is located on Mendocino Redwood Company timberlands. We captured and radio-tagged the male 31 August 2000, and radio-tagged the female on 11 June 2001. The pair nested in 2001 and fledged 1 young. This territory appeared to exhibit the most turnover among owls within the study area. We found the first female dead on 12 July 2001. The radio-transmitter quit functioning weeks earlier, so we were unable to locate that owl during that time. The only remains of that bird were the leg-bands and some feathers. We captured and radio-tagged a second female there in July 2002. On 25 July 2002, we found the original male dead, apparently a result of predation. Throughout the remainder of 2002 the female appeared to be alone, and by spring 2003 she began acting like a floater and became difficult to locate. We identified a new pair in the site center in April 2003. We recaptured and radio-tagged the new birds on 2 June 2003. The second territorial female remained in the territory as a floater, and her radio was removed on 20 July 2003. In early 2004 these birds became increasingly difficult to locate, and on 31 March 2004, we detected a new pair of owls in the site center. On 4 May 2004 we found a new female at the site and fitted her with a transmitter package. We did not capture the new male with her. In fall 2004 we observed a spotted owls on the road near the site center. It was not banded, so we tried to capture it. Minutes later, while recording the location of the female via telemetry, we heard her hooting with a male, so we presumed the owl on the road was a floater in the territory.

Berry Gulch--. This territory is on Jackson State Demonstration Forest. We captured and radio-tagged the male 21 April 2001, and radioed the female on 11 June 2001. The pair nested that year and fledged 1 young. The pair nested again in 2004, but failed to produce young. They again nested in 2005 but we were unable to determine if they successfully fledged young.

Telemetry data--. Of the 25 spotted owls that were radio-tagged, we monitored 9 owls for 4 or more years each; five were monitored 3 to 4 years; eight were monitored for 1 to 2 years; and we tracked the remaining 3 for less than a year (Table 2). All of the owl pairs that provided the primary data for this study nested successfully at least once during the study. We summarize the number of birds monitored, telemetry points recorded, and numbers of random inventory points within home ranges in Table 3 for 23 choice sets. The number of telemetry points per set ranged from 31 to 325, and we recorded over 100 telemetry points for 15 of those choice sets.

We show overall habitat conditions within the choice sets in Table 4. Compared to random points nocturnal telemetry points on average were associated with forest stands that contained greater basal areas, more basal area of redwood, higher densities of tanoak, and greater densities of trees > 26 inches DBH. Nocturnal foraging locations also were lower in elevation and were at lower distances from nest sites, on average.

HOME RANGE ESTIMATES

Home range sizes for each study site--. In Table 5, we list site-specific annual home range sizes based upon fixed kernel (FK) home range algorithms. For the 90% FK, annual home ranges varied from 159 to 1,685 acres, but the average 90% FK home range for each year did not vary highly. We found averages of 780, 761, 810, 802, and 681 acres from 2000 through 2004, respectively. Across all 5 years, the 90% FK home range averaged 767 acres. We found that the 75% FK home ranges size varied from 63 to 974 acres across all estimates, but the average 75% FK from 2000 through 2004 was 359, 348, 361, 394, and 316 acres. Across all years the average 75% FK home range was 356 acres. For our estimate of core areas, that is the 50% FK home range, areas occupied from 2000 though 2004 ranged from 25 to 339 acres. However, average core areas varied little and were 133, 122, 139, 146 and 119 acres from 2000 through 2005, respectively. The overall core area average for all years was 132 acres.

HABITAT SELECTION MODELING

Abiotic factors--. We found several physical environmental factors, or abiotic factors, that emerged as important influences on habitat selection by spotted owls for foraging. As expected from other studies, distance to nest site was a strong influence, and the relation was non-linear. That means that the relative likelihood of use of a specific forest stand for foraging diminishes increasingly rapidly with distance from nests. This relationship is expressed quantitatively by the average 50% fixed kernel home range, where owls spent most of their time hunting for prey: 50% of the use was concentrated within 132 acres, which comprised 17% of the average annual home range. We also found that the relative probability of use by spotted owls decreased with increasing distance from small streams and with increasing elevation. Both of the latter relationships also appeared to be non-linear. Finally, we found that the relative probability of use for foraging increased with increasing distance from roads. However, the average distance from roads for telemetry points (308 meters) was only 13 m greater than the average distance that random points were located from roads (see Table 4). We do not believe that such a small distance is biologically significant.

Vegetative Factors--. We found that the density of trees that were 10 to 22 inches DBH had a quadratic relation with the relative probability of use by owls, as did the basal area of trees greater than or equal to 26 inches DBH. Thus, the relations with density of 10-22 inch trees and basal area of trees ≥ 26 inches DBH appeared to be decline above certain levels. That is, there could be too many trees, as we've observed for California spotted owls (Irwin et al. 2007). Other important vegetative variables included evergreen hardwoods. For example, basal area of tanoak had a significant influence (positive), also up to a point. Finally, we found negative relation with basal areas of Pacific madrone and that of canyon live oak. The latter two influential factors seem somewhat surprising, but the statistical relations were weak, and these apparent results may be an artifact of relatively low frequencies of occurrence. The interim RSF, or relative probability of use of a patch of forest larger than 5 acres is:

$$\mathbf{W = \exp[1.39\,e^{-3}*DISTNEST - 4.61e^{-7}*DISTNEST^2 + 2.47e^{-3}*DISTROAD + 5.15e^{-3}*DISTWATER - 9.35e^{-6}*DISTWATER^2 - 3.48e^{-3}*ELEVFEET + 2.08e^{-6}*ELEVFEET^2 + 1.43e^{-3}*TPA_{10\text{-}22} - 4.35e\text{-}7*TPA_{10\text{-}22}{}^2 - 9.60e^{-3}*TPA_{GE26} + 1.44e^{-4}*TPA_{GE26}{}^2 - 3.09e^{-4}*BASAL_{TANOAK} - 6.55e^{-6}*BASAL_{TANOAK}{}^2 - 5.90e^{-3}*BASAL_{MADRONE} - 8.10e^{-3}*BASAL_{LIVEOAK} + 2.39e^{-5}*BASAL_{LIVEOAK}{}^2]}$$

When we applied the preliminary RSF model to the inventory data, it resulted in maps of relative probabilities for the owls at each site. The RSF values are shown in yellow for low relative probabilities to dark blue for higher relative probabilities in Figures 3-5. We overlaid the distribution of telemetry points on the RSF values as a first-stage check on the reliability of the RSF model. There seemed to be variable correspondence between the actual telemetry points and model-estimated relative probabilities. In some cases, the apparent higher RSF values occurred along the edges of the home ranges. As a result, we have little confidence in the overall reliability of this preliminary model at this time. We believe a better model will be derived by including interaction terms, including estimates of snags and downed woody debris, and by incorporating a larger sample of random landscape locations. A small random sample does not permit a strong ability to discriminate between habitat and environmental conditions at random locations from those at telemetry points. Moreover, there were habitat changes during the study at some of the home ranges; incorporating those changes also is likely to result in a more satisfying model.

DISCUSSION

Previous experience indicated that spotted owls often spend some 60-80% of their time in comparatively small core areas that comprise only 20-25% of their annual home ranges. We observed that owls near Ft. Bragg also spend 50% or more of their time in areas as small as 132 acres or about 17% of their 90% FK home ranges. This could well be a result of high densities of the owl's prey. Of course, a subjective 50% contour should not necessarily be construed to be a true core area, which may be included in the ranges of areas described by the 50% to 75% fixed kernel probability distributions. As shown in Table 5, the average values ranged from 132 acres (50% FK) to 356 acres (75% FK). The 50% FK estimates (range = 48-548 acres) are similar to core-area estimates for 15 Northern Spotted Owls at the Elliott State Forest, Oregon (~215 acres) and for 9 Northern Spotted Owls in northwestern Oregon (~250 acres). Overall, the 50%-75% FK home range estimates are slightly smaller than our original prediction based upon theoretical models of energetics and body mass that core areas would be between 500 and 1,000 acres.

Although our analyses are still incomplete, the trends suggest some topics that could be important for forest management planning. First, the analyses indicate that there can be too much basal area for optimal use, suggesting that some reduction of basal areas in dense stands with trees 10-22 inches DBH might improve foraging habitat for northern spotted owls in this area, and that leaving some trees larger than 26 inches in DBH is likely to benefit owls. Also, we believe that activities that promote tanoak could benefit spotted owls, although there seems to be an upper limit. We hope to identify that limit in final analyses. However, tanoak is traditionally considered to compete for growing space with valuable conifers, and we do not know if there may be any level of tanoak retention that might be considered acceptable. Finally, we are unsure about the apparent negative influence of madrone and canyon live oak, because other investigators have suggested that these species promote habitat for the owl's preybase. On the other hand, canyon live oak was relatively rare, and was not found in many samples. In the case of madrone, it might be possible that it can also be too abundant, such that owls may hunt for prey along edge. We intend to probe more deeply into these topics during the final analyses.

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Table 1. Definitions of environmental and structural variables that we used to characterize forest stand conditions used by California spotted owls from 1999-2004 near Chico, California, USA.

Variable	Definition and unit	Abbreviation
Vegetation covariates		
Basal area	Cross-sectional area of all stems in a stand measured at breast height (m^2/ha)	BASAL
Douglas-fir BA	Basal area occupied by Douglas-fir trees >12.7 cm dbh	BASALDFIR
Ponderosa pine BA	Basal area occupied by ponderosa pines >12.7 cm dbh	BASALPP
White fir BA	Basal area occupied by white fir trees >12.7 cm dbh	BASALWFIR
Fir basal BA	Combined basal areas of Douglas-, red, and white fir	BASALFIR
Hardwood BA	Basal area occupied by hardwood species, in 2 groups: 12.7-20 cm dbh (small); >20 cm dbh (large)	BASALHDW
Canopy cover	Proportion of ground (%) covered by forest tree crowns	CANCOV
Quadratic mean diameter	Diameter of tree corresponding to average basal area of a stand of trees (cm)	QMD
Trees/hectare	Total no. of trees/ha >12.7 cm dbh in a stand	TPH
Size class	Density of green trees of specified size (e.g., TPA13 is density of trees ≥13cm dbh;	TPAxx
Small tree density	Density (no./ha) of green trees 12.7-25 cm dbh	SMALL
Large snags	No. of snags ≥66cm dbh and >1.8m tall	SNAG
Abiotic covariates		
Distance to streams	Distance (m) from telemetry or random point to nearest permanent stream	DWATER
Elevation	Elevation of point (m) above mean sea level	ELEV
Roads	Distance (m) to nearest traveled road	ROAD
Nest	Distance (m) to nesting site	NEST

Table 2. Telemetry locations by quarterly period, March 2000 through February 2005. (1 = Mar-May; 2 = Jun-Aug; 3 = Sep-Nov; 4 = Dec-Feb).

		2000				2001				2002				2003				2004			
Site	Sx	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
S Fk Noya R	F	X	X																		
	M	X	X	X																	
Dead Man Trest	F1		X	X	X	X	X														
	F2									X											
	F3															X	X	X	X	X	
	M	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sointula Gulch	F1	X	X	X	X	X	X	X	X	X	X	X	X		X						
	M		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
N Fk James	F						X	X	X	X	X	X	X		X	X	X	X	X	X	X
	M	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Caspar Creek	F						X	X	X	X	X	X	X	X	X	X		X	X	X	X
	M1		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	M2																		X	X	X
Peterson Gulch	F						X	X	X	X	X	X	X	X	X		X	X	X	X	X
	M	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S Fk Big River	F		X	X	X	X	X	X	X	X	X				X	X	X	X	X	X	
	M		X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	
N Fk Camp	F1					X	X	X										X			
	F2										X	X	X	X							
	F3														X	X	X				
	F4																	X	X	X	X
	M1			X	X	X	X	X	X	X	X										
	M2														X	X	X	X	X		
Berry Gulch	F						X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	M					X	X	X	X	X	X	X							X	X	X

Table 3. Numbers of random and telemetry locations for spotted owl resource selection function (RSF) analysis from 2000-2005 near Ft. Bragg, California, USA. Choice set include telemetry and random points.

Location[a]	Label	Sex	Telem	Random	Choice set
So. Fk Noya River	7A	M	31	42	1
Dead Man Trestl	7B	F1&F2	107	313	2
Dead Man Trestl	7B	F3	68	60	3
Dead Man Trestl	7B	M	325	329	4
Sointula Gulch	7C	F	199	284	5
Sointula Gulch	7C	M	290	462	6
N Fk James Cr.	7E	F	217	203	7
N Fk James Cr.	7E	M	323	344	8
Caspar Creek	7F	F	198	233	9
Caspar Creek	7F	M1	254	377	10
Caspar Creek	7F	M2	39	132	11
Peterson Gulch	7G	F	210	402	12
Peterson Gulch	7G	M	300	314	13
So. Fk Big River	7H	F	218	401	14
S. Fk Big River	7H	M	273	453	15
No. Fk Camp Cr.	7J	F1	30	153	16
No. Fk Camp Cr.	7J	F2	55	208	17
No. Fk Camp Cr.	7J	F3	44	258	18
No. Fk Camp Cr.	7J	F4	73	175	19
No. Fk Camp Cr.	7J	M1	154	312	20
No. Fk Camp Cr.	7J	M2	66	240	21
Berry Gulch	7K	F	239	250	22
Berry Gulch	7K	M	113	302	23

Table 4. Averages and standard errors (SE) for selected habitat and environmental conditions at foraging, and random locations, based upon telemetry points and random landscape locations within home ranges of spotted owls from 2000-2005 near Ft. Bragg, California, USA.

Variable[a]	Foraging		Random	
	Ave.	SE	Ave.	SE
BASAL (ft^2/ac)	254	2.5	228	1.9
BASALREDWOOD	157	1.8	137	1.7
TANOAK/ac	125	3.8	106	2.7
BASAL LIVEOAK	1.1	0.1	1.8	0.2
SMALL(5-10)/ac	132	2.9	129	2.2
TREES 10-22 in(no.ac)	91	1.3	94	1.1
TREES> 26 in. (no./ac)	13.9	0.3	11.1	0.2
QMD (in)	15.0	0.1	14.7	0.1
ASPECT(°)	168	2	167	1
ROAD (ft)	308	3	295	3
ELEV (ft)	1878	20	2017	21
NEST (ft)	819	36	934	7
DWATER (ft)	210	3	274	3
SLOPE (degree)	20	0.1	20	0.1

[a] Definitions of variables are provided in Table 1.

Table 5. Annual fixed kernel (FK) home range sizes (acres) for spotted owls near Ft. Bragg, California.

Location[a]	Site Label	Sex	90% FK	75% FK	50% FK
So. Fk Noya River	7A	M			
Dead Man Trestle 2000	7B	F	555	222	78
Dead Man Trestl	7B	M			
2000			578	328	138
2001			621	235	70
2002			663	351	183
2003			345	161	65
Sointula Gulch	7C	F			
2000			401	221	91
2001			159	67	34
2002			190	63	25
Sointula Gulch	7C	M			
2000			247	78	39
2001			328	128	45
2002			415	168	56
2003			762	320	122
2004			714	290	126
N Fk James Creek	7E	F			
2001			247	82	38
2002			722	278	88
2003			380	121	59
2004			465	192	77

Table 5. Cont'd.

Location[a]	Site Label	Sex	90% FK	75% FK	50% FK
Caspar Creek	7F	F			
2001			745	240	90
2002			440	147	69
2003			860	341	143
2004			588	318	170
Caspar Creek	7F	M			
2000			1571	567	206
2001			1180	488	140
2002			879	291	119
2003			1426	635	151
Caspar Creek	7F	M2			
2004			491	257	117
Peterson Gulch	7G	F			
2001			1528	677	288
2002			1521	443	146
2004			480	175	52
Peterson Gulch	7G	M			
2000			1071	383	182
2001			918	447	107
2002			1583	673	159
2003			1685	974	339
2004			1161	620	200

Table 5. Cont'd.

Location[a]	Site Label	Sex	90% FK	75% FK	50% FK
So. Fk Big River	7H	F			
2000			1093	588	163
2001			804	398	69
2003			855	386	144
S. Fk Big River	7H	M			
2000			998	605	251
2002			977	555	194
2003			889	541	202
2004			521	270	75
No. Fk Camp Cr.	7J	F2			
2002			889	573	310
No. Fk Camp Cr.	7J	F3			
2003			835	408	99
No. Fk Camp Cr.	7J	F4			
2004			559	285	105
No. Fk Camp Cr.	7J	M			
2000			764	423	103
2001			1006	463	179
No. Fk Camp Cr.	7J	M2			
2003			666	236	81
Berry Gulch	7K	F			
2001			778	420	184
2002			869	500	246
2003			574	316	144
2004			623	345	168

Table 5. Cont'd.

Location[a]	Site Label	Sex	90% FK	75% FK	50% FK
Berry Gulch	7K	M			
2001			1111	637	277
2004			1025	380	111

Figure 1. Locations of study areas in the Adaptive Management Project involving spotted owl habitat selection, highlighting Study Area 7 near Ft. Bragg, California.

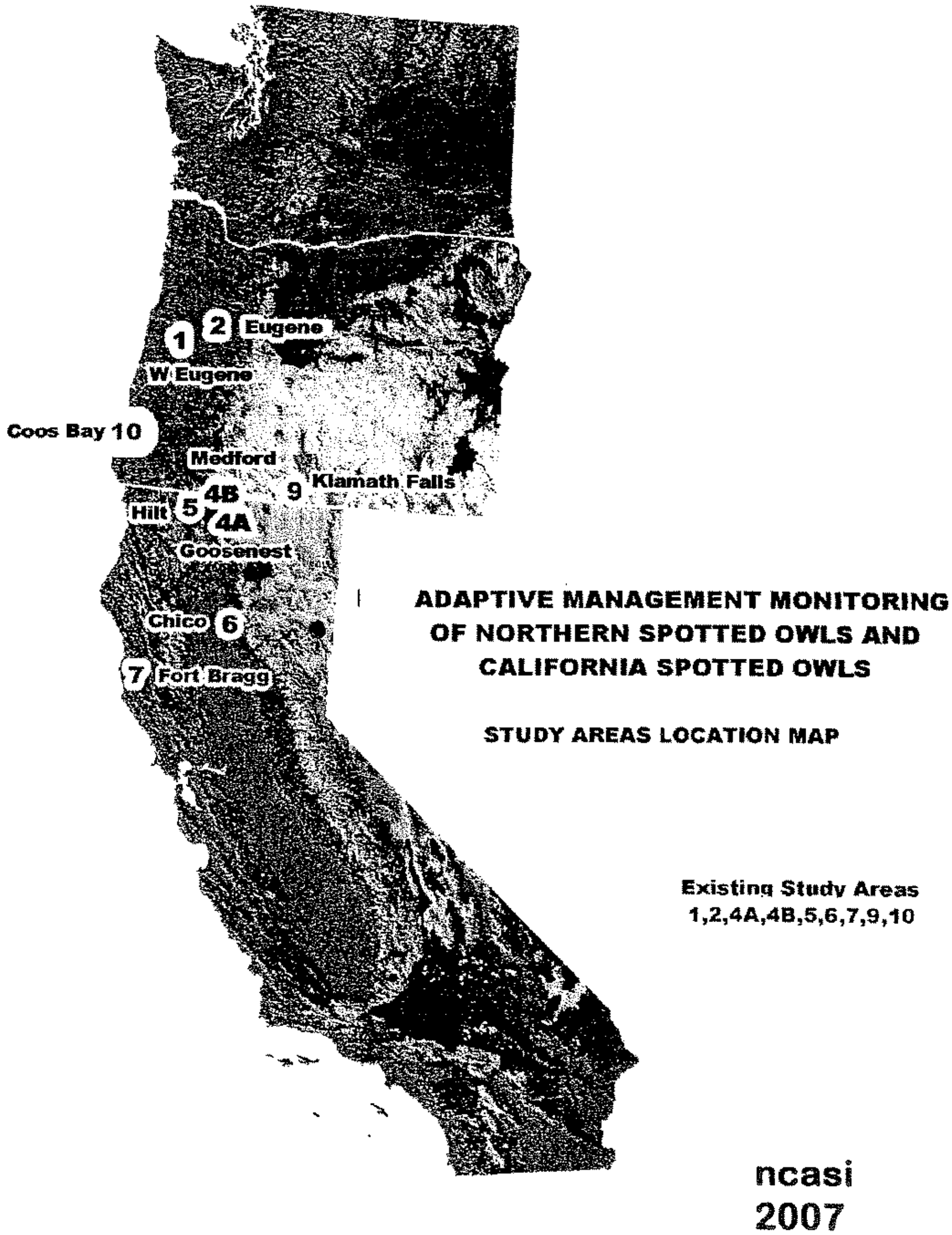

Figure 2. Site names and 95% minimum convex polygon home ranges for northern spotted owls in the Ft. Bragg, California study area. Also shown is the forest-inventory grid for the Jackson Demonstration State Forest, and the random landscape plots sampled by NCASI field crews.

Figures 3-5. Maps of telemetry points and plots of resource selection function (RSF) values, which are relative probabilities of plots being used for nocturnal foraging by northern spotted owls. Yellow and green indicate low relative likelihood of use and blue and purple indicate higher relative probabilities, based upon the combined data for all spotted owls. The RSF is quite incomplete, and is shown here only for purposes of illustration.

NEXT STEPS

By late fall and early winter, we anticipate completing habitat inventories at Springfield, Oregon. That would leave only 2 study areas where habitat inventories remain to be completed(Klamath Falls and Coos Bay). We expect to complete RSF analyses for Study Area 2 (West Eugene), Study Area 4A (Yreka) and Study Area 9 (Ft. Bragg) by or before mid-winter as well. And we hope to write and submit a research paper on spotted owl initial responses to partial-harvest silviculture by Spring 2007, presuming that we can acquire pre- and post-harvest inventory data and associated descriptions of silvicultural treatments. Finally, we hope to implement 1 or 2 new radio-tracking studies on Barred Owls, which of course would not represent a continuation of this project.

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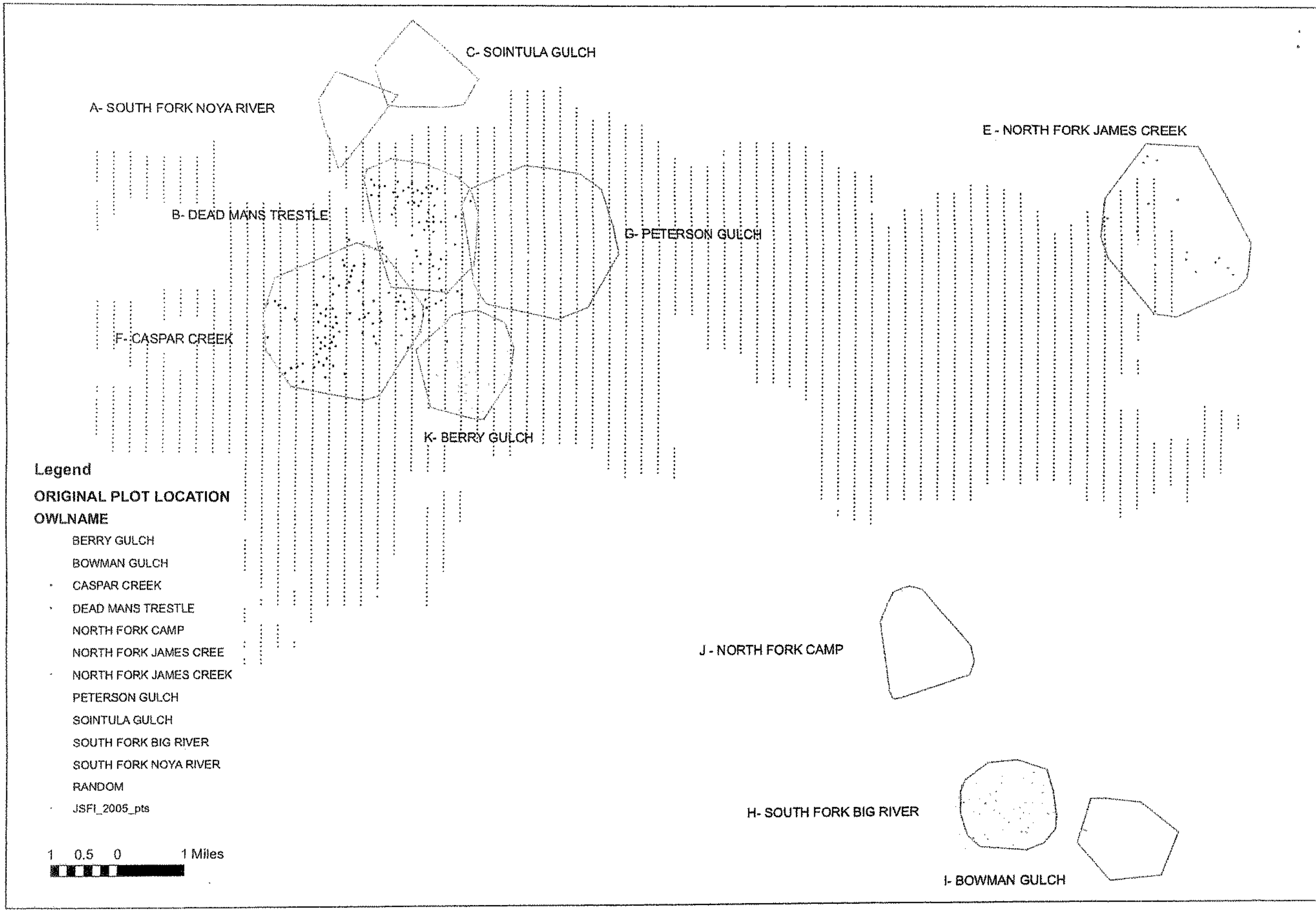
C- SOINTULA GULCH
A- SOUTH FORK NOYA RIVER
E - NORTH FORK JAMES CREEK
B- DEAD MANS TRESTLE
G- PETERSON GULCH
F- CASPAR CREEK
K- BERRY GULCH
Legend
ORIGINAL PLOT LOCATION
OWLNAME
BERRY GULCH
BOWMAN GULCH
CASPAR CREEK
DEAD MANS TRESTLE
NORTH FORK CAMP
NORTH FORK JAMES CREE
NORTH FORK JAMES CREEK
PETERSON GULCH
SOINTULA GULCH
SOUTH FORK BIG RIVER
SOUTH FORK NOYA RIVER
RANDOM
JSFI_2005_pts
1 0.5 0 1 Miles
J - NORTH FORK CAMP
H- SOUTH FORK BIG RIVER
I- BOWMAN GULCH

Map 1

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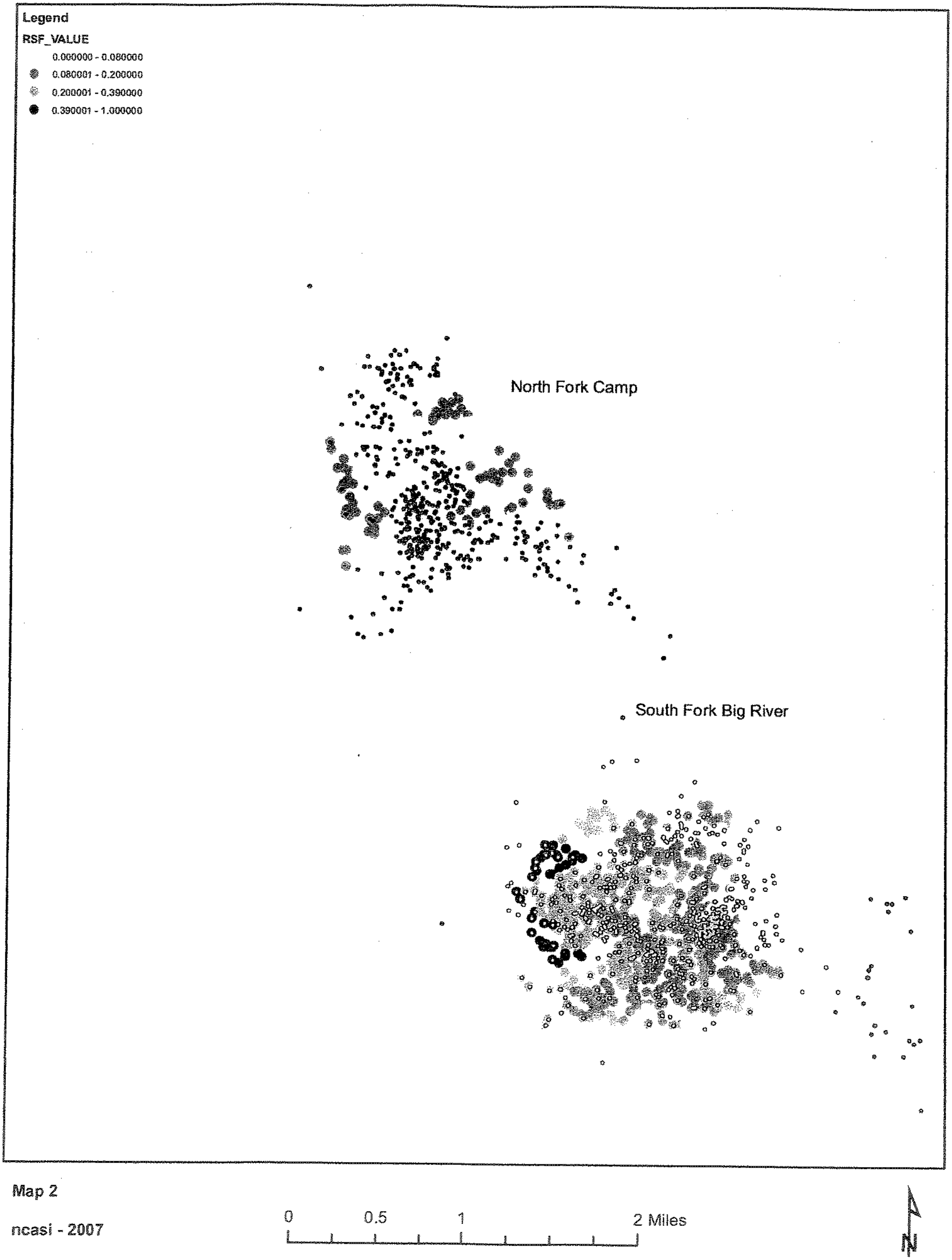
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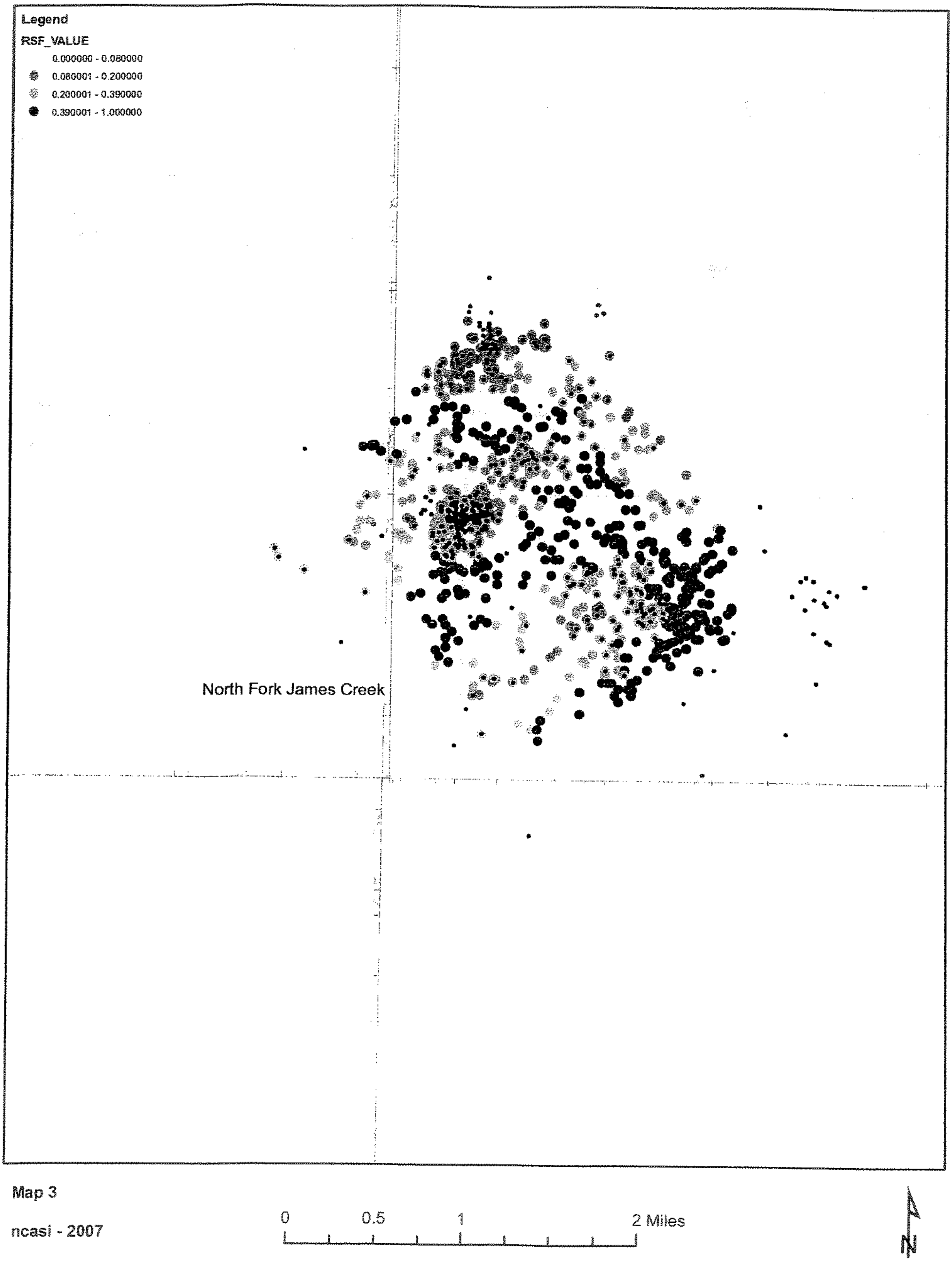
0.000000 - 0.080000
0.080001 - 0.200000
0.200001 - 0.390000
0.390001 - 1.000000
North Fork Camp
South Fork Big River
Map 2
ncasi - 2007
0
0.5
1
2 Miles
N



Map 3

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