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Adaptive Management Monitoring of Spotted Owls

Annual Progress Report – January 2004

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Re: Recovery Permit TE-834385-3

INTRODUCTION

Extensive public and private forests from northern California through Washington occur in early to mid-successional stages. Private, state and federal landowners are expected to manipulate many such forests to achieve various objectives via intermediate silvicultural treatments such as commercial thinning or partial harvesting. In addition, comparatively dry Mixed Conifer forests are increasingly identified for some forms of silvicultural intervention to reduce hazardous fuel loads because of the uncharacteristically large and intense wildfires that have recently ravaged such forests. Moreover, many regulatory and voluntary objectives are aimed at maintaining specific habitat-structural elements (e.g., snags, coarse woody debris, riparian buffer zones). Specific voluntary considerations are often applied under guidelines of the Forest Stewardship Council or the Sustainable Forestry Initiative to reduce fuel loading and promote growth of large trees.

Responding to questions about silvicultural intervention for restoring and sustaining forest-health, recent federal regulatory agency policy statements call for a long-term view to identify possible future benefits of forest treatments (U.S. Dept. Interior/U.S. Dept. Commerce 2002 a, 2002 b). That perspective includes evaluating net long-term benefits as well as short-term impacts in agency consultations regarding activities that may affect threatened or endangered species. Doing so for spotted owls is challenging, because no strong biological information or validated tools exist to support reliable estimates of effects of commercial thinning, partial cutting or hazardous fuel reduction projects at multiple scales and over short- and long term planning horizons. Lee and Irwin (submitted) recently proposed a modeling process that holds promise for evaluating fuel reductions in forests occupied by the California Spotted Owl (CSO) in the Sierra National Forest, California, and Meiman et al. (2004) described initial (apparent avoidance) response to commercial thinning in 40-65 year old Douglas-fir/Western Hemlock forest by 1 male Northern Spotted Owl (NSO) in northwestern Oregon. Thus, there is a dearth of field experience and technical constructs to guide silvicultural planning in young and intermediate stands in areas occupied by spotted owls.

Previous spotted owl studies emphasized nest sites or contrasted relative owl use of seral-stages or age classes. Yet, thinning, partial harvesting or hazardous fuels reduction programs do not change forest seral stages--only stand density, composition, or size class distribution. Moreover, seral-stage forest habitat models, which are generally based on even-aged concepts, have never provided satisfactory reliability for predicting wildlife population responses at any scale (Short and Hestbeck 1995, Irwin 1998, DeGraaf 2002). This probably precludes predicting spotted owl responses in mixed-age, Mixed Conifer forests, which often do not fit even-aged classification schemes.

Longterm research approaches that integrate wildlife biologists, foresters and land managers within an active adaptive management experimental framework are required to understand ecological processes in the context of sustainable resource management (DeStefano 2002). Indeed, the greatest advances in species conservation and recovery will be made via such approaches that employ manipulative experiments (Irwin and Wigley 1993) within an information-theoretic analytic approach (Burnham and Anderson 1998). Our long-term project includes an integrated research approach that involves manipulative and retrospective experiments within an information theoretic framework.

Accordingly, we monitored responses of both NSOs and CSOs to conditions that resulted from previous applications of such less intensive forestry practices (i.e, a retrospective emphasis). Also, we have collected observations of initial owl behavioral responses to intermediate silvicultural treatments within home ranges. The project thus involves both repeated observational experiments and manipulative experiments. In previous reports, we emphasized retrospective analyses using resource selection function (RSF) modeling because those analyses are more robust and provide the strongest conclusions. Here, we include additional RSF modeling results and provide preliminary results on initial owl behavioral responses to silvicultural treatments.

The project should contribute to NSO recovery efforts as well as to CSO conservation by helping to integrate owl habitat needs within projects designed to promote longterm forest sustainability. For example, the products will provide information and tools for:

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 will 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 that should:

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 2002 Annual Report provide descriptions of methods, treatments, research design and biological rationale for the project. The primary objectives allow comparisons among owl foraging use of forest stands with and without previous silvicultural treatments, and before-vs.-after silvicultural treatments. 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 samples of spotted owls relative to habitat conditions generally available within sampled landscapes.
2. Habitat use vs. availability within home ranges.

3. Use of individual patches or forest stands (such as before and after silvicultural treatment).

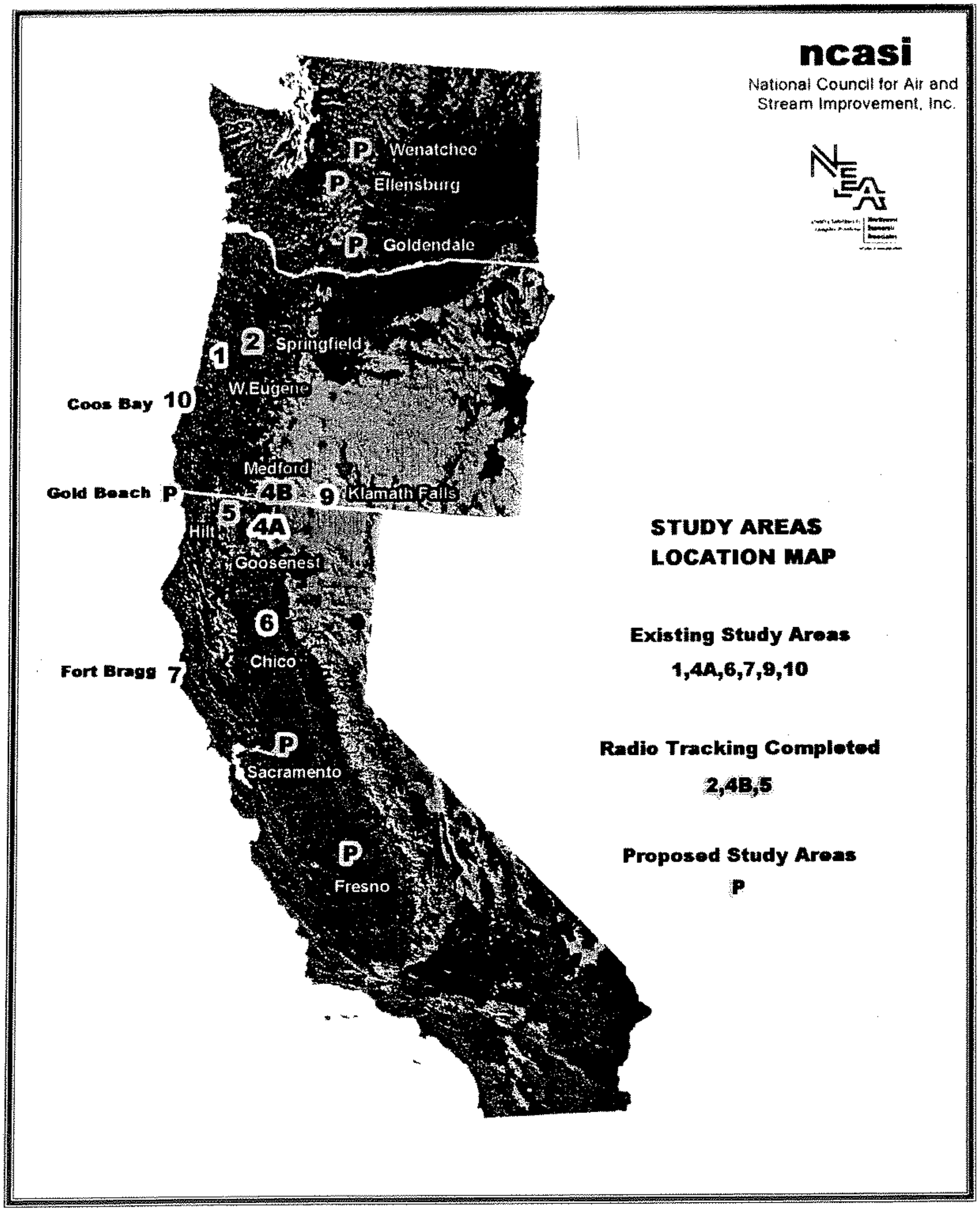
In this report, we provide new information on direction and important trends in analyses. The information adds to, but does not necessarily replace, previously reported information. We caution readers that more data will be collected and analyzed, so it is possible that some trends may change with final analyses. Appendix A provides an update that clarifies certain topics regarding methods and study design in response to recent U.S. Fish & Wildlife Service questions about the project.

STUDY AREAS

This study employs a repeated, or multiple study-area (Figure 1) approach (Johnson 2002), which allows data to be combined in meta-analyses for several analysis areas. One analysis area, with 2 study-area replicates (Study areas 1 & 2) is situated 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. An additional study-area replicate in Douglas-fir/Western Hemlock was implemented in 2003 on BLM and private timberlands near Coos Bay, Oregon. Results from that area will likely ultimately be combined with information acquired in Study Areas 1 and 2 because of similarity in forests.

A second analysis area, now 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 timberlands administered by the USDA Forest Service (Klamath National Forest) and USDI Bureau of Land Management as well as private timberlands primarily 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. Information from this study area might be supplemented with previous telemetry information acquired by Pious (unpubl. data, Louisiana Pacific), which might serve to increase sample sizes or provide for model validation. Or, we anticipate comparing results with those from

Figure 1
MAP OF STUDY AREA LOCATIONS FOR ADAPTIVE MANAGEMENT MONITORING OF NORTHERN AND CALIFORNIA SPOTTED OWLS



RSF modeling being conducted by L. Diller (pers. Comm.) from Simpson Resource Company (now Green Diamond Resource Company).

Finally, in cooperation with U.S. Forest Service research and management personnel, we developed and submitted 2 supplemental proposals that, if funded and subsequently approved by all cooperators, would implement new study-area replicates in Douglas-fir/Western Hemlock forests in Western Oregon (Agness Ranger District of Siskiyou-Rogue River National Forest) and in Mixed Conifer forests of the Wenatchee and Okanogan National Forest along the eastern slope of the Cascades in Washington. Both project areas have benefited from U.S. Fish and Wildlife Service technical consultations. NCASI and U.S. Forest Service staff scientists are also contemplating submitting a 3rd proposal early in 2004 for a replicate that would evaluate responses by NSOs and possibly barred owls (*Strix varia*) to forest-health restoration treatments in the Mixed Conifer forests of the Gifford-Pinchot National Forest and adjacent state and private timberlands in Washington. The 2002 Annual Report and Appendix A provide additional details about current study areas.

Below, we summarize telemetry data collected from all study areas and then provide more detailed analyses for Study Areas 5, 6 and 7. These analyses identify trends in the data, but readers should recognize that additional analyses will be undertaken as additional information arrives, especially that regarding vegetation conditions on federal lands. The updated analyses include data from habitat-inventory plots from 9 owl home ranges in Study Area 6 and from 2 owl home ranges in Study Area 7, and more general or categorical habitat data from portions of home ranges of NSOs in Study Area 5. Analyses link owl habitat selection with forest vegetation conditions and abiotic or planimetric covariate factors such as distance from nest sites, elevation, topography and distance from streams.

SUMMARY OF TELEMETRY DATABASE

In Table 1 we summarize the number of birds monitored, telemetry points recorded and cumulative home range estimates for individual study areas. We listed the 50%,75% and 95% Fixed Kernel (FK) and the Adaptive Kernel (AK) home ranges, as well as the 95% modified minimum convex polygon (MMCP) home range size. We have monitored 147 spotted owls at 83 owl home-ranges during the course of the project. From Spring 1998 through 1 October 2003, field crews recorded the locations of the telemetered birds 24,317 times. That excludes 212 additional locations of owls monitored to date in Study Area 10, as well as limited data for a few owls in Study Area 3 (which was initiated but not developed

Table 1. Summary of telemetry locations and cumulative home range size (acres) by study area, 1998-2003[a]

Study Area Name	Study Area	No. Tel. Points	Fixed Kernel			Adaptive Kernel			MMCP
			50%	75%	95%	50%	75%	95%	95%
West Eugene	1	2524	280	931	4061	409	1064	4853	8680
East Eugene	2	3308	247	697	3313	555	1334	4451	9202
Yreka, Ca.	4A	3151	128	364	1490	239	584	2005	3973
Medford, Or.	4B	5041	210	510	1824	303	706	2376	5373
Hilt, Ca.	5	2414	147	435	2101	261	673	2806	4400
Chico, Ca.	6	4018	198	530	2017	317	754	2446	15385
Fort Bragg, Ca.	7	3052	110	330	1179	144	369	1313	1559
Klamath Falls, Or.	9	809	172	405	1940	323	712	2294	6405
Average			**187**	**525**	**2241**	**319**	**775**	**2818**	**6872**

[a]Includes birds at all sites with ≥ 50 telemetry locations gathered over a period ≥ 8 months.

because of insufficient federal funding) and data for a few owls that died or for which transmitters failed shortly after capture and were not replaced.

Home range sizes for each study site--. In Table 2 we listed site-specific home range sizes using FK, AK, and 95% MMCP home range algorithms, and listed smoothing parameters (S.P.) that were used. The S.P. refers to the user-defined smoothing parameter that was used in both the FK and the AK home range analyses. The number of telemetry points influences choice of the S.P. and the amount of smoothing needed to establish a reasonable home range boundary. The smoothing parameter is also determined by the relative concentration or spread of telemetry points within a given home range. Thus, a FK home range with approximately 50-75 points annually will show a home range comprised of many small polygons or islands with very little connectivity (Figure 2), also observed by Kie et al. (2003). Increasing the smoothing parameter blends or smoothes many of these small islands into a more continuous home range. Thus, the FK for the same home range with 100-250 telemetry points will have a smoother home range boundary with a smaller smoothing parameter. Because of this, the 95% FK algorithm tends to result in smallest home range estimates (i.e, a 95% probability that the home range is included within the boundary).

In comparison, AK home ranges tend to combine fewer points into a few small polygons and to lump more points into larger polygons. If the smoothing parameters are too small, the algorithm will exclude many more points than the FK but still include more acreage in the points that are included within the home range. Thus, the 95% AK tends to over estimate the true home range (Seaman et al. 1999). Because both kernel methods are probability functions, there is a certain amount of subjectivity in determining the appropriate smoothing parameters. That is, one must view output before deciding the S.P. that accounts for a reasonable area that encompasses the probability density distribution. Therefore, we provide data for the 3 home range algorithms for comparative purposes.

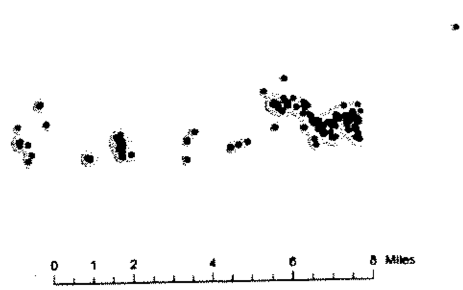
Estimates of cumulative home range sizes, based upon the fixed kernel, adaptive kernel, and 95%MMCP for 8 study areas are provided for 83 owl cumulative home ranges that have been occupied by owl pairs in Table 1 (both members of each pair were not tracked in every case). Overall cumulative home range size, using a 95% fixed kernel estimator, averaged 2,241 acres. The average 95% adaptive-kernel estimate was 2,818 acres and the 95% MMCP was 6,872 acres.

Figure 2

"Effects of different smoothing parameters on home range estimation using fixed and adaptive kernel methods at one owl site."

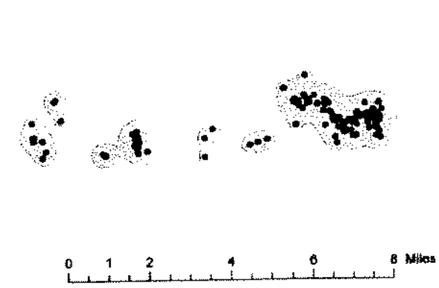
Fixed Kernel

95% Fixed Kernel
Smoothing Parameters = 150



2629 acres

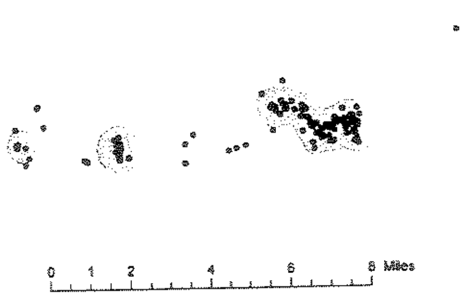
95% Fixed Kernel
Smoothing Parameters = 300



4526 acres

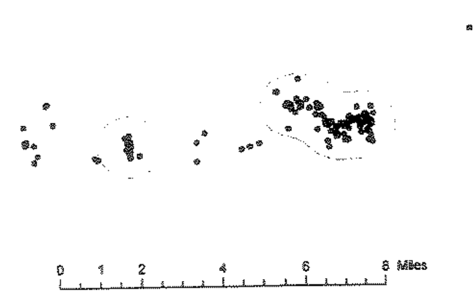
Adaptive Kernel

95% Adaptive Kernel
Smoothing Parameters = 300



2974 acres

95% Adaptive Kernel
Smoothing Parameters = 600



4622 acres

Table 2. Summary of telemetry data and cumulative home range size, in acres, for each spotted owl home-range site by study area (designated by letters, with number of telemetry points in parentheses), 1998-2003[a].

STUDY AREA	50%FK	75%FK	95%FK	S.P.	50%AK	75%AK	95%AK	S.P	95%MMCP
1- West Eugene, OR									
A(364)	548	1335	3608	200	773	1530	4120	500	5628
D(472)	118	590	4712	200	362	1099	5521	500	16830
E (63)	48	161	1199	150	205	683	2110	500	3415
F (102)	206	675	4267	200	197	514	4366	300	4840
H (379)	387	1735	8179	250	690	1765	9954	750	27918
I (593)	317	850	3330	350	472	1106	4676	1000	5088
J (229)	550	1839	4329	150	471	1494	4420	200	4859
K (257)	139	637	4692	250	199	733	6126	650	6935
L (65)	210	555	2233	250	308	655	2386	500	2605
AVERAGE	**280**	**931**	**4061**		**409**	**1064**	**4853**		**8680**

Table 2. Continued.

STUDY AREA	50%FK	75%FK	95%FK	S.P.	50%AK	75%AK	95%AK	S.P	95%MMCP
<u>2- East Eugene, OR</u>									
A (311)	514	1402	4918	150	1358	2571	5816	750	31221
B (108)	136	330	2342	300	337	756	3363	750	5378
BH (130)	293	1535	6936	150	797	2740	9381	500	16923
C (71)	154	326	1154	350	292	602	1551	500	2386
E (321)	111	314	1534	250	237	537	2310	750	3260
F (442)	205	582	4799	250	482	1469	6474	650	9925
G (381)	134	447	1812	250	259	716	2246	500	3490
H (381)	374	837	3786	350	738	1567	5243	1000	12145
I (279)	203	477	2978	250	675	1627	5037	750	6320
J (453)	297	646	3697	350	437	961	4436	1000	6196
L (431)	292	775	2484	250	494	1133	3109	500	3975
AVERAGE	**247**	**697**	**3313**		**555**	**1334**	**4451**		**9202**

Table 2. Continued.

STUDY AREA	50%FK	75%FK	95%FK	S.P.	50%AK	75%AK	95%AK	S.P	95%MMCP
<u>4-A Yreka, CA</u>									
A (390)	83	348	1590	150	68	289	1737	250	1814
B (431)	129	302	1292	250	230	489	1347	500	1797
E (677)	256	514	1663	350	545	1142	2920	1000	4595
G (209)	143	290	1382	150	158	316	1614	250	1883
H (58)	81	211	744	150	182	364	909	350	1223
K (569)	138	492	1826	250	191	452	2008	500	2764
X (317)	133	519	1612	250	379	1304	3416	750	7395
Y (84)	70	310	2122	150	205	510	2788	400	12507
Z (416)	115	294	1178	150	196	393	1302	250	1779
AVERAGE	**128**	**364**	**1490**		**239**	**584**	**2005**		**3973**

Table 2. Continued.

STUDY AREA	50%FK	75%FK	95%FK	S.P.	50%AK	75%AK	95%AK	S.P	95%MMCP
4B- Medford, OR									
C (441)	263	559	1432	350	396	839	2165	750	5425
D (305)	146	329	2087	250	252	545	3102	500	4717
F (837)	176	573	2038	150	202	626	2273	500	3776
I (609)	227	485	1380	250	467	949	2378	500	4587
O (651)	236	540	1662	350	250	560	2099	750	2750
P (515)	89	285	988	150	163	560	1453	450	1882
S (631)	109	372	1249	150	111	311	1328	250	1701
T (615)	356	748	1868	500	385	802	1910	750	2835
U (135)	274	679	3944	200	383	970	4753	650	20432
Q (302)	227	527	1592	350	425	893	2296	750	5629
AVERAGE	**210**	**510**	**1824**		**303**	**706**	**2376**		**5373**

Table 2. Continued.

STUDY AREA	50%FK	75%FK	95%FK	S.P.	50%AK	75%AK	95%AK	S.P	95%MMCP
<u>6- Chico, CA</u>									
A (555)	193	531	2437	250	366	823	2771	750	6033
B (243)	91	232	1698	250	196	472	2600	600	6249
C (621)	62	178	674	150	61	237	733	350	757
D (648)	161	483	1853	250	250	629	2059	500	4401
E (386)	216	523	2139	250	349	772	2657	600	12970
G (374)	221	524	2214	250	390	902	2871	600	94209
I (512)	282	689	1706	150	449	865	1981	250	2215
J (103)	60	280	1357	100	95	366	1953	200	2028
K (438)	296	1101	3620	250	404	1201	3941	600	11393
L (138)	400	763	2471	250	608	1273	2894	750	13591
AVERAGE	**198**	**530**	**2017**		**317**	**754**	**2446**		**15385**

Table 2. Continued.

STUDY AREA	50%FK	75%FK	95%FK	S.P.	50%AK	75%AK	95%AK	S.P	95%MMCP
<u>5- Hilt, CA</u>									
A (290)	158	545	3873	150	239	791	5007	300	7243
B (240)	187	422	2582	350	323	690	3069	850	6095
C (217)	140	446	2979	250	478	1110	3885	750	10388
D (96)	53	201	728	100	64	235	826	200	1012
E (86)	225	537	2890	350	433	924	4916	850	6531
F (124)	59	118	655	100	93	210	863	300	814
G (108)	142	384	1236	150	132	345	1341	250	1078
I (400)	259	723	2753	250	387	985	3306	750	6167
J (402)	147	414	1463	200	260	557	1785	450	2169
K (243)	35	339	1409	100	173	739	1980	200	1981
L (208)	214	660	2541	150	294	818	3891	450	4924
AVERAGE	**147**	**435**	**2101**		**261**	**673**	**2806**		**4400**

Table 2. Continued.

STUDY AREA	50%FK	75%FK	95%FK	S.P.	50%AK	75%AK	95%AK	S.P	95%MMCP
<u>7- Ft. Bragg, CA</u>									
A (50)	72	223	612	150	56	201	626	200	590
B (384)	210	424	1298	250	315	617	1511	550	1783
C (420)	71	163	669	150	95	214	676	250	668
E (434)	92	270	1737	250	116	247	1893	650	2898
F (424)	165	352	1632	150	181	417	1837	300	2449
G (360)	198	833	2089	150	278	887	2266	300	2566
H (398)	48	271	969	150	67	259	1160	350	1031
J (319)	74	268	917	150	79	216	1054	300	1026
K (263)	56	190	692	150	109	261	792	350	1024
AVERAGE	**110**	**333**	**1179**		**144**	**369**	**1313**		**1559**

Table 2. Continued.

STUDY AREA	50%FK	75%FK	95%FK	S.P.	50%AK	75%AK	95%AK	S.P	95%MMCP
9- Klamath Falls, OR									
A (125)	294	838	2629	150	489	1044	2974	300	12493
B (136)	108	255	1607	250	151	324	1752	350	2513
C (148)	127	281	1807	250	210	450	2179	650	3243
E (98)	115	360	2063	250	466	1226	3145	450	3599
F (52)	100	217	1903	250	202	497	2409	550	7147
G (85)	257	506	1752	150	369	690	1849	350	11301
H (53)	179	390	1552	250	350	736	1814	650	2811
I (112)	192	390	2204	250	344	730	2233	750	8131
AVERAGE	**172**	**405**	**1940**		**323**	**712**	**2294**		**6405**

[a]Study areas 1, 2, 4A, 4B, and 5 were initiated in 1998; Study Area 6 was initiated in 1999; Study Area 5 was discontinued in 2000; Study Area 7 was initiated in 2000, while Study Area 9 began in 2002. S.P. is a smoothing parameter associated with kernel home-range algorithms (see text for explanation).

Core areas are defined as those areas used disproportionately within home ranges. Previous experience indicates that spotted owls often spend some 60-80% of their time within 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. As shown in Table 2, those values ranged from 187 acres (50% FK) to 525 acres (75% FK) and from 319 acres (50% AK) to 775 acres (75% AK). The 50% FK estimates (range = 110-280 acres) are similar to core-area estimates for 15 owls at the Elliott State Forest, Oregon (~215 acres) and for 9 owls in northwestern Oregon (~250 acres). Overall, the 50%-75% FK home range estimates support our original prediction that core areas would include some 500-1000 acres.

Reproduction and Survival of Radio-Tagged Owls

Previous studies found evidence that 23-27 gram transmitter backpacks influenced spotted owl survival (Foster 1992) or reproductive success (Paton et al. 1991). We used 7-9 gram back-pack radio harnesses. In previous reports we indicated that we could not conclude that the smaller backpack harnesses affected survival or reproduction. Of course, annual mortality among adult spotted owls does occur and is expected to be about 15-18%, based upon demographic studies being conducted across the range of the owl.

Between 1 October 2002 and 1 October 2003 we recorded 10 mortalities among adult owls within the 8 current study areas: Area 1 (4); Area 2 (0); Area 4-A (0); Area 4B (0); Area 6 (2); Area 7 (0); Area 9 (4), and Area 10 (0). No owls died in association with capture and handling. The mortalities were related to heavy parasite loads, caused by predation (perhaps 1 association with parasite loads), or causes were unknown. When we detect and find a ead owl, we record its location using the geographical positioning satellite (GPS) system, d send the intact carcass the next day via express mail to the University of California, vis, where a complete pathological examination is conducted. Leg bands and the radio kpack are retained for inspection. If we find only remnant body parts, we store the ains in a plastic bag in a freezer until we receive instructions for appropriate disposal from I.S. Fish and Wildlife Service.

A recent addition to the study included radio-tagging 7 spotted owls at 5 sites near lay, Oregon. All of those owls survived since first capture in June 2003. Because we that work rather late, we were unable to capture and radio-tag as many owls as planned. We expect to complete capturing and radio-tagging owls at 4-5 more sites in spring 2004.

Another topic of interest involves reproductive performance of the owls relative to the harness transmitters, recognizing that existing habitat conditions, weather, and silvicultural treatments could also influence reproduction. The number of owls sampled at each study-area replicate is too low to provide conclusive information regarding those potential influences (i.e., demography is beyond the scope of the project). Therefore, we simply describe the reproductive output for radio-tagged owls on the 9 study areas for 2001-2003 in Table 3. The overall average reproductive success was 20%, and ranged from 0%-77%. In 2003, we found 8 fledglings on the 55 sites where owls were monitored (0.14 fledglings/site). There are no pre-study data available for comparison. Reproductive rates on the individual study areas appeared consistent with those observed for owls in the surrounding areas that were being monitored during the same time periods. Therefore, while reproductive success has not been high in the mixes of forests managed under varying objectives, available evidence gathered to date does not support a conclusion that the 7-9 gram backpack radioes are interfering with either survival or reproductive success of the radioed birds in this study. Also, there is insufficient information to determine if the silvicultural treatments conducted prior to or during the project have affected reproduction or survival.

There are two other topics of interest: the owls' fidelity to home ranges following silvicultural treatments and relative use of specific forest sites that received silvicultural treatments. While some seasonal movements occurred outside of breeding season home ranges, we found that no owls vacated their home ranges after silvicultural treatments were applied. To date, at least 19 thinning and partial harvests (implemented with varying landowner objectives and densities of retained trees) have occurred in home ranges occupied by spotted owls in this project. One thinning occurred on Study Area 1, 3 each on Study Areas 2, 4A, 4B, and 7, while 4 shelterwood preparatory harvests occurred on Study Area 6. The pre- and post-harvest habitat conditions have not yet been measured and mapped for those areas, so we can report only general observations. We have not observed any owls leaving their home ranges permanently or even leaving their home-range sites while the manipulations were occurring. In several cases, we observed radio-tagged owls using the edges of treated areas as the harvests were occurring. Possibly, this use of the edge resulted from small mammals moving away from the manipulations. Also, there could have been a "fence" effect, in which dispersing young mammals outside the treatment areas temporarily increased in densities where the stands conditions contrasted.

Carey et al. (1992) observed that northern spotted owls were capable of significantly reducing densities of prey by concentrating their hunting in certain areas. Subsequently, these areas were used less often until the small mammal populations rebounded. The pattern of owl behavior that we have observed suggests a similar scenario is possible in which the small mammal population densities shifted and may have been reduced as the owls exploited them along the stand edges. If so, one might predict a delay in subsequent use by owls until the small mammal populations respond along with the vegetative changes initiated by the treatments.

RSF MODELS OF FORAGING HABITAT SELECTION

Below, we present habitat-modeling results from 3 study areas: Study Areas 5, 6 and 7. Resource selection functions, or RSF (Manly et al. 1993, 2002) provide an optimal means of identifying underlying functional relationships between the spotted owl and its environment. When linked to a geographic information system (GIS), and evaluated using manipulative experiments, RSF models provide powerful decision-support tools for natural resource management (Boyce et al. 2002), with applications in cumulative effects analysis or risk assessment, forest management planning, and population viability analysis (Boyce et al. 1994, Boyce and McDonald 1999, Boyce and Waller 2000). Irwin and Hicks (1995) and Hicks et al. (in press) applied RSF modeling to northern spotted owls for Plum Creek Timber Company's habitat conservation plan (HCP) for the Snoqualmie Pass area, Washington, and Simpson Resource Company recently developed a RSF model to support HCP planning efforts in northwestern California (T. McDonald and L. Diller, pers. comm.). For our purposes, the crucial topic involves developing RSF models that predict foraging habitat selection by spotted owls based upon a set of biotic features and physical environmental covariates.

For the analyses presented here, we estimated log-linear models using beta-coefficients from logistic regressions for individual owl sites and developed discrete-choice models (Manly et al. 2002) in which data for all owls within a study area are combined to identify common factors. The 2002 interim report provides details, which we abbreviate here. The analyses were developed from over 5,000 telemetry and random points at Study Area 5,

Table 3. Reproductive success of radio-tagged spotted owls, 2001-2003

	Study Area									
Year	1	2	4A	4B	5	6	7	9	10	Total or Ave.
					Number of Home Ranges					
2001	6	8	7	10	8	8	8	a	a	55
2002	6	8	7	10	8	8	8	9	a	64
2003	6	8	6	10	b	8	8	9	5	55
					Number of Fledglings Produced					
2001	3	7	0	2	0	0	11	a	a	23
2002	2	7	2	1	2	5	2	2	a	23
2003	0	0	0	2	b	2	0	2	2	8
					Average Number Fledglings Per Home Range					
2001	0.50	0.88	0.00	0.00	0.00	0.00	1.38	a	a	0.42
2002	0.33	0.88	0.29	0.10	0.25	0.63	0.25	0.22	a	0.36
2003	0.00	0.00	0.00	0.20	b	0.12	0.00	0.22	0.40	0.14

[a] Study had not begun until 2003.
[b] Study was discontinued in 2002.

7,000 points at Study Area 6, and ~1,600 points at Study Area 7. About 5% of the telemetry points were excluded from analyses because they were >120m from inventory plots. We chose 120m as the cutoff because that distance is slightly larger than the mean telemetry error (84m) plus 2 SE (i.e., 32m).

To our knowledge, we are the first to develop RSF models for owls relative to structural variability *within* forest stands, based upon forest inventory data. Previous telemetry studies of habitat relationships among spotted owls generally assessed forest habitat conditions on the basis of categorical descriptions of forest successional stages (e.g., plantation, pole, young, mature, old) or age classes. In developing logistic regression models for NSOs in western Oregon, Glenn et al. (2004) found that such seral stages accounted for only a modest amount of the variation in habitat selection. We suspected that such broad categories would provide even less satisfying descriptors for the highly variable uneven-aged forests involved in our project. Therefore, for Study Area 6 we compared the relative utility of predicting owl foraging habitat use between measured habitat inventory data (not available for all points at Study Area 5) and California wildlife habitat relationships (WHR) classes, which combine overstory composition, canopy closure and size class information.

Glenn et al. (2004) noted that distance from an owl's nest site was the strongest variable in discriminating between telemetry- and random points within home ranges. Because of previous work (Haufler and Irwin 1994), we included distance to nest site and several additional factors that pertain to the physical environment. Carey and Peeler (1995) provide another previous example, in which they included what they called landscape units, which were GIS composites of landforms and vegetation.

Our ultimate aim is to develop parsimonious RSF models of foraging habitat selection that are matched to the scale of underlying biological processes within owl home ranges. For example, we assumed that spotted owl habitat selection for foraging is most likely to be associated with topography, areas in productive vegetation types along riparian zones, specific vegetation composition, conditions around nest sites, tree density and forest structures (e.g., snags) that are believed to influence populations of the owl's prey, and thereby the owl population. Such information 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 could help in determining if it matters to owls where vegetation conditions occur, or, by inference where silvicultural treatments occur (e.g., ridges vs. stream bottoms) or should be applied cautiously.

STUDY AREAS

Study Area 6--. RSF models are most well-developed for Study Area 6 because of the availability of detailed forest inventories. We described RSFs for 8 home ranges occupied by California spotted owls (CSO) in the 2002 annual report and 2002 summer interim report, and Clark (2002) reported on factors influencing use of core areas by the same owls. Here, we describe parsimonious *a priori* resource selection function (RSF) models that are compared as alternate hypotheses for accounting for variation in combined data from 9 owl home ranges in that study area. Each cumulative home range contained pairs of owls at various times, although both members of pairs may not have been monitored simultaneously.

The 2002 annual report describes the Chico Study Area. Briefly, that study area lies approximately 30 miles east of Chico, California, on timberlands primarily owned by Sierra Pacific Industries. Some U.S. Forest Service tracts are included. Primary vegetation types include Mixed Conifer stands, which largely include Ponderosa pine (*Pinus ponderosa*), Douglas-fir, and a large component of Tanoak (*Lithocarpus densiflorus*) and California Black Oak (*Quercus kelloggii*). Radio-tracking at 9 owl home ranges provided data for modeling nocturnal habitat selection (i.e., foraging).

Study Area 7--. This area is near Fort Bragg, California on timberlands owned by California Department of Forestry & Fire, Mendocino Redwoods Company and The Campbell Group. Radio tracking at 8 home ranges continues to provide data for assessing and modeling nocturnal habitat selection by Northern Spotted Owls there. For this report, we acquired forest inventory data from Mendocino Redwoods Company for two cumulative home ranges (each with a pair of owls) that occur entirely within their ownership. This study area is predominantly Redwood forest on the west side (i.e., near the coast) and a mixture of Redwoods and Douglas-fir and Tanoak further inland.

Study Area 5--. This area involves Mixed Conifer forests immediately east of the town of Hilt, California. It includes forested tracts administered by the Klamath National Forest that are mixed with private commercial timberlands owned by Fruitgrowers Supply

Company. Radio tracking at 11 cumulative home ranges provided the data for modeling nocturnal habitat selection by NSOs. We have yet to acquire detailed forest inventory information for the U.S. Forest Service tracts, so we report below initial modeling that combines data from all owls and includes categorical data using a mix of company timber types and California WHR classes (i.e., forest type, size class, and overstory canopy density), along with physical covariates and inventory data provided by Fruitgrowers Supply Company.

METHODS

We obtained forest inventory data from each company. Sierra Pacific Industries sampled their forests and intervening federal timberlands at a rate of 1 vegetation-inventory plot per 4 acres. Such a level of resolution of habitat structural measures was not available to previous investigators (except for nest-site descriptions). The inventory data we obtained for Study Are 6 provided an opportunity to compare WHR classes and habitat structures at or near telemetry points with similar data from random landscape locations within owl home ranges. We also acquired forest inventory data for two owl home ranges at Study Area 7, and limited information from company-owned timberlands in Study Area 5.

Habitat Variables--. We hypothesized several variables would influence foraging habitat selection by CSOs and NSOs, including indices of stand density (West 1982, Long 1985, Lilieholm et al. 1993), such as basal area, quadratic mean diameter, overstory canopy cover and tree density by size classes. Each measure provides a slightly different perspective of stand conditions (Table 4). Owl telemetry locations were plotted on habitat maps as the geometric centers of telemetry error polygons. We excluded from analyses those triangulations that resulted in error polygons larger than 2 ha (approximately 5 acres), as well as telemetry and random locations > 120m from an inventory plot. For all analyses, the basic unit of analysis was the union of telemetry data points that defined the cumulative home ranges for all owls occupying a territory during the study. In this manner, we are able to incorporate data from an owl that only occurs on a site for a short period of time, provided that other owls (e.g., a mate or replacement bird) are monitored sufficiently to circumscribe a home range. We used the minimum convex polygon (MCP) home range as a template for estimating availability. Radio-tagged owls at each territory described in this report were monitored for 10-60 months.

RSF Modeling--. Probabilistic methods such as logistic regression (Manly et al.

Table 4. Definitions of environmental and structural variables used to characterize forest stand conditions.

Variable	Definition and unit	Abbreviation
Basal area	Cross-sectional area of all the stems in a stand measured at breast height and expressed per acre of land area (ft^2/ac).	BA
Canopy cover	Proportion of ground (%) covered by forest tree crowns	CANCOV
Coarse woody debris	Estimate of dead woody material on forest floor, based on standardized methods for estimating fuel loads (High, Moderate, Low).	CWD
Distance to streams	Distance (m) from telemetry- or random point to nearest permanent stream. As measured from GIS – stream layers mapped from USGS 7.5- minute quad maps and GPS line features.	DWATR
Elevation	Elevation of point (m) above mean sea level	ELEV
Quadratic mean diam.	Diameter of tree corresponding to the average basal area of a stand of trees (inches). Including trees > or = 4 inches dbh	QMD
Relative density index	Integrates basal area and size (QMD) in 1 covariate	SDI
Snag	Density of standing dead tree > 4 inches diameter, of various species (no./acres)	SNAG
Trees per acre	Total number of trees > 4 inches in diameter in a stand (no. /acre).	TPA
Size Class	Number of green trees per acre of specified size class	GREEN
Pine Basal area	Basal area of Ponderosa pine trees	PINEBA
Douglas-fir basal area	Basal area of Douglas-fir trees	DFIRBA
White fir basal area	Basal area of White fir trees	WFIRBA
Hardwoods	Basal area of all hardwood species, including shrubs	HARD
Hardwood trees	Basal area of hardwood trees > 8 inches dbh	HARD8

1993) are appropriate for developing RSF models based on use vs. availability, as demonstrated for NSOs by North and Reynolds (1996), Meyer et al. (1998), and Glenn et al. (2004). We used logistic regression to provide coefficients for log-linear models of the relative influences of the several vegetative and abiotic factors (covariates) within home ranges. To do so, we compared conditions at telemetry points with those at a similar number of random points (i.e, available) within home ranges.

In developing RSF models to account for variation in habitat selection patterns, we followed the process described by Franklin et al. at. (2000), in which we used existing science to generate plausible *a priori* models as hypotheses that should account for variation in habitat selection patterns. We reviewed ecological literature to identify factors that would be combined in RSF models, including physical environmental factors (elevation, slope, aspect, distance from streams), descriptors of forest stand structural conditions and tree species composition. Ultimately, we hope to include snags and fallen dead trees, which are important indicators of fuel loads and could influence abundance of the owl's prey. Forest stands that are relatively near streams should contain a greater abundance of prey via a greater expression of understory vegetation (Carey et al. 1992), and thereby influence habitat selection (Haufler and Irwin 1994, Irwin 1998). We also presumed that elevation would be a factor because of a shift in vegetation composition, such as from Ponderosa pine/Douglas-fir/hardwood at low elevations to more pure fir. The latter forest type has less prey biomass in similar vegetation types in southwestern Oregon (Carey et al. 1992).

Several studies found vegetation structures influence spotted owls (Thomas et al. 1990, Call et al. 1992). For example, snags are likely to influence abundance of the owl's prey species such as flying squirrels (*Glaucomys sabrinus*), and coarse woody debris on the forest floor has been shown to influence NSO habitat use while foraging (Irwin et al. 2000). Also, spotted owl foraging is likely to be associated with specific vegetation communities or tree species known to influence the owl's prey. In the case of the CSO and the NSO in Mixed Conifer forests, various woodrats (*Neotoma* spp.) are important prey whose abundance may be influenced by mast or fruit-producing plants such as oaks (Atsatt and Ingram 1983). In addition, red tree voles (*Arborimus longicaudus*) feed principally on needles of Douglas-fir trees (Carey 1991), and owl nests are most frequently found in Douglas-fir trees in some areas (Buchanan et al. 1993). Woodrats are also strongly associated with riparian zones (Anthony and Zabel 2003), so distance from streams was hypothesized as an important covariate.

The relationships between likelihood of use by owls and the several covariate factors could be linear, curvilinear (quadratic), or threshold (see Franklin et al. 2000). For example, a linear relationship involves owl use that increases or decreases steadily with increasing amounts of a factor, such as density of large trees, distance from a stream or increasing elevation. A curvilinear, or quadratic, relationship would exist for a covariate that has an optimal level, above and below which probability of use declines, resulting in a unimodal or "hump-backed" pattern. A quadratic relationship can be represented by the term, $\beta_1 X_1 - \beta_2 X_2^2$. Another plausible hypothesis is that the relation could be more or less a threshold, in which use is low (or high) with increasing measures of a factor, up to some level, above which use increases (or decreases) rapidly. A quasi-threshold relationship can be represented by the natural logarithm of a variable.

We used logistic regression to estimate coefficients for covariates to be used in log-linear models for individual owl sites (Manly et al. 1993): **W/(1+W)**, where $W = e^{f(\hat{w}_i)}$, and $\hat{w}_i$ is the familiar linear equation, $\boldsymbol{\beta_o + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots \beta_i X_i}$, and the X_is represent the habitat covariates. The log-linear form is simply the numerator, **W**.

Physical environmental covariates that may influence foraging habitat selection by radio-tagged birds can be measured from maps more precisely than vegetative habitat factors. Thus, we initiated the modeling process by identifying a small set of "best" models with 2-4 planimetric physical environmental covariates first. Then, we added variables for forest stand structural conditions. Because the several stand-density variables are correlated, and because we wanted to examine only a comparatively small set of overall models to minimize the potential for identifying spurious models ("data-dredging" or over-fitting), we developed separate models that included basal area, canopy cover, total tree density and quadratic mean diameter. After identifying the best models that included physical and stand condition covariates, when possible we compared models with the number of "small" trees/acre (5-14 inches dbh) and "large" (> 22 inches, > 26 inches, or > 30 inches dbh) and subsequent models that included basal area of specific tree species to represent variation in composition. Irwin et al. (2004) identified small trees were negatively correlated with reproduction and site occupancy in Washington, and numerous studies demonstrated a close association with large trees (reported in Thomas et al. 1990).

We used change-in Akaike's information criterion (Akaike 1973), or ΔAIC (estimated by $Chi^2 - 2$ (d.f. model 1- d.f. model 2)), to identify the most parsimonious models to represent variation in the data, that is, the models that accounted for the most variation with the fewest model variables. Models that represented hypotheses to be compared are identified in Table 5. In previous analyses (reported in the 2002 annual report dated Jan. 2003), we ran a relatively small set of models twice—in the first we withheld data from 1 home range, as a quasi-cross validation exercise to evaluate the stability of covariates in the models and their coefficients, as well as the relative rankings of various models. Doing that provided confidence in the models because the covariates or their coefficients did not change materially.

***RESULTS and DISCUSSION OF CSO ANALYSES*--.** The 9 CSO home ranges were 830-1200m in elevation and contained forests where average basal areas within survey plots ranged from 150-225 square feet per acre. Average basal area for plots nearest to telemetry points was 200 ft^2/acre, with little use occurring near plots that contained less than 50 ft^2/ac or in those with > 300 ft^2/acre. Basal area at inventory plots nearest to random points averaged 183 ft^2/ac. The forests in the home ranges apparently were moderately closed, as overstory canopy cover exceeded 58% and averaged nearly 70% in inventory plots. The forest samples predominantly contained intermediate trees (average quadratic mean diameter ranged from 12-14 inches), and were relatively dense (density ranged from 372-544 trees/acre). On average, the telemetry points were inventory plots that contained an average of 150 trees/acre (± 3.9 se) that were 5-14 inches dbh, whereas plots nearest to random points averaged 170 (± 4.5 se) such trees/acre. Many of the sample plots included some larger trees, and home ranges contained an average of about 3 large green trees (> 26 inches dbh) per acre. A range of 10-60% of the basal area within home ranges was comprised of Ponderosa pine, 30-60% was in Douglas-fir, 5-15% was in white fir, and up to 54% was comprised of hardwoods. The best models for the 9 individual owl sites are displayed in Table 6.

Physical Factors--. Abiotic factors, including distance to nest, distance to water, elevation (aspect was not included in this analyses) strongly influenced CSO foraging habitat selection. Likelihood of use declined rapidly and non-linearly with increased distance from nests. Except for 1 home range (Powellton) forest habitats were more likely to be used for foraging by CSOs if they occurred at lower elevations and/or nearer to streams than available at random (Table 6). Owls at the Powellton site were more likely to use intermediate

Table 5. Descriptions of *a priori* model-hypotheses to discriminate telemetry points from randoml
landscape locations within home ranges of California Spotted Owls near Chico, California.

Hypothesis	Linear structure	Pseudothreshold	Quadratic
I. Physical environmental factors			
1. Negative effect of distance from streams	$\beta_{Dwater} < 0$	$\beta_{ln(Dwater)} < 0$	$\beta_{Dwater} < 0, \beta_{ln(Dwater)}^2 > 0$
2. Use increases with distance from streams	$\beta_{Dwater} > 0$		
3. Use decreases with increasing elevation	$\beta_{Elev} < 0$	$\beta_{ln(Elev)} < 0$	$\beta_{Elev} < 0, \beta_{ln(Elev)}^2 > 0$
4. Use increases with increasing elevation	$\beta_{Elev} > 0$	$\beta_{ln(Elev)} > 0$	
II. Tree density factors			
1. Use varies with tree basal area	$\beta_{BA} > 0$	$\beta_{ln(BA)} > 0$	$\beta_{BA} > 0, \beta_{(BA)}^2 < 0$
2. Use varies with quadratic mean diam.	$\beta_{(QMD)} > 0$	$\beta_{ln(QMD)} > 0$	$\beta_{(QMD)} > 0, \beta_{(QMD)}^2 < 0$
3. Use varies with weighted mean diam.	$\beta_{WTD} > 0$	$\beta_{ln(WTD)} > 0$	$\beta_{WTD} > 0, \beta_{(WTD)}^2 < 0$
4. Use varies with tree density	$\beta_{TPA} > 0$	$\beta_{ln(TPA)} > 0$	$\beta_{TPA} > 0, \beta_{(Dens)}^2 < 0$
5. Use increases with canopy cover	$\beta_{CANCOV} > 0$	$\beta_{ln(CANCOV)} > 0$	$\beta_{CANCOV} > 0, \beta_{CANCOV)}^2 < 0$
III. Tree species basal area			
1. Use increases with Douglas-fir	$\beta_{DFir} > 0$	$\beta_{ln(Dfir)} > 0$	$\beta_{DFIR} > 0, \beta_{DFIR}^2 < 0$
2. Use increases with White-fir	$\beta_{WFir} > 0$	$\beta_{ln(Wfir)} > 0$	$\beta_{WFir} > 0, \beta_{Wfir}^2 < 0$
3. Use decreases with Ponderosa pine	$\beta_{Ppin} < 0$	$\beta_{ln(Ppin)} < 0$	
4. Use increases with Hardwoods	$\beta_{Hdw} > 0$	$\beta_{ln(Hdw)} > 0$	$\beta_{(Hdw)} > 0, \beta_{(Hdw)}^2 < 0$
5. Use decreases with Hardwoods	$\beta_{Hdw} < 0$	$\beta_{ln(Hdw)} < 0$	

Table 6. Top 3 models that account for variation in habitat selection by California Spotted Owls in 9 home ranges near Chico, California.

Site Name	Model Variables	Chi^2	d.f.
BOUNDARY			
	ELEV – ELEV^2 + ROAD – ROAD^2 - NEST + NEST^2 + PINE + LnDFIR	296.2	8
	ELEV – ELEV^2 + ROAD – ROAD^2 - NEST + NEST^2 + PINE + LnDFIR -HARD8	296.2	9
	ELEV – ELEV^2 + ROAD – ROAD^2 - NEST + NEST^2 + PINE – SLOPE	290.3	8
CEDAR			
	ELEV – ELEV^2 + ROAD – ROAD^2 - NEST + NEST^2 – WATER - PINE – DFIR + SLOPE + WFIR - HARD – HARD8	176.6	11
	ELEV – ELEV^2 + ROAD – ROAD^2 - NEST + NEST^2 – WATER - PINE + SLOPE + LnWFIR – HARD8	167.0	9
	ELEV – ELEV^2 + ROAD – ROAD^2 - NEST + NEST^2 – WATER - PINE + SLOPE + WFIR – HARD8	165.7	9
COLDHILL			
	ELEV – ELEV^2 + LnROAD – NEST + NEST^2 + GREEN>10 - SMALL	363.7	7
	ELEV – ELEV^2 + LnROAD – NEST + NEST^2 + GREEN>10 - SMALL + HARD8	365.6	8
	ELEV – ELEV^2 + LnROAD – NEST + NEST^2 + GREEN>10 - SMALL + LnHARD8	364.3	7
GARLAND			
	SLOPE – ELEV – GREEN>22	60.0	3
	SLOPE – ELEV – BASAL	58.2	3
	SLOPE – ELEV – PINEBA	57.2	3
IKE DYE			
	ELEV – ELEV^2 + ROAD – ROAD^2 - NEST + NEST^2 + QMD – QMD^2 + GREEN >30 - SNAG34 - LnDFIR – LnHARD8	103.4	12
	ELEV – ELEV^2 + ROAD – ROAD^2 - NEST + NEST^2 + QMD – QMD^2 + GREEN >30 - SNAG34 - LnDFIR	100.8	11
	ELEV – ELEV^2 + ROAD – ROAD^2 - NEST + NEST^2 + QMD – QMD^2 + GREEN >30 - SNAG34 - DFIR + DFIR^2 – LnHARD8	103.4	12

elevations at great distances to streams. The top models for 5 owl home ranges included a non-linear variable (either threshold or unimodal) for distance to roads. At this time, we do not know if that statistical relation may be a function of a direct biological influence of traffic along roads or a result of locations of roads relative to more direct factors influencing the abundance or availability of prey. For example, snags adjacent to roads may have been removed by firewood cutters or for safety precautions.

Stand Conditions--. Variables describing stand conditions, particularly indicators of density or basal area, influenced the likelihood that a random point would be used as a foraging location. Overstory canopy cover was not a strong predictor except for 1 home range (Powellton), where its effect was unimodal. Models developed from data acquired through 2002 more often included terms for total quadratic mean diameter (QMD) or BASAL AREA. In Table 6, models for only 3 home ranges contained these terms. Instead, BASAL AREA of individual tree species or species groups were more important. For example, BASAL area of Ponderosa pine had negative coefficients in 2 of 3 home ranges where pine was an influence. In other cases, Douglas-fir was an important covariate, either non-linear (Boundary, Ike Dye, Inskip) or linear (Cedar, Lovelock). Basal area of hardwoods > 8 inches in diameter-at-breast height (DBH) also was a frequent covariate, usually with a negative coefficient (Boundary, Cedar, Ike Dye, Lovelock), but not always (e.g., Coldhill). In that single case, Coldhill, the density of small-diameter trees had a negative effect. The density of comparatively large trees (> 22, > 26 or > 30 inches dbh) was an important covariate in models for 5 home ranges (Garland, Inskip, Platt, Lovelock, and Powellton).

WHR VS. STAND MEASURES--. In discrete-choice analyses that combined data for the 9 CSO home ranges, we found that the California Wildlife Habitat covariates provided reasonable ability to discriminate between telemetry and random points (Table 7). In those analyses, relative to the reference covariates, Sierran Mixed Conifer classes 3M, 4M, 4D, and 6D and Mixed Conifer Hardwood Classes 4D and 6D had positive coefficients, whereas Ponderosa Pine (PPN) classes 1O and 2M had negative coefficients. Reference covariates included Mixed Conifer Hardwood classes 3D and 3M, BARE, and PPN classes 3D and 4D, which were combined because their statistical effects were similar or because of small sample sizes.

In discrete-choice models that included only forest stand conditions, canopy cover (non-linear threshold transform), density of trees > 26 inches dbh, and basal area of Douglas-

Table 6. Continued

INSKIP		
- SLOPE + ELEV – $ELEV^2$ - NEST + $NEST^2$ + GREEN >22 + DFIR – $DFIR^2$	260.7	8
- SLOPE + ELEV – $ELEV^2$ - NEST + $NEST^2$ + GREEN >22	256.6	6
- SLOPE + ELEV – $ELEV^2$ - NEST + $NEST^2$ + GREEN >22 + LnDFIR	258.0	7
PLATT		
SLOPE + ELEV – $ELEV^2$ + ROAD – $ROAD^2$ + WATER – $WATER^2$ - NEST + $NEST^2$ + GREEN >26	348.1	11
SLOPE + ELEV – $ELEV^2$ + ROAD – $ROAD^2$ + WATER – $WATER^2$ - NEST + $NEST^2$ + BASAL	346.2	10
SLOPE + ELEV – $ELEV^2$ + ROAD – $ROAD^2$ + WATER – $WATER^2$ - NEST + $NEST^2$ + LnTPA	342.8	10
LOVELOCK		
-LnELEV + WATER – NEST + $NEST^2$ + GREEN>30 –SNAG05 – LnPINE + HARD8 –$HARD8^2$	151.3	9
-LnELEV + WATER – NEST + $NEST^2$ + GREEN>30 –SNAG05 – LnPINE + LnHARD8	144.3	8
-LnELEV + WATER – NEST + $NEST^2$ + GREEN>30 – SNAG05 + PINE + DFIR – WFIR – HARD + HARD8	141.8	11
POWELTON		
SLOPE + ELEV – $ELEV^2$ + WATER - NEST + $NEST^2$ + LnQMD	195.4	7
SLOPE + ELEV – $ELEV^2$ + WATER - NEST + $NEST^2$ + CANOPY – $CANOPY^2$	192.6	7
SLOPE + ELEV – $ELEV^2$ + WATER - NEST + $NEST^2$ + GREEN>26	189.6	7

Table 7. Top models to account for variation in habitat selection by California Spotted Owls in 8 home ranges near Chico, California: A. Models based upon WHR system; B. Models based upon measured habitat conditions; C. Combined models.

Model	Chi^2	d.f.
A. California Wildlife Habitat Relationships (WHR) Classes		
1) SMC (3M+4M, 3D, 4D, 6D) MCH (4D, 6D) – PPN (1O,2M)[a]	221.6	8
2) SMC (3M+ 4M, 3D, 4D, 6D) + MHC (-3M, 3D, 4D, 6D) – PPN (1O,2M, 3D+4D)	224.6	11
3) SMC (4D,6D) + MHC (-3M, 3D, 6D) – PPN (1O, 2M, 3D+4D) – BARE	203.3	9
4) SMC (4D, 6D) + MHC (-3M, -3D) – PPN (2M) – BARE	177.1	6
B. Forest Stand Conditions		
5) LnCANOPY + GREEN>26 – SNAG>14 – LnPINE + LnDFIR –HARD>8	212.6	6
6) LnCANOPY + GREEN>26 – SNAG>18 –LnPINE + LnDFIR – HARD>8 –GREEN< 14	210.5	7
7) LnCANOPY + GREEN>26 - LnPINE + LnDFIR - HARD>8	204.7	5
C. COMBINED WHR and STAND CONDITIONS		
8) SMC (3M+4M, 3D, 4D, 6D) MCH (4D, 6D) – PPN (1O,2M) + LnCANOPY + GREEN>26 – LnPINE + DFIR – $DFIR^2$ + HARD>8 - $HARD>8^2$	325.7	15
9) SMC (3M+4M, 3D, 4D, 6D) MCH (4D, 6D) – PPN (2M) + LnCANOPY + GREEN>26 – LnPINE + DFIR – $DFIR^2$ + HARD>8 - $HARD>8^2$	321.3	14
10) SMC (3M+4M, 3D, 4D, 6D) MCH (4D, 6D) – PPN (1O,2M) + BASAL + $BASAL^2$ + LnCANOPY + GREEN>26 + DFIR – $DFIR^2$ - HARD>8	321.6	15

[a] Reference covariates were: PPN 3D, 4D, MCH 3D, 3M, and BARE

fir (non-linear threshold transform) had positive coefficients, whereas density of snags >14 inches dbh, pine basal area (non-linear threshold transform), and basal area of hardwoods > 8 inches dbh had negative coefficients. While appearing similar, we could not directly compare the relative utility of models that included only WHR covariates or only forest structure measures because of unequal sample sizes. That is, the datasets were slightly different because some points for which we obtained WHR classes were not inventoried, and vice versa.

The combination of forest stand structure and WHR covariates (Table 7) resulted in models that accounted for a great deal more variation in the telemetry data than either habitat structure or WHR alone. The best combined models included the same variables for WHR, but included slight changes in habitat structure covariates. In the combined models, the effects of Hardwood and Douglas-fir basal area were non-linear and unimodal (Figure 3). We have not yet added physical covariates to such models, but expect that doing so will further strengthen the RSFmodels.

The analyses suggest some options for integrating conservation of CSOs with goals for a sustainable forest environment. When foraging, CSOs selected moderately dense forest structures in stands that are relatively close to nest sites (average = 700m) and often with a few (average approx. 4) large trees/acre (≥ 26 inches dbh) close to streams, usually in lower slope positions on moist northeast slopes. Based upon those results, we speculate that the owl's prey are probably more abundant in the riparian zones or moist forests within this study area. Both bushy-tailed and dusky-footed woodrats, important prey items in the study area, are riparian associates in forests west of the Cascade crest in the Pacific Northwest (Zabel and Anthony 2003). In addition, tree species composition is an important influence in relative use of forests by CSOs for foraging. For example, we found that basal area of hardwood trees had negative effects on likelihood of use and basal area of Douglas-fir had positive effects on likelihood of use. Several trends in the data suggest that trees can be too dense, which is supported by re-analyses of data from the Sierra National Forest by Lee and Irwin (submitted). As suggested in previous reports, the variability in covariates among models for individual home ranges suggests that silvicultural practices probably need to be tailored specifically to individual home ranges based upon relative tree species composition, among other factors.

At this time, our analyses support a view that there may be an optimal forest density, such that inventory plots with a range of approximately 160-320 square feet of basal area per acre likely receive the most use, whereas silvicultural treatments that retain approximately 80-160 square feet of basal area per acre should support relatively frequent foraging use by CSOs. Subsequently, stands with such structural conditions might be expected to receive increasing use as tree crowns respond to the increased spacing. Verner et al. (1992) predicted an initial modest decline in use, followed by equal or perhaps higher levels of use of stands that are treated via partial harvests. Verner et al. (1992) recommended retaining large (> 30-inch dbh) healthy and cull trees for nest stands. Our analyses suggest that trees ≥ 26 inches dbh influence foraging habitat selection: average densities of such trees in inventory plots near telemetry points were approximately 4/acre, whereas random points in the home ranges averaged 2.5 such trees per acre.

FIGURE LEGEND

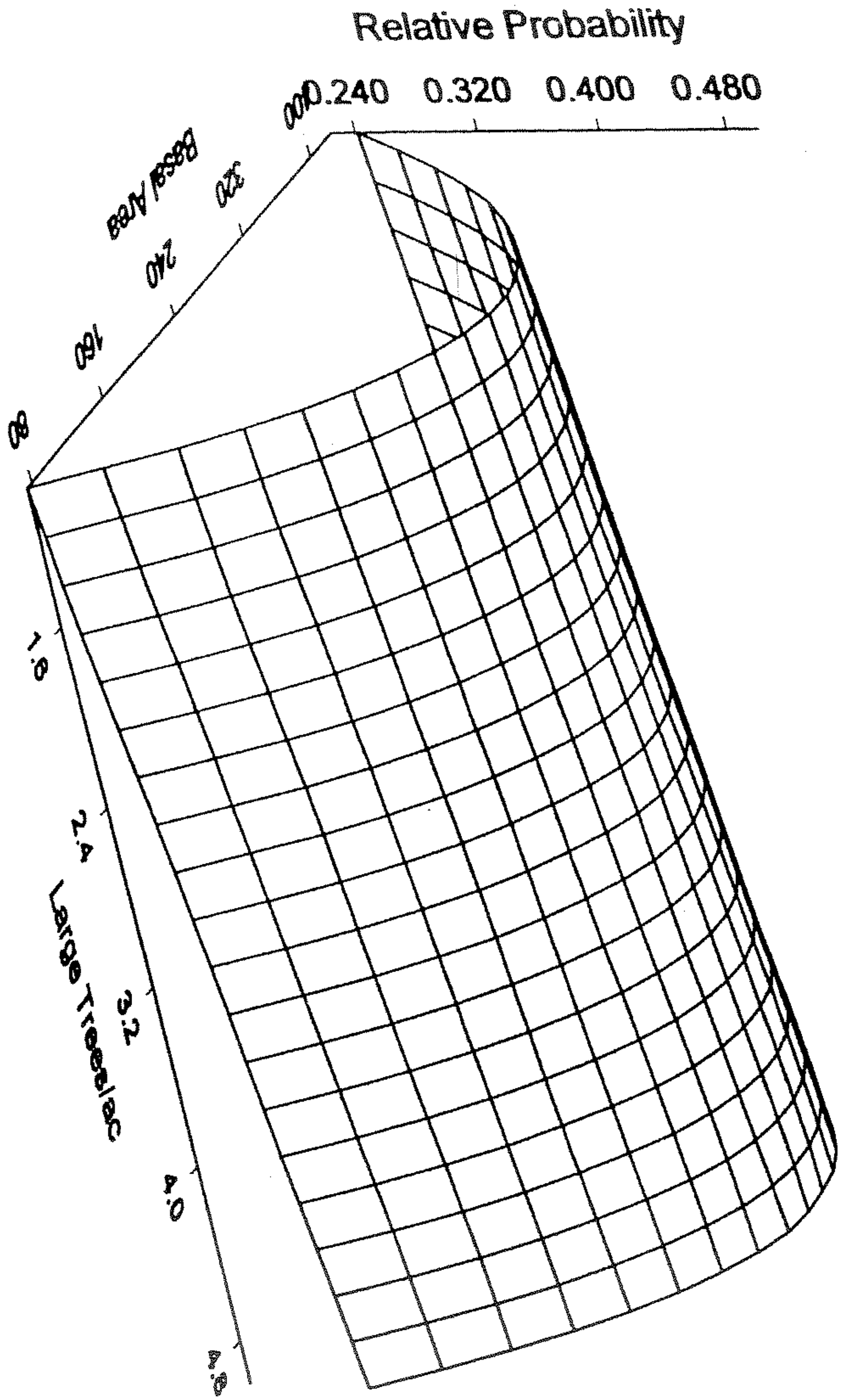
Figure 3. Representation of relative effects of basal area of Douglas-fir and density of trees larger than 26 inches in diameter on relative likelihood of use of a stand by California spotted owls for foraging. Note that this graph describes a situation in which the relative effects of other important covariates are held constant, such as basal area of hardwoods, physical covariates, etc.

Verner et al. (1992:25) indicated that they wouldn't be surprised to find a brief period of reduced use (< 5 years) after partial-cutting operations. They believed that such practices would be unlikely to degrade spotted owl habitat significantly over the short term, and may even improve habitats over the long term. Our analyses of initial CSO behavioral responses generally support their opinion, although the size-class and species of tree to be removed or retained matters, as does the residual basal area. Removal of smaller-diameter trees (< 14 inches dbh), such as for reducing hazardous fuels, probably would benefit CSO over both the short and long runs. This appears generally true for trees less than 14 inches in diameter and probably specifically includes ponderosa pine and hardwoods (probably tan oak), both of which had negative statistical relationships with likelihood of use by CSOs.

Several physical environmental covariates exhibited stronger statistical effects than descriptors of vegetation. For example, in areas close to nest sites, extensive removal of large trees would be expected to reduce habitat quality, whereas thinning projects to reduce basal area of smaller trees should improve foraging conditions. Similarly, placing hazardous fuels treatments along ridge lines or along south-west facing slopes probably would have minimal effects on CSOs, because the owls are much more likely to use mesic northeast slopes near riparian zones. Similarly, partial harvesting (e.g., shelterwood harvests), thinning or fuel reduction treatments would be expected to have relatively reduced effects at higher elevations and >600-800 m from nests.

We reiterate from past reports that, as in real estate, location matters greatly to CSOs. Therefore, the habitat value of forest stands depends crucially upon where the indicated structural conditions are located in relation to riparian zones, an owl's nest, and topography. As such, assessments of short-term impacts of partial harvesting should account for the specific locations of the proposed treatments.

While the results are encouraging and useful, we are not yet satisfied with the combined RSF models, and therefore do not recommend widespread application at this time. First, we may use model-averaging processes to define final models. Second, additional data will be collected through March 2004. Third, we want to examine the data for differences in conditions within core areas and the remainder of the home ranges. Fourth, we want to determine if different factors influence foraging use in the non-breeding season vs. the nesting season. When that work is completed, we expect to develop a modeling



Relative Probability
0.240
0.320
0.400
0.480
Basal Area
80
160
240
320
400
Large Trees/ac
1.6
2.4
3.2
4.0
4.8

algorithm that can be linked with a GIS to produce maps of relative habitat quality for CSOs. Until that work is completed, we encourage cautious applications of the results reported herein.

SUMMARY of CSO RESULTS

1. A probabilistic model was developed that, with further development, could predict CSO response to thinning or hazardous fuels treatments.
2. Abiotic factors exerted strong influences on CSO foraging habitat selection. CSOs were more likely to use forested habitats at lower elevations near streams and steeper north to northeast-facing aspects.
3. Variables describing stand density influenced foraging habitat selection, including QMD or BASAL AREA, most often as a quadratic term, indicating that an optimal forest density may exist.
4. Overstory canopy cover was not a strong predictor of foraging habitat selection.
5. Likelihood of use declined linearly with increasing density of trees < 14" dbh.
6. Use increased with increasing density of trees > 26" dbh.
7. Tree species composition matters: Douglas-fir basal area was a positive influence, whereas the influence of hardwoods (probably tanoak) and Ponderosa pine was negative.
8. Silvicultural practices probably need to be tailored to individual areas based upon topography, forest density, and relative tree species composition.
9. We speculate that hazardous fuel reduction treatments or other silvicultural treatments that retain approximately 80-320 square feet/acre of basal area should support spotted owls in these forests, recognizing that approximately 160-250 square feet per acre may provide optimal foraging conditions in some cases. Providing a few trees > 26 inches DBH per acre apparently enhances use.
10. Additional analyses are warranted prior to widespread application of results.

RESULTS AND DISCUSSION OF RSF MODELS IN COASTAL REDWOOD FORESTS--. We received habitat and environmental information for two NSO owl home ranges in Study Area 7, for which we have gathered > 800 telemetry points. Information used in the initial analyses and acronyms is presented in Table 8.

Physical variables--. Similar to the CSOs, the top-ranked models that discriminated between telemetry points and random points within owl home ranges included elevation, distance to nest, and distance to streams, as shown in Table 9. The coefficients for elevation were negative and non-linear—either threshold or unimodal. The sign for coefficients for distance to nest was negative, most often unimodal. Also, the coefficients for distance to streams were negative and linear. These results suggest that foraging is most likely to occur in locations relatively close to nest sites near riparian zones.

Stand conditions--. Foraging patterns by the radio-tagged NSOs at Northfork Camp

Table 8. Definitions and acronyms for covariates used in RSF models for Coastal Redwood forests.

Covariate Name	Description
REDEN	Density (stems/acre) of Redwood trees, estimated in size classes < 8 inches (REDDEN0), 8-16 inches (REDEN8), 16-24 inches (REDDEN16), 24-32 inches (REDDEN24), and > 32 inches (REDDEN32).
DFIRDEN	Density of Douglas-fir trees, estimated in same size classes as for Redwood (i.e., DFIRDEN, DFIRDEN8, etc.).
TANDEN	Density of Tanoak trees, estimated in same size classes as above.
BASALCON	Basal area (sq.ft/ac) of all conifers, estimated in same size classes as above.
HARDBASAL	Basal area of all hardwoods, estimated by size class, as above.
REDVOL	Volume (cubic ft/ac) of Redwood trees within same size-classes as above.
DFIRVOL	Volume of Douglas-fir trees, as above.
CONVOL	Volume of all conifers, using same size classes as above.

Table 9. Top-ranked models to account for variation in habitat selection at 2 Northern Spotted Owl home ranges near Fort Bragg, California.

Model	Chi^2	% Concordance	d.f.
Northfork Camp			
1) - Ln(ELEV) - DWATR – NESTDIST + $NESTDIST^2$ + TANOAK<8 – TANOAK8 – REDVOL8	166.6	68.4	8
2) - Ln(ELEV) - DWATR – NESTDIST + $NESTDIST^2$ + TANOAK<8 – TANOAK8 – REDVOL8 + REDVOL24	133.5	65.3	7
3) -Ln(ELEV) -DWATR + TANOAK<8 – TANOAK8 – REDVOL8 + REDVOL24 – REDWDEN8	131.4	66.6	6
3) - Ln(ELEV) - DWATR + NESTDIST + + TANOAK<8 – TANOAK8 – REDVOL8 + REDVOL24	134.5	66.1	8
Southfork Big River			
1) ELEV – $ELEV^2$ - NESTDIST + $NESTDIST^2$ – DWATER + REDDEN24	69.9	61.4	7
2) ELEV – $ELEV^2$ - Ln(NESTDIST – DWATER + REDDEN24	57.2	59.8	6
3) ELEV – $ELEV^2$ - NESTDIST – DWATER + REDDEN24	46.1	60.1	6
4) ELEV – $ELEV^2$ – DWATER + REDDEN24	38.9	58.1	5

were influenced by density of Tanoak, with a positive coefficient for small-diameter Tanoak (< 8 inches DBH) and a negative coefficient for 8-16 inch DBH Tanoak. The likelihood of a patch being used for foraging by the Northfork Camp NSOs decreased in stands with increasing densities of Redwood trees 8-16 inches in DBH. Three models included a positive influence of increases in cubic volume of Redwood trees 24-32 inches in DBH.

The only vegetative factor that was a strong influence for owls at Southfork Big River was the density of Redwood trees 24-32 inches DBH. Interestingly, the nest site for owls at the Southfork Big River site is in a stand with > 75% overstory canopy cover that is comprised mostly of small-diameter (< 8 inches DBH) Tanoaks and some residual second-growth Redwood trees. The same birds have apparently occupied this site for at least 13 years, and have been comparatively productive. We emphasize, of course, that additional covariates might be supported in RSF models constructed from additional data.

Results and Discussion of RSFs for Study Area 5--. We acquired information that provides a glimpse of habitat selection patterns by a sample of NSOs using private timberlands near Hilt, California. We report only results of discrete-choice modeling, which was based upon nearly 6,000 telemetry and random points. At this point, however, we do not possess detailed habitat inventory information from all parts of home ranges that contain national forest lands in the study area. Therefore, we use California WHR categories, timber types used by the company for internal management planning, and physical covariates such as distance to streams or nest sites, along with some data on forest inventory reported to us by Fruitgrowers Supply Company, the primary landowner.

The RSF models for NSOs at Study Area 5 indicated that the top-ranked models that discriminated between telemetry points and random points within owl home ranges included elevation, distance to nest, and distance to streams. The statistical relation with elevation was non-linear and unimodal. The statistical relation for distance to streams was also non-linear, but the coefficient was negative for a pseudo-threshold relation, suggesting a high likelihood of use within a short distance of streams. Distance to nest was a negative quadratic relation with probability of use for foraging.

Using moderately closed, mid-seral Douglas-fir within WHR size and density class DF3M as the reference indicator variable, the relative likelihoods of use of WHR types DF4O, MC3M, MC3O, MC3L and DF3L stands were strongly positive. MC3L and DF3L are company-designated timber types with 12-24 inch QMD and 30-50 ft^2/ac of basal area. In contrast, the probability of owl use in Non-forested or poorly-stocked sites and clearcuts (CC) was strongly negative. Basal area of Ponderosa pine had a negative coefficient, whereas basal area of trees 6-34 inches in DBH had a quadratic relationship. However, the coefficient was negative, so the relation would suggest a potentially spurious concave unimodal relation in which probability of use is high at low and very high levels of basal area.

These preliminary analyses show strong similarities with RSF models from Study Areas 6 and 7. For example, relations with planimetric variables such as distance from nest sites and streams, and elevation were quite similar. This suggests that landforms and riparian zones may well be common influences among the several study areas. Furthermore, the apparent gradient in habitat values for foraging seems reasonable. For example, the analyses suggest the following ranking of habitat values at Study Area 5: Non-commercial forest (NCFL) > Clearcut > PP3L > MC3L > RH > DF3M > MC3O > MC3M > DF3L > DF4O (RH includes rehabilitation units that involve brushfields that were converted to conifer plantations < 10 years old). While much of the ranking seems reasonable, the data reported to us do not contain a full set of forest structural conditions available within Study Area 5. Until we acquire inventory information from U.S. Forest Service tracts, which are likely to contain more areas of late-seral forest, we cannot be sure that the patterns are altogether reliable and urge appropriate caution in interpretations

DISCUSSION AND NEXT STEPS

Stand inventory-based forest or habitat structure data provide much stronger RSF models when added to map-based categorical descriptions of vegetation conditions at owl sites. Such data allow probing of specific relationships (linear, unimodal, or threshold) that cannot be conducted using categorical data. Such data also provide for development of silvicultural prescriptions in terms that foresters understand. Yet, there is much more data to collect and analyze before we make widespread recommendations. In particular, we need to acquire stand inventory data from the forests managed by the USDA Forest Service and USDI Bureau of Land Management. Toward that end, we have submitted two proposals that, if funded, would provide financial resources for detailed habitat inventories. In addition, we plan additional analyses that will help evaluate the reliability of the various RSF models for purposes of predicting spotted owl responses to thinning or to intermediate silviculture. This is likely to entail cross-validation procedures in which a portion of the data is withheld and predicted by RSFs that are constructed from the remaining data. Also, we have the opportunity to predict habitat selection by including a larger set of owls in Douglas-fir/western hemlock forests at Springfield, based on the analyses presented herein. Finally, we intend to begin the challenging evaluation of results of comparisons of stand-level selection by owls whose home ranges received silvicultural treatments.

In addition, we have entered into discussions with possible collaborators who have shown interest in implementing the study in two new areas. One such area is on the "eastside" of the Cascades in Washington, in the Wenatchee and Okanogan National Forests. Actually, this location would become a separate study with different personnel and funding, and may include objectives for estimating habitat selection by barred owls. We also submitted a proposal to initiate radio-tracking at an area within the south coastal area of Oregon. The U.S. Forest Service has developed a program of forest restoration there, providing an opportunity to collect data that would add important information to the 3 existing study-area replicates in Douglas-fir forests in Western Oregon.

Finally, we plan to describe in future reports how the RSF models can be used by federal forest managers, forestry companies, and regulatory agencies in support of decisions associated with managing or protecting spotted owl habitats. For example, the models presented herein could be used at known owl sites to estimate the potential short-term consequences of a forest management plan in similar forested environments. Also, longterm consequences could be estimated by linking model output with forest-growth projections that estimate future habitat conditions after thinning or partial harvesting. In either case, our data strongly indicate that the **location** of the treatments relative to streams, elevation and nest sites seems to be as important as the type of habitat that may be modified. For example, Figures 4-11 demonstrate that physiography is important in all study areas. RSF models can account for such influences as well as those related to forest stand density, tree size and composition.

FIGURE LEGENDS

Figure 4. Three-dimensional view of telemetry locations of Northern Spotted Owls in a home range in Study Area 1. Note the prevalence of use near small-order streams.

Figure 5. Raised relief map of telemetry locations of Northern Spotted Owls in a home range in Study Area 2. Note the frequent telemetry points near the nest site and near streams.

Figure 6. Example of a 3-dimensional view of telemetry locations of Northern Spotted Owls in a home range in Study Area 4A. Note the preponderance of points in concave topography in or near riparian zones.

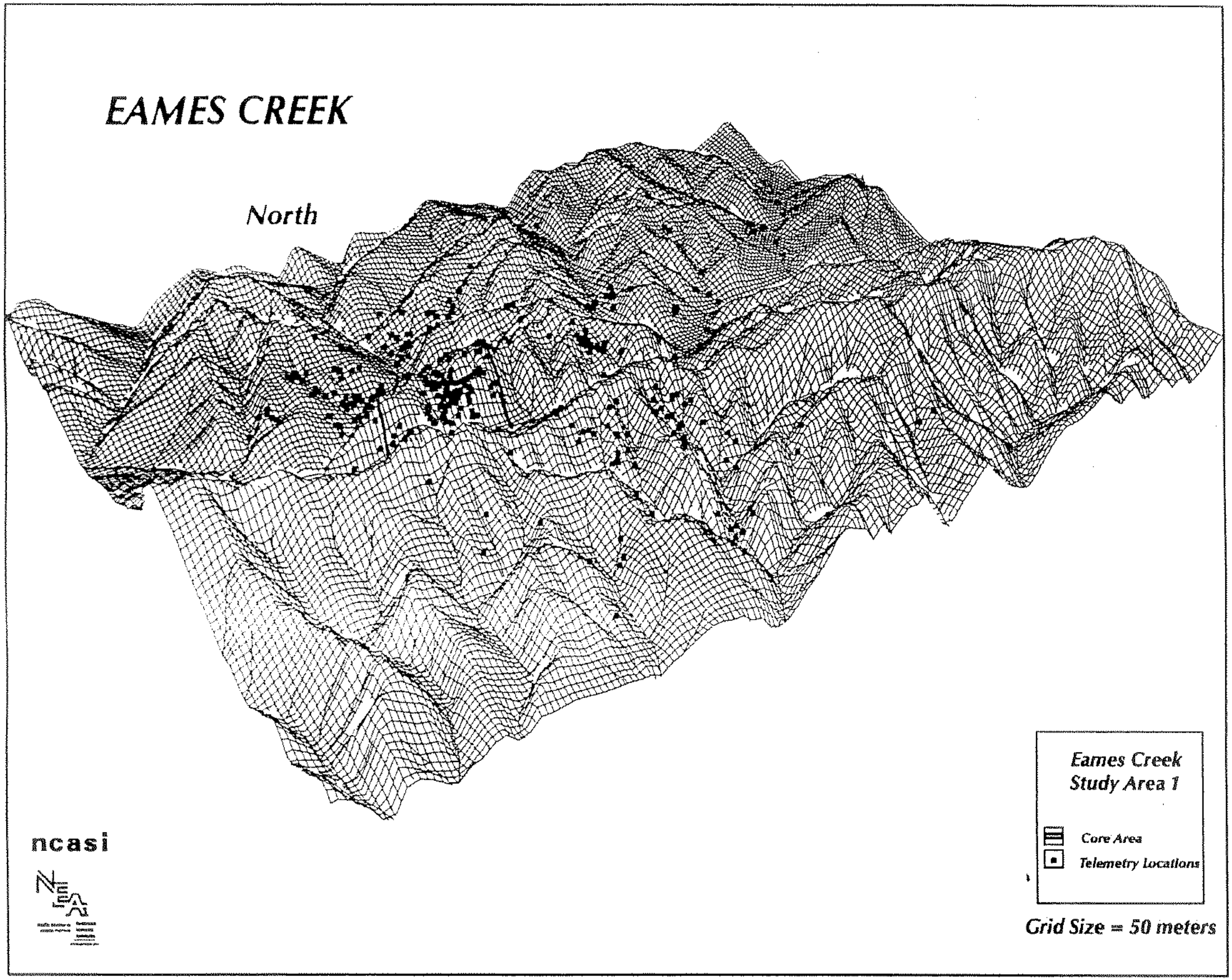
Figure 7. Raised-relief map of telemetry locations of Northern Spotted Owls in a home range in Study Area 4B.

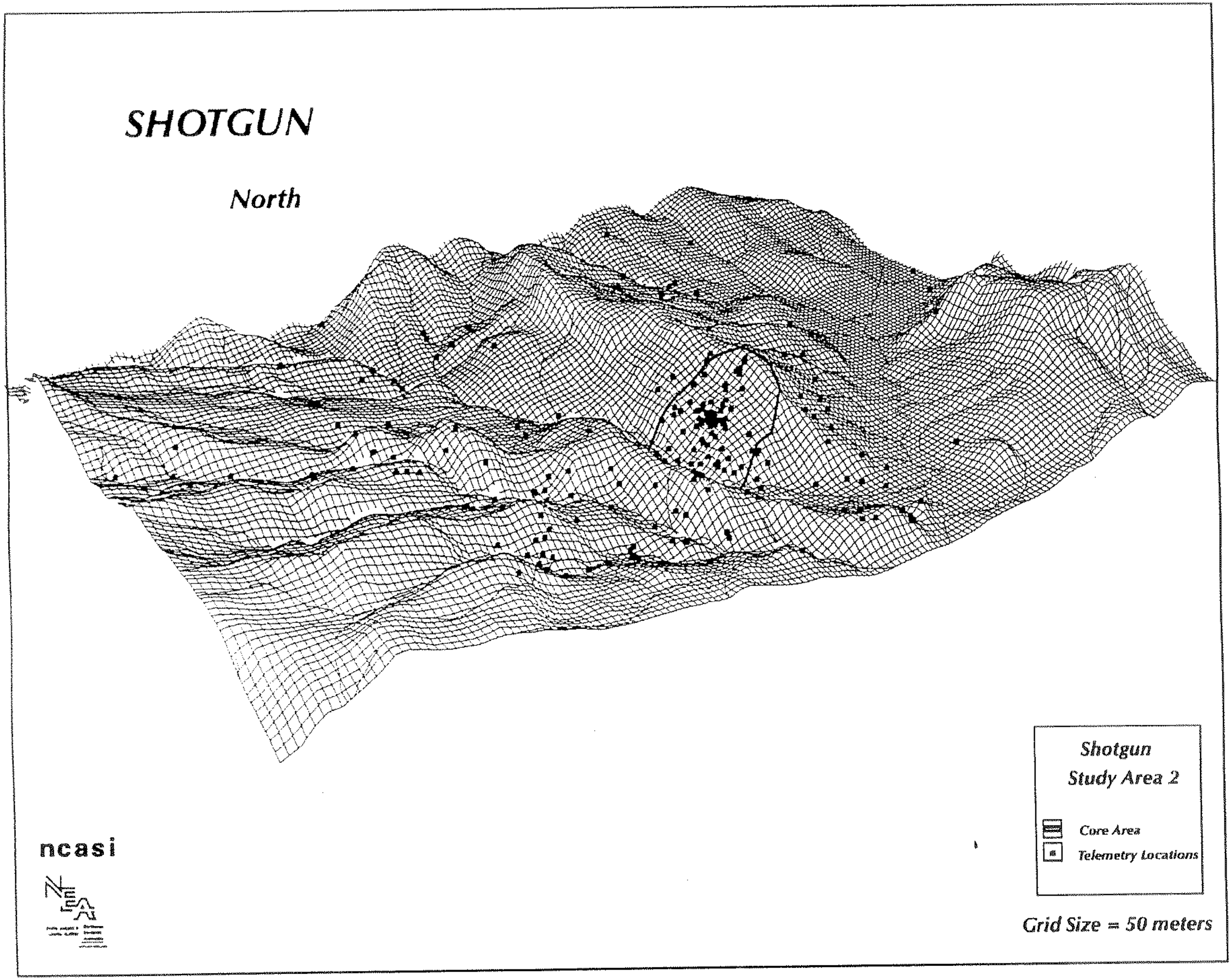
Figure 8. Map of telemetry locations of Northern Spotted Owls in a home range in Study Area 5. Note extensive use of moist, north slopes and proximity to nest and riparian zones.

Figure 9. Map of telemetry locations of California Spotted Owls in a home range in Study Area 6. Note heavy use of mesic slopes, the small core-use area, and the prevalence of use near small-order streams.

Figure 10. Map of telemetry locations of Northern Spotted Owls in Coastal Redwood forests in a home range in Study Area 7. Once again, note the prevalence of use in low elevations near riparian zones.

Figure 11. Three-dimensional view of telemetry locations of Northern Spotted Owls in a plateau situation in Study Area 9. Again, note that most of the use occurs in a linear pattern in concave topography along small drainages.


EAMES CREEK
North
Eames Creek
Study Area 1
Core Area
Telemetry Locations
Grid Size = 50 meters
ncasi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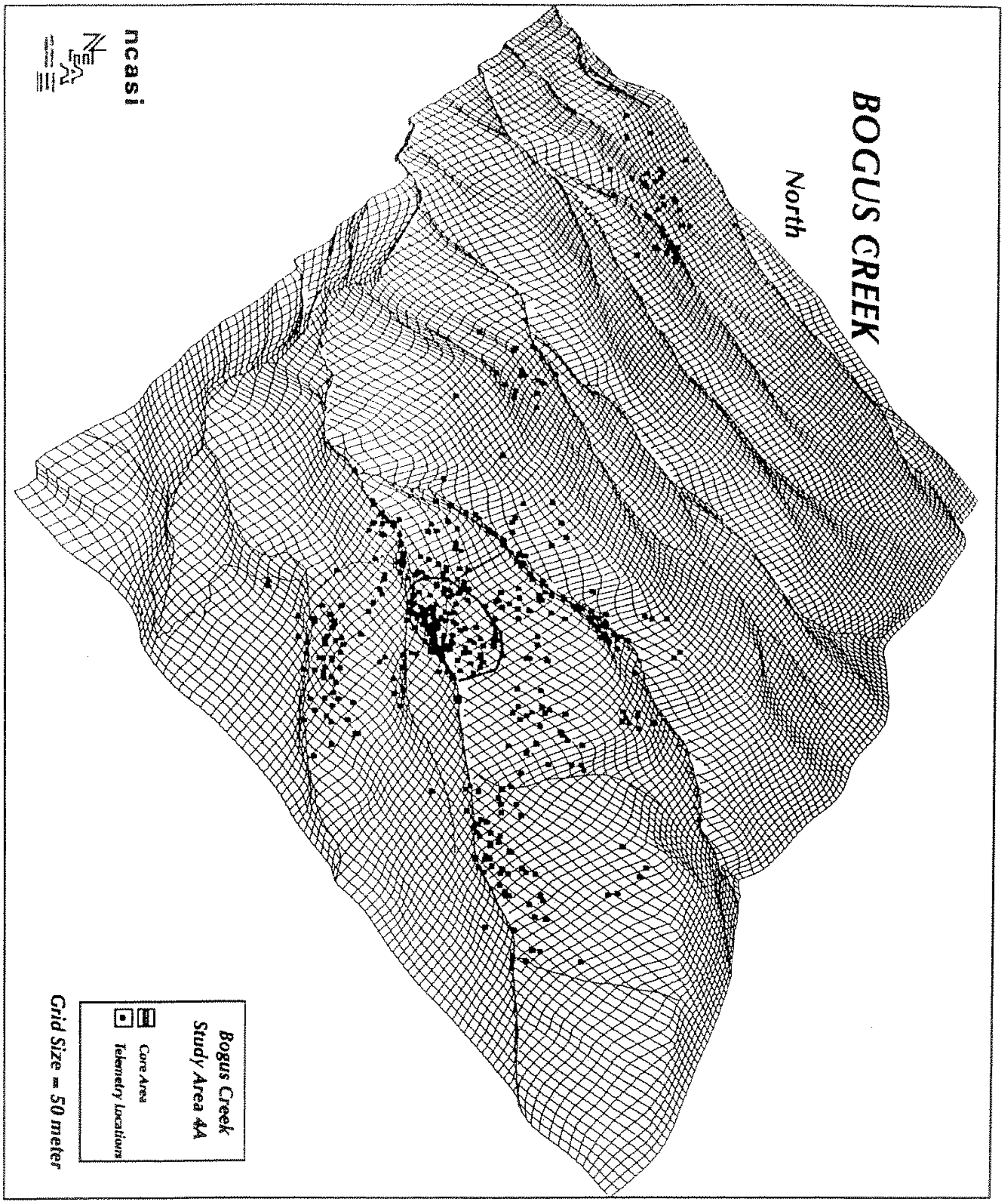
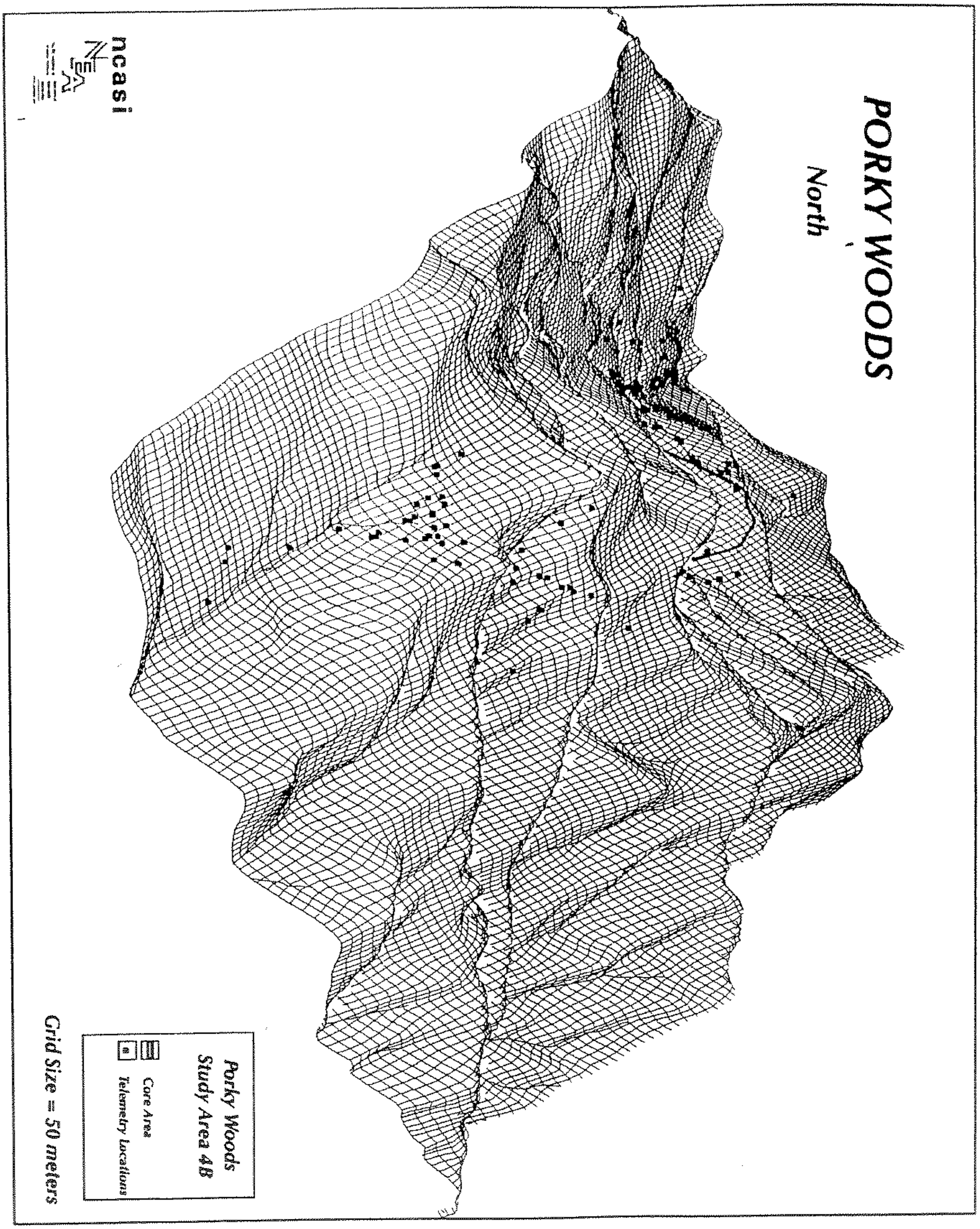
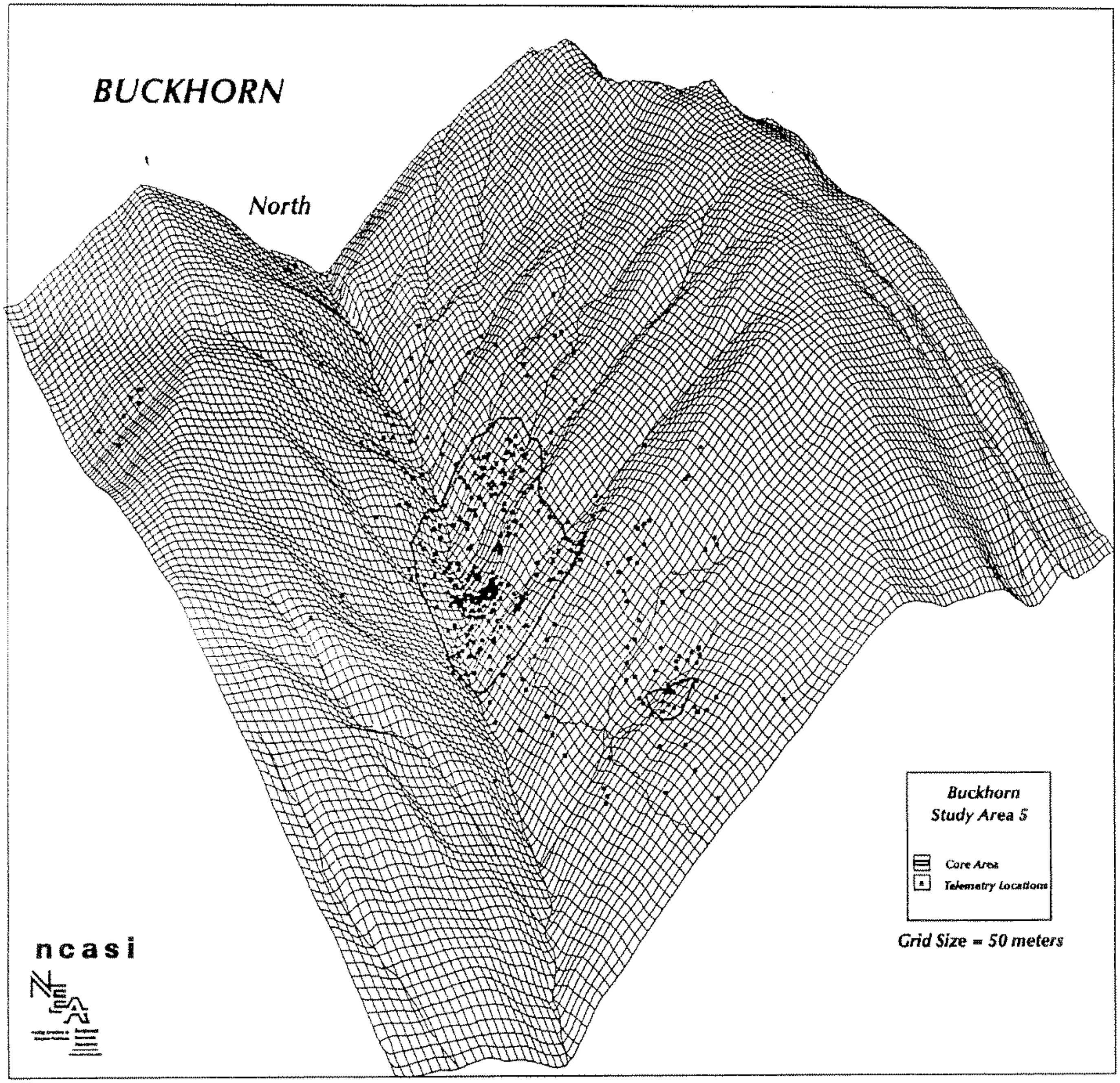
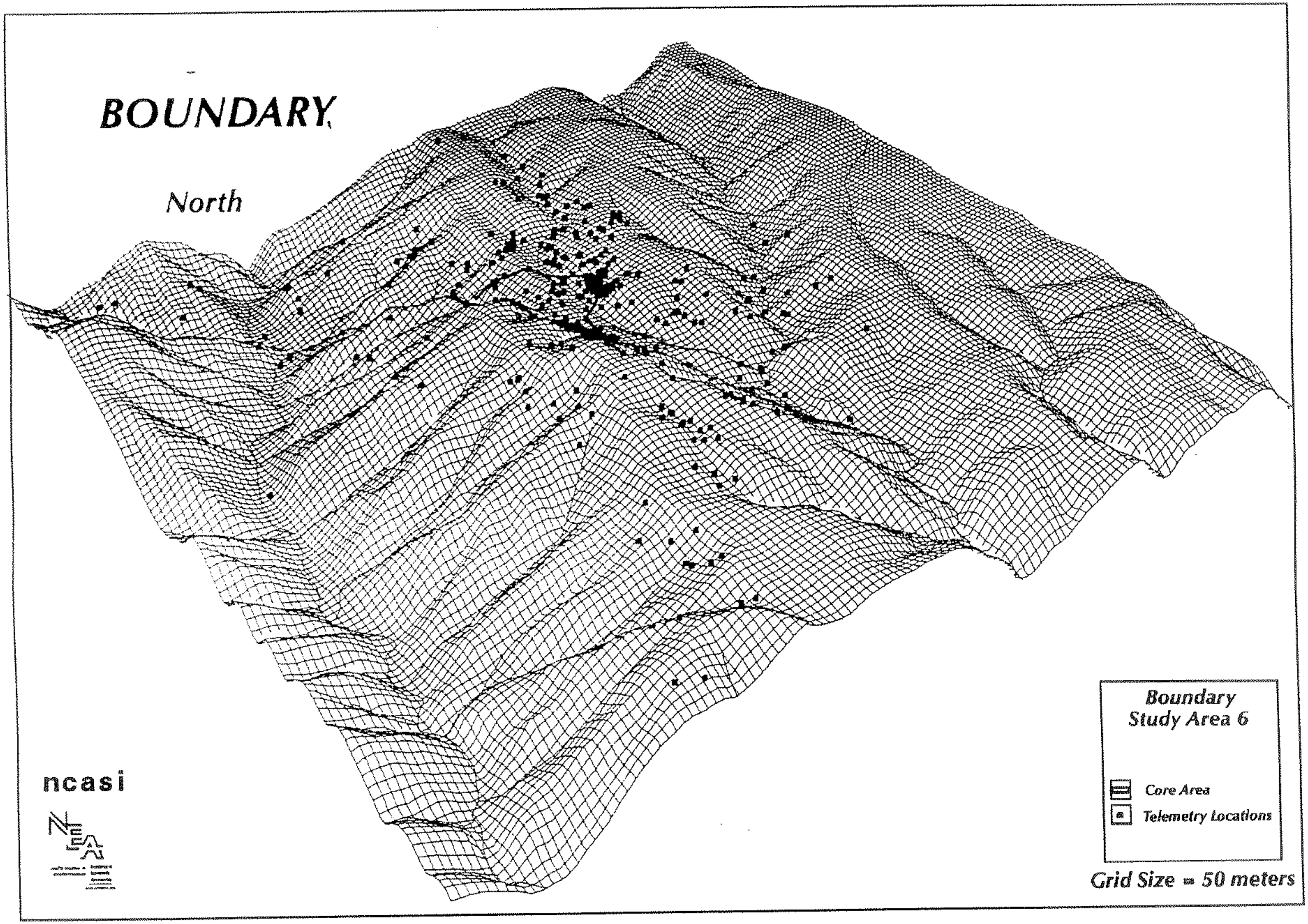
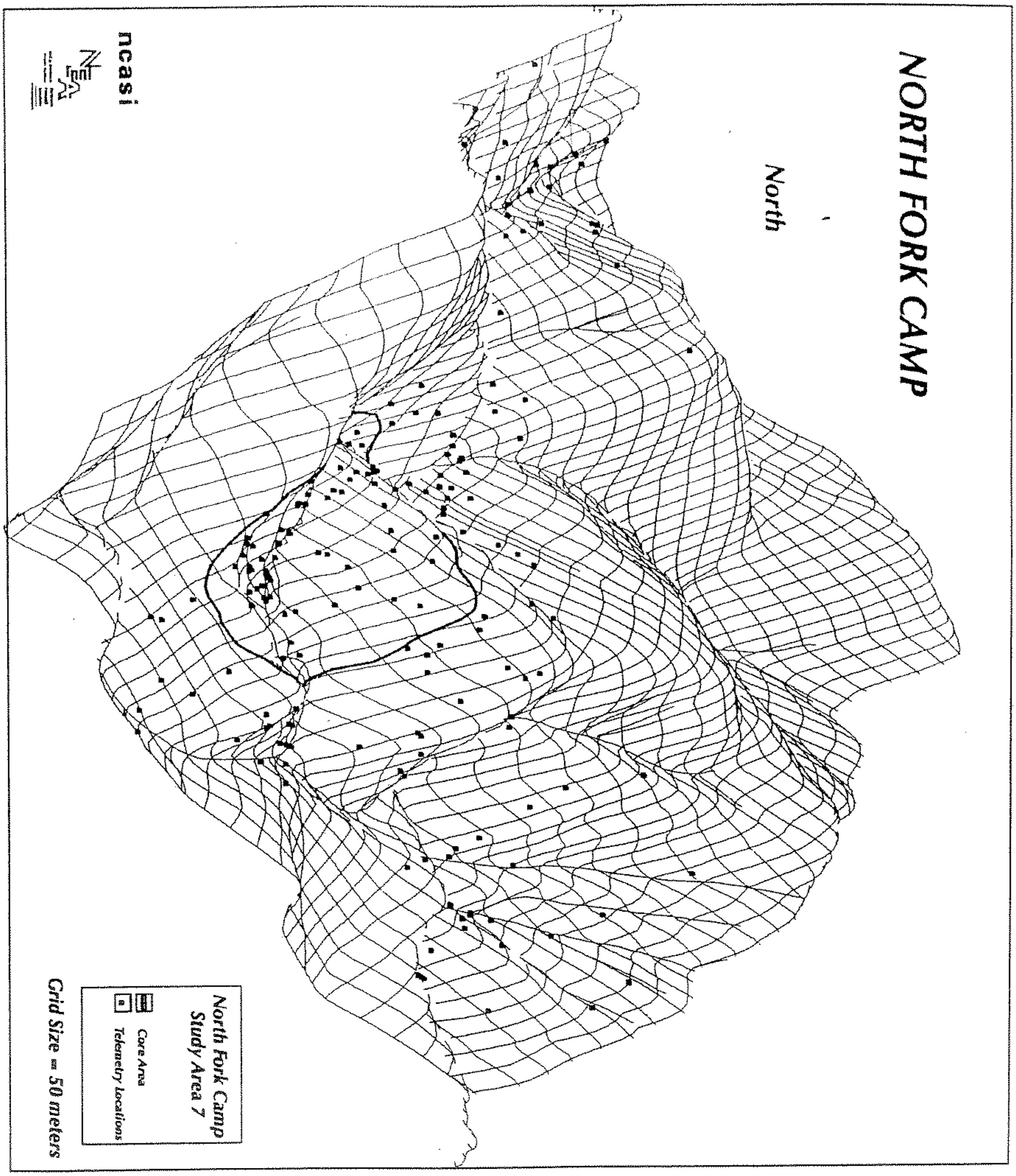
North
Shotgun
Study Area 2
Core Area
Telemetry Locations
Grid Size = 50 meters
ncasi


BOGUS CREEK
North
ncasi
Bogus Creek
Study Area 4A
Core Area
Telemetry Locations
Grid Size = 50 meters


PORKY WOODS
North
ncasi
Porky Woods
Study Area 4B
Core Area
Telemetry Locations
Grid Size = 50 meters


BUCKHORN
North
Buckhorn
Study Area 5
Core Area
Telemetry Locations
Grid Size = 50 meters
ncasi


BOUNDARY
North
ncasi
Boundary
Study Area 6
Core Area
Telemetry Locations
Grid Size = 50 meters


NORTH FORK CAMP
North
ncasi
North Fork Camp
Study Area 7
Core Area
Telemetry Locations
Grid Size = 50 meters

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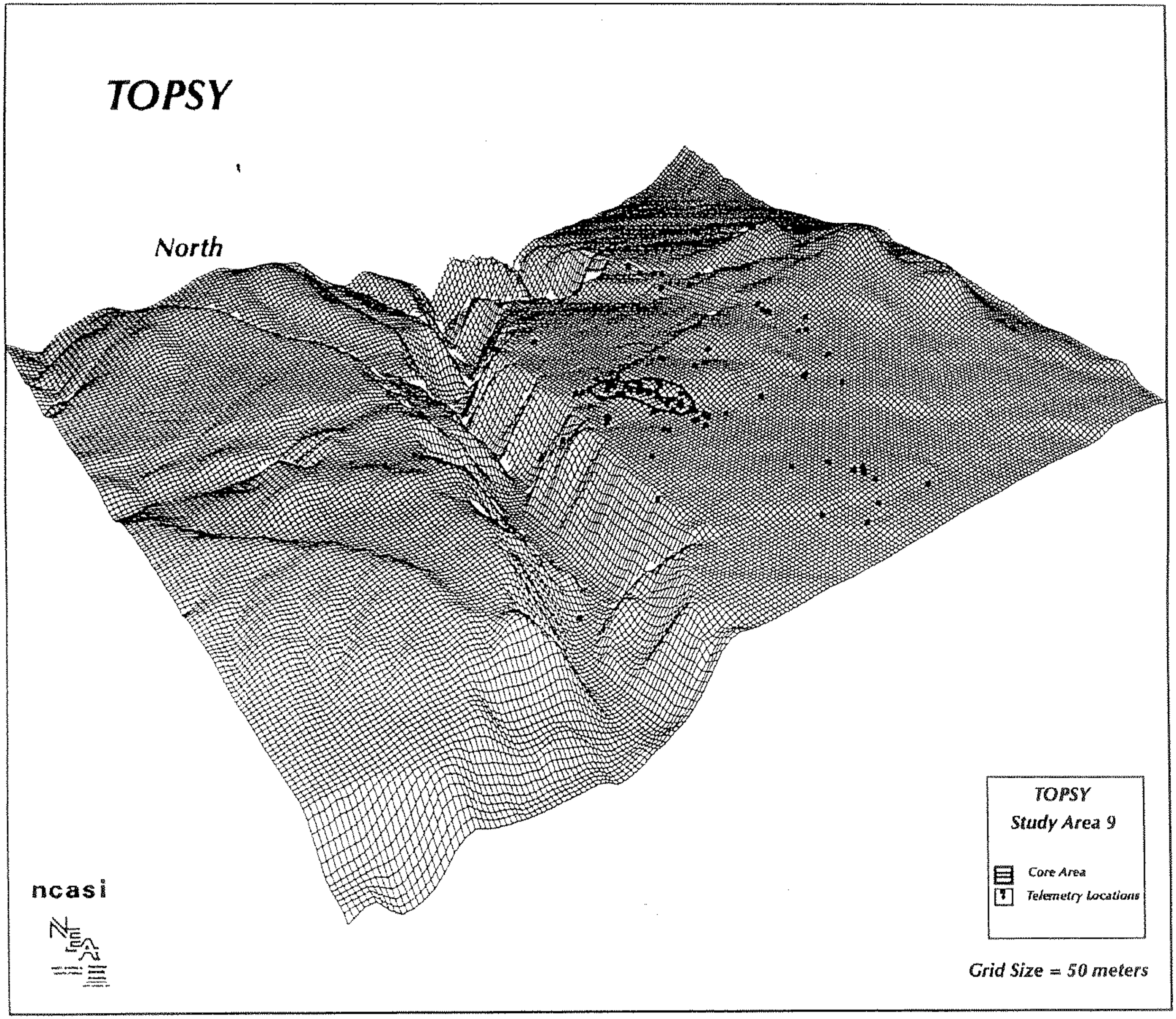
TOPSY
North
TOPSY
Study Area 9
Core Area
Telemetry Locations
Grid Size = 50 meters
ncasi

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APPENDIX A. STUDY PLAN SUPPLEMENT:

REVISED STUDY DESIGN AND DEVELOPMENT OF THREE NEW STUDY-AREA REPLICATES

Submitted to U.S. Fish and Wildlife Service

Re: Recovery Permit TE-834385-3

5 May 2003

Principal Investigator: Dr. Larry L. Irwin
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National Council for Air and Stream Improvement

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INTRODUCTION

This document clarifies and amends certain aspects of the 1998 Study Plan, as the Adaptive Management Monitoring study has evolved somewhat since implementation in 1998. The amended aspects apply to our request for implementing the project at Study Area 7 near Fort Bragg, California; Study Area 9 near Klamath Falls, Oregon; and a study site near Coos Bay, Oregon. The clarifications also apply to ALL study sites where work has been conducted to date, such that all data are compatible for statistical pooling as discussed herein.

There have been no changes to the study's original experimental design. That is, we continue to plan to use the same goals and objectives as in the original study plan and the same field plans: a) use telemetry to track up to 10 owl pairs in each new study site; b)

work with cooperators who would identify approximately 5 owl sites that they expect to treat silviculturally (preferably within 1,000-acre core areas), hopefully after 1 or 2 years of monitoring; c) include retrospective analyses; d) identify up to 5 owl sites as alternates in case owls at 1 or more of the original 10 might die or leave; e) apply resource selection function analysis to the data, etc.

Yet, since the project was initiated, we modified the field method for acquiring radio-telemetry data. We switched from tail-mounted transmitters to backpacks. Doing so has no influence on the study's results and interpretations, except to significantly increase the rate of data acquisition. We also added some clarification in annual reports regarding minimum telemetry sample-size data that could be used for home range estimation and habitat selection analyses, which appeared to change the study design. Further, there has been some confusion about what the Study Area is and which study sites were to be included.

Here, we justify adding the 3 new study sites and provide explanations for the above-mentioned study-design topics. To facilitate understanding, all new language added since the 1998 Study Plan was written is typed in bold face, while original language remains in standard font.

GOALS AND OBJECTIVES

The overall goal of this study is to evaluate Spotted Owl responses to commercial thinning in young Douglas-fir stands and to partial harvesting in Mixed Coniferous forests. The primary objectives involve acquiring data that will allow statistically defensible comparisons a) among owls at sites with and without silvicultural treatments and b) before vs. after the silvicultural treatments for individual owls. Based upon manipulative experiments and evaluations of previous forestry applications (i.e., retrospective analyses), **which have been increasingly emphasized, following peer-review recommendations,** we intend to satisfy the following objectives:

a. estimate home range sizes and configurations;

b. quantify habitat selection at the landscape, home range and stand levels;

c. estimate the sizes of core areas; and

d. identify areas of concentrated use for foraging.

Strong reasons remain that justify conducting this study and including the new study sites. First, the study will provide data on home range and habitat selection for certain areas that are vastly different from forests where previous owl studies were conducted. For example, the Klamath Falls study site represents a Mixed Conifer forest area that Verner et al. (1992) acknowledged as a type for which scientists still do not know explicit stand structural characterizations that result in superior, suitable, marginal or unsuitable habitat. We anticipate that the information to be gathered in this study will help clarify owl-habitat relationships in such forests, thereby broadening the scope of scientific knowledge that applies to recovery of the northern spotted owl.

Second, the information gathered at Fort Bragg and Coos Bay (largely private and state forests) could be used to support development of habitat conservation plans (HCP). We are aware that at least 1 private landowner is considering using the data to support an HCP. If the cooperators so choose, the data could support HCPs by identifying steps to minimize or mitigate impacts. Moreover, the information could suggest incentive-based conservation strategies for private lands' contributions toward recovery of the owl, as suggested by the Draft Spotted Owl Recovery Plan of 1992.

...Further, most previous studies of owl habitat use examined variation *among* forest successional stages to infer Spotted Owl habitat requirements. Studies of successional stages have been described as a taxonomic, or categorical approach to animal-habitat relationships. This study takes an additional step by evaluating owl responses to variability *within* forest stands.... As such, the information could help direct future silvicultural actions toward structural variation within stands that promotes occupancy by owls.

Further, this study promises to advance our scientific knowledge because it proposes a manipulative experimental approach—unequivocally the most reliable method for evaluating changes in wildlife habitat use that result from manipulations of forest structure and density. Results might stimulate recommendations for actions that may either minimize the impact of harvest activities or even enhance habitats over the long run. If so, the information might eventually be found to help promote long term recovery of the owl, following appropriate demographic-response studies. To the extent that such a long term goal is possible, one might envision a future in which conservation reserves and managed "matrix" lands are inter-twined in a dynamic landscape mosaic.

NEW STUDY-SITES WITHIN A BROADER STUDY AREA

To begin the study in 1998, we proposed to include clusters in western Oregon and northern California. Depending upon financial support and local interest in 1999, **we indicated that** we may add study clusters in northern California and possibly in both the eastern and western Cascades of Washington. Multiple study areas, each containing a cluster of at least 10 Spotted Owl sites (5 treatment and 5 control sites) will be selected. **Also, we will identify up to 5 alternate sites to include in case birds at the original sites die, leave, or the site is no longer usable for other reasons (e.g., wildfire). If that should happen, we would identify the additional sites and request the Service for permission to include them.** This will help increase statistical power for some tests. And broad sampling of habitats from Washington to California will maximize application of results. Multiple study areas allow an evaluation of environmental sources of variation due to attributes that distinguish physiographic provinces. Environmental sources of variation include regional and local climate, topography, parent materials of the soil (Amundson and Jenny 1997).

There has been some confusion about what is the Study Area and which study sites were to be included. This concern arose partly because of the emphasis on the CASPO in our annual reports (which happened because of the fact that we acquired complete data there first). It appeared to the Service that we might not have been acquiring sufficient data for existing study sites as planned, yet we were requesting amendments to the research capture permit to initiate research at new study sites.

As described numerous times in the original Study Plan, we planned from the outset to include multiple study sites, beginning with 4 or 5 and adding new study sites as cooperators were identified and financing became available. As such, the project

encompasses a repeated-study approach with staggered entry in time. The original Figure 1 shows that the study design called for an overall Study Area that included multiple study sites throughout the geographic range of the Northern Spotted Owl and much of the range of the California Spotted Owl. We also explained the value of repeating the study-site clusters across the range of the owl in Point number 4 on Page 27 of the original Study Plan. Further, the first full paragraph on Page 28 of the Study Plan describes the value of pooling the data for purposes of statistical inference.

All study-sites (or "clusters" or replicates) within the Study Area, including those at Ft. Bragg, Klamath Falls, and Coos Bay, were chosen using a similar stepwise process. First, we looked at whether the potential study site was part of an ongoing owl demography study area. In fact, one candidate study-site that we identified within the north Coast Range of Oregon was discarded because our activities there would have conflicted with one of Dr. Eric Forsman's demography studies. Second, we sought permission to implement the study in cooperation with various private, state and federal landowners. That included seeking cooperators who were interested in having the work done on their timberlands and who were willing to provide financing. Third, we determined if a sufficient number of owl sites occurred in reasonable proximity of each other, and might fit within somewhat flexible sideboards we chose for inclusion in the study.

Then we asked cooperators if there are several owl sites that have reasonably high likelihood of actually being treated silviculturally and what the schedule of treatments is (so that we could ensure approximately 1 to 2 years of pre-disturbance monitoring). In the case of Klamath Falls, several of the areas planned for treatments are on BLM lands for which consultations with the Service had already occurred (to our knowledge, consultations have been completed for all but 1 of the BLM owl sites). In private lands cases where treatments may be planned within owl sites, we strongly encourage cooperators to consult with the Service to assess potential impacts on owls. In some cases, such consultations with Service biologists occur as a matter of course in timber-harvest plan approval (i.e., California). Fifth, we indicated to prospective cooperators that we give preference to owl sites in young and intermediate forests that have been managed in the past (to allow for retrospective analyses), but try to avoid owl sites that are dominated primarily by late-successional forests interspersed with clearcuts and young plantations. Of course, we would not necessarily avoid monitoring a few owls at sites with conditions outside our general sideboards if no others were available and the cooperators wanted the information. Finally, we gave preference for owl sites where owl pairs have nested successfully.

Additional Reasons for Including the Coos Bay Study Site

On Page 16 of the original Study Plan we indicated that we had planned to include study-site clusters in the Western hemlock Zone of western Oregon, including timberlands owned by Georgia Pacific Corporation (now owned by Plum Creek Timber) and Boise Cascade Corporation in the Coast Range. Timberlands there consist primarily of young- to intermediate forests approximately 40-80 years in age. In some cases, the stands are interspersed with isolated patches of older timber.

The Coos Bay study site represents only the 3rd replicate involving thinning in young Douglas-fir/western hemlock forests. The original Study Plan suggested we would try to identify 4 replicates. Also, funding from the Bureau of Land Management and private companies has been arranged. We previously submitted maps of the Coos Bay study site, identifying which of the sites were to be used for treatments and which were to be used for "control" sites.

Moreover, the data on responses to thinning at Coos Bay ultimately will be pooled with data from Study Areas 1 and 2, where there have been 4-5 thinning treatments to date. Pooling of data will increase sample sizes and thereby, our ability to make conclusions about responses to thinning. Finally, overall data from the owl sites at Coos Bay will be pooled for retrospective analyses with the other two study-site replicates in similar forests (Study areas 1 and 2).

Reasons for Including the Klamath Falls Study Site (Study Area 9)

In the original Study Plan, several study-sites were identified in an area from near Medford, Oregon to Yreka, California in the *Mixed Conifer Zone, where partial harvesting will be the primary treatment.* Relationships between forest conditions and Spotted Owls in this area differ from that in the Oregon Coast Ranges and Cascades Provinces (Meyer et al. 1998 Wildlife Monograph). In the Klamath Province, Meyer et al. (1998) found that owls show a positive response to forest fragmentation, and speculated that Spotted Owls may be able to tolerate a greater degree of timber harvesting, possibly because their prey populations respond differently to timber harvesting than those in the Western Hemlock Zone.

The Klamath Falls study site replaces Study Area 3 in the Rogue River National Forest, where we initiated work that was ended prematurely because federal cooperators were unable to continue their logistical and financial support. We subsequently learned that the Bureau of Land Management was planning a program of partial harvesting (partly for reasons of reducing threats to wildfires) in spotted owl sites near Klamath Falls. The agency has already consulted with the Service on the project, as indicated above. The BLM and Winema National Forest staff biologists were interested in having NCASI monitor responses of the owls involved in their project. In addition, Boise Cascade and U.S. Timberlands had been monitoring owls on their adjacent timberlands for several years, and also were interested in radio-telemetry monitoring of habitat selection. The combination represented a strong likelihood of completing a study area replicate there, as well as a strong likelihood of including manipulative treatments. Moreover, we will be able to take advantage of detailed timber inventories on private lands, reducing costs of acquiring such detailed information throughout the study area. Finally, the data from the Klamath Falls study replicate will be pooled with the data from (at least) Study Areas 4a and 4b. Maps of specific owl sites to be included at Klamath Falls were previously submitted to the Service.

Reasons for Including the Ft Bragg Study Site (Study Area 7)

This study area involves coastal redwood forests that are subject to thinning. We learned that the Jackson State Demonstration Forest and adjacent private timber companies had conducted some monitoring of spotted owls in the past, so there was a background of useful information. More importantly, those cooperators were interested in monitoring spotted owl responses to their thinning programs, and were interested in financing a study-site replicate there. For example, The California Department of Forestry and Fire Protection (CDF) recently completed a management plan for the Jackson State Forest and wanted NCASI to evaluate habitat selection and population responses. The CDF has indicated that the information will support planning for long-term forest sustainability and attainment of recovery objectives.

One of the companies involved had acquired some previous telemetry data on home ranges and habitat use of spotted owls. That information can be used for comparative purposes, at least. Importantly, it seems possible that the old and new data can be pooled to increase sample sizes, as long as the habitat maps match conditions available during the previous work. In addition, conducting research at Study Area 7 will help to provide a full understanding of the range of variation that managers might expect with thinning in sites occupied by spotted owls across their geographic range. Finally, Service staff biologist Phillip Detrich had indicated to us a desire to acquire new information that may lead to refinement of habitat definitions for that area. We previously submitted maps of the Ft. Bragg study site, in which we identified which sites were to be used for treatments and which were to be used for "control" sites.

RADIO TELEMETRY

Because there are questions about the possible effects of 20-24-gram backpack-mounted transmitters on reproduction and survival (Paton et al. 1991, Foster et al. 1992), we plan to use tail-mounted radio transmitters equipped with two-year batteries (total mass = 7.5-8.0 g). At two year intervals, the owls will be recaptured for transmitter replacement. Tail-mounted transmitters are lost when the central retrices are molted, eliminating the need for a final recapture at the end of the study. However, because Spotted Owls molt in alternate years, and the molt cycle of individual owls may not be known, additional captures may be necessary to replace transmitters lost prematurely by molting. Initially, owls may be fitted with a sub-miniature leg-mounted transmitter, to facilitate recapture after re-growth of tail feathers.

We modified the field method for acquiring radio-telemetry data when we switched from tail-mounted transmitters to backpack harnesses. This happened for all study-sites, so it does not affect the analyses, results and interpretations under the original Study Plan. It did, however, significantly increase the rate at which we were able to build our telemetry database: a large number of tail-mounted transmitters fell from the birds prematurely. Moreover, there is recent information that suggests that backpack supported transmitters actually have lesser effects on birds than tail-mounted transmitters (E. Forsman, pers. commun.)

The following section was reported in the annual report for 2001: Because there were questions about the possible effects of 20-24-gram backpack-mounted transmitters on owl reproduction and survival (Paton et al. 1991, Foster et al. 1992), we initially used tail-mounted radio transmitters (total mass = 7.5-8.0 g). However, we temporarily lost contact with a large number (81) of owls because their tail-mounted transmitters were lost when the central rectrices were molted. This resulted in discontinuous data strings, which could have important consequences to some analyses. It also disrupted radio-tracking activities for other owls because field personnel reduced nocturnal radio-tracking in order to re-capture owls that dropped their rectrices and transmitters.

As a result, in spring 2000 we began employing back-pack harnesses for attaching the small transmitters. These back-pack transmitters are considerably lighter in mass than used in previous studies (<8g vs. 23-27g). In our previous experience at Springfield, Oregon (Irwin et al. 2000) in using such light-weight transmitter back-packs, reproductive success among owls was not influenced. For example, forty-percent of several owls monitored with radio-backpacks from 1990-1992 reproduced, whereas only 20% of the same birds reproduced from 1993-1996, after radio-backpacks were removed.

Thirty-percent of several other birds without transmitters in the study area were reproductive from 1990-1996.

In addition, while we do not have a means for direct comparisons among birds in the same areas in the same years, evidence from home range analyses also suggests that the small backpack transmitters do not affect owls significantly. For example, annual minimum convex polygon home ranges for 19 owls in our previous study were 1829 ha (Miller et al. 1992), much smaller than the 2587 ha observed by Thrailkill and Meslow (1989) for owls that carried the larger back-pack transmitters in a similar young-forest study area. In fact, the home ranges in our previous work were comparable to those observed by Wagner and Meslow (1988) in the southern Oregon Cascades (1575 ha), where there is much more late-successional and old-growth forests. If the small backpack transmitters indeed affect owls, one would expect much larger home ranges in areas with low amounts of late-successional and old-growth forests (< 10%), but that has not been the case.

We have subsequently reported additional information that supports our belief that the small back-pack transmitters do not influence reproduction among owls, as has been observed for owls with larger transmitters. After switching to backpack harnesses, data collection has proceeded much more smoothly. Also, we cannot detect any effects of the backpack transmitters on survival rates. In fact, survival rates of radio-tagged owls in this study appear to exhibit higher survival rates than estimated via population models in the ongoing demographic studies.

STATISTICAL ANALYSES

After the study began, we added some clarification in annual reports regarding minimum sample size data that would be acceptable for home range and habitat selection analyses. Doing so appeared to change the study design. Actually, the new documentation was an attempt to clarify but not replace data needs for the analytical procedures. The original Study Plan seemed to suggest that we needed 100-115 telemetry

points per bird per year and that we would emphasize pairs. We modified that in subsequent reports, however, by indicating that we could be able to make use of as few as 50 telemetry points per owl site per year. That avoided the problem that would occur if only a single bird could be captured at a site or if 1 died or left. Thus, the field sampling schedule wasn't actually changed; instead, our ability to analyze the overall data was improved. We now know that a minimum number of telemetry locations that appears to be required to delineate a home range is approximately 50 distributed across at least 8 months, although we still hope for as many as the sampling schedule, weather, etc. would allow each year (i.e., as many as 100 independent samples per bird). Having more data strengthens the resource selection models and probably will help to identify dominant influences but also factors that are relatively important at some locations but not others. Learning about study-site specific or individual owl-site specific influences could lead to greater specificity in planning.

In the original Study Plan we indicated that we might reach an optimal number of 115 telemetry points (an upper level) if everything went well according to the sampling schedule of 2-3 attempts to locate each bird each week. Yet, the most important aspect is that delineating a home range at an occupied owl site is what is needed for reaching our goals and constructing the resource selection function (RSF) models. Given the radio-tracking schedule, more than 50 telemetry points have been logged for most birds each year (except for birds with tail-mounted transmitters). Over time, the total number of points tallied at individual owl sites has risen dramatically, such that we will have obtained well over 200 telemetry points for most home owl sites. These data will be pooled for RSF analyses. The data will also be pooled, where possible, over two or more years for cumulative home range estimates, as suggested by Carey et al. (1992 Ecological Monograph), who pointed out that an annual home range may underestimate the amount of space used by an owl or owl pair. Thus, while estimating annual home range size remains an important objective, it will primarily be used for comparative purposes rather than evaluating owl responses to habitat conditions.

An important point to remember is that the owl site is the unit of replication for most analyses, not the individual radio-tagged owl, an owl pair at a site, or the number of telemetry points per bird per week or year. We do need a minimum set of data to be able to delineate a home range for each site (i.e., at least 50 telemetry points distributed over 8-12 months), yet we will continue to record as many telemetry points as possible within each home range given the sampling regime, level of funding and logistics.

Another important strong point is that using the owl site as the unit of replication and the revised minimum data requirements minimize data loss if an owl dies or leaves during the study. As long as we can delineate a home range at an owl site, we can use all data collected there, even if 1 of the birds dies or leaves after being located less than 50 times. That is one of the strengths of using discrete-choice models for analysis: having both members of a pair and finding each bird as many as 100 times obviously adds more data, and provides a reasonable field standard to strive for, but was never an absolute requirement for analysis, as some have interpreted based on the original Study Plan.

A related item that was not very clear in the original Study Plan is that the method of statistical analysis allows us to develop RSFs not only for individual owls and the sample of owl sites within a study site, but also for groups of study sites within a region, such as the Douglas-fir region or the Mixed Conifer region. Thus for example, data from Study sites 4a (Goosenest), 4b (Medford), 5 (Fruitgrowers), possibly 6 (Chico) and 9 (Klamath Falls) ultimately will be pooled, significantly strengthening the statistical analyses and improving our ability to detect effects of changes in habitat conditions. Moreover, building the final RSF models from pooled data allows the results to be extrapolated to other areas with similar forest conditions.

Finally, the success of completing tasks at each study site and the subsequent pooling of the telemetry and habitat data for analyses are made possible via a well organized central database and GIS management system. That work is contracted to Northwest Economic Associates. The database management system makes it possible, for example, for a participating company to request, on close to real-time basis, the telemetry records for a specific owl site or all owl sites on their timberlands for planning purposes. Similarly, the Forest Service, Fish and Wildlife Service, or other agency could request

and receive maps of telemetry points from federal or state lands within a certain study site. Most importantly, once all data from telemetry, forest conditions, and GIS physical environment layers are collected, the seamless database allows the Principal Investigator to construct and compare RSF models among individuals, study-site replicates, and groups of study sites within physiographic regions. It may also be possible to construct a meta-model that involves all data, although such an enterprise is beyond the scope of the study at present.

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