Chapter 4

New Information on the Northern Spotted Owl

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INTRODUCTION

Since completion of the Interagency Scientific Committee's Conservation Strategy in 1990, a variety of new information has been released on the biology of the northern spotted owl (Strix occidentalis caurina), including estimates of demographic rates of the owl (Anderson and Burnham 1992), dispersal (Forsman et al. unpub.), and hybridization with the barred (Hamer et al. in press). This chapter contains a summary and assessment of new information released since January 1992, including updated information for most of the studies described by Anderson and Burnham (1992). Implications of the new information are discussed relative to the selected alternative, Alternative B, in the Final Environmental Impact Statement on Management for the Northern Spotted Owl on the National Forests (USDA 1992) (hereafter referred to as the Final Environmental Impact Statement). Information on location, size, and types of demographic studies that are being conducted on the spotted owl is provided in Appendix 4-A. An annotated list of reports and publications released since January 1992 is provided in Appendix 4-B.

DEMOGRAPHIC ANALYSES

The Anderson and Burnham Report

Between 1985 and 1987, researchers began five long-term demographic studies of spotted owls in Washington, Oregon, and northwestern California. These studies were designed to investigate demographic rates of spotted owls, including age-specific birth and death rates, and population trends. In September 1991, a group of researchers convened at Fort Collins, Colorado (hereafter called the Fort Collins workshop), to conduct an analysis of the demographic data from the five studies. The Fort Collins workshop was led by Drs. David Anderson and Kenneth Burnham of the Colorado Cooperative Fish and Wildlife Research Unit, and by two visiting French scientists John Dominique Lebreton and Mr. Rodger Pradel.

The Fort Collins workshop included an analysis of data from each individual study area as well as a "meta-analysis" in which data from all five areas were examined in combination to determine if any overall trends emerged from the data. The meta-analysis was conducted by John Dominique Lebreton, David Anderson, Kenneth Burnham, and Rodger Pradel. A synopsis of the Fort Collins workshop was written by Anderson and Burnham and provided to the Northern Spotted Owl Recovery Team in November 1991 for inclusion in the Draft Recovery Plan for the Northern Spotted Owl (USDI 1992) (hereafter referred to as the Draft Recovery Plan). The version of the report that appeared as Appendix C in the April 1992 Draft Recovery Plan is hereafter cited as Anderson and Burnham (1992). A copy of the report is provided Appendix 4-C of this document. Results of the Fort Collins workshop were also presented at the Annual Meeting of the Cooper Ornithological Society in Seattle, Washington, on June 23, 1992.

Methods used to analyze the data at the Fort Collins workshop were based on Jolly-Seber open population models (Pollock et al. 1990) that provide estimates of age, sex, and time-specific survival rates based on the capture histories of marked animals. In this case, the marking technique consisted of placing color bands on the legs of owls and reobserving the owls on their breeding territories in subsequent years to develop their capture histories. A "capture history" is simply a row of zeros or ones, representing the year-by-year capture (or reobservation) history for an individual. A 1 means the animal was seen during a particular year, and a 0 means it was not seen. Based on multiple years of data, Jolly-Seber models estimate a recapture probability (the probability that a marked individual will be observed or recaptured in a given year~ given that it is still alive). The recapture probability is then used to calculate an adjusted survival estimate, based on the number of individuals actually reobserved each year. Estimates of survival rates and reproductive rates are then used to calculate the population growth rate, which is referred to as "Lambda" or "A'. In a stationary population, Lambda is equal to 1. In a population that is declining or increasing, Lambda is less than or greater than 1, respectively. The reproductive parameter used to estimate age-specific birth rates at the Fort Collins workshop was fecundity~ defined as the number of female young produced per year, per territorial female. Fecundity was determined by counting the number of young leaving nests and dividing by two (a 50:50 sex ratio was assumed). Females that did not nest or that nested and failed were assigned a fecundity value of zero.

The analysis performed at the Fort Collins workshop indicated that growth rates of territorial female populations on all five study areas were significantly less than 1, indicating that all five populations were declining. Estimated rates of decline on the individual study areas ranged from 6 to 16 percent per year, with a simple average rate of decline of approximately 10 percent per year (Anderson and Burnham 1992:Table C.4). Based on a meta-analysis of the combined data set, Anderson and Burnham (1992:327) concluded that, "...even with optimistic assumptions about juvenile survival rates, the best information suggests that the population of resident, territorial owls has declined, on average, at an estimated rate of 7.5 percent each year during the 1985-91 period..." This analysis estimated the rate of change of the population of territorial females rather than the entire population. Rates for the entire population were unknown, but are obviously strongly effected by the female segment of the population. Minor corrections in the data on two study areas were made after the Fort Collins workshop (Forsman pers. comm.), but were not considered significant enough to warrant a reassessment of the meta-analysis.

The meta-analysis indicated that not only were populations of territorial females declining on the individual study areas~ but that female survival rates were declining over time. Anderson and Burnham (1992:325) concluded that, "Because the evidence strongly indicates that R decreased during the 1985-91 period, one must infer that λ also decreased over this period. That is, the rate of population decline was accelerating during the study period."

The indication of an accelerating rate of population decline was probably the most troubling finding of the Fort Collins workshop. Based on ecological theory it could be predicted that a population that has passed some sort of demographic threshold might begin to decline at an accelerated rate, either as a result of declining survival rates, or declining reproductive rates. Some ecologists and population experts suggested that the declining female survival rate was evidence that the northern spotted owl population had already passed such a threshold, beyond which it might be difficult to recover (Orians 1992, Kareiva 1992~ Harrison 1992). Anderson and Burnham (1992:328) were more conservative in their assessment, concluding only that, during the time period of the studies, "...the rate of population decline has probably accelerated". Our assessment of these results is discussed later in the section titled Population Thresholds.

Update of Demographic Estimates on Study Areas Examined by Anderson and Burnham (1992)

Since the Fort Collins workshop in 1991, another year of data has been collected on each of the five study areas examined by Anderson and Burnham (1992). The Scientific Analysis Team contacted researchers on all five areas to see if they could update their estimates of survival and reproductive rates with 1992 data. Scientists conducting research on four of the five areas provided updated estimates of survival and fecundity. In addition, the Scientific Analysis Team requested that scientists conducting research on nine other study areas provide estimates of fecundity for spotted owls on their areas. The latter information was used to examine differences among areas.

For the four areas for which we received additional information on survival, adding one more year of data resulted in relatively minor changes in average survival rates (compare estimates in Table 4-1 with Table C.2 in Appendix 4-C). In two areas (Olympic Peninsula and Medford), survival rates of adult females increased slightly (2-4 percent), and in two areas (H.J. Andrews and Roseburg) they were essentially unchanged.

Table 4-1 Estimates of Age-Specific Annual Survival (ø) of Female Northern Spotted Owls Four Study Areas in Oregon and Washington.

Study Area	First year ($ø_J$)	s.e. ($ø_J$)	All later years ($ø_A$)	s.e. ($ø_A$)
H.J. Andrews (Western Oregon)	0.190 [a]	0.043	0.836 [a]	0.016
Medford (Southwestern Oregon)	0.220 [a]	0.031	0.826 [a]	0.011
Roseburg (Southwestern Oregon)	0.266 [a]	0.046	0.860 [a]	0.011
Olympic Peninsula (Western Washington)	0.143 [a]	0.034	0.846 [a]	0.018

[a] No sex-specific differences in adult survival rates were detectable, thus estimates are for males and females combined.

In 1992, reproduction by spotted owls was high on most areas for which data were available. As a result, average fecundity of territorial females increased slightly on all five study areas that were included in the Anderson and Burnham report (compare Table 4-2 below with Table C.3 in Appendix 4-C). Because population growth rate calculations are relatively insensitive to fecundity, however, we anticipate that this will have only a very slight positive effect on population growth estimates.

It should be noted that fecundity rates from some areas are considerably higher than those from the five study areas examined in Anderson and Burnham 1992 (see Appendix 4-C). The most notable differences were for studies on the Wenatchee National Forest on the east slope of the Cascades where fecundity averaged nearly twice the average reported in the Anderson and Burnham report (compare values for Wen-PNW and Wen-NACASI study areas in Table

4-2, with values in Table C.3 in Appendix 4-C). The Scientific Analysis Team cannot account for these differences except to hypothesize that weather conditions and prey populations may have been more conducive to reproductive success on the east slope of the Cascades during the years studied. It should also be noted that fecundity is relatively high for owls occupying predominantly young forests and mixed-age forests on private lands in northwestern California (Simpson and LP-Calif study areas in Table 4-2). In contrast, owls occupying predominantly young and mid-aged forests in western Oregon had relatively low fecundity (Siuslaw and Eugene Bureau of Land Management-east study areas in Table 4-2).

Table 4-2 Estimates of Age-Specific Fecundity (b) for Female Northern Spotted Owls on Study Areas in Oregon and Washington. Fecundity is defined as the number of female young produced per female owl per year. [a]

Study area	Subad 1 (12 mos.)		Subad 2 (24 mos.)		Adult (36 mos.)	
	(b_1)	s.e. (b_1)	(b_2)	s.e. (b_2)	(b)	s.e. (b)
Willow	0.115	0.058	0.344	0.023	0.344	0.023
H. J.A.	0.163	0.086	0.163	0.086	0.359	0.096
Medford	0.132	0.055	0.132	0.055	0.323	0.048
Roseburg	0.110	0.047	0.110	0.047	0.325	0.041
Olympic	0.223	0.089	0.223	0.089	0.396	0.087
Wen-PNW	0.262	0.178	0.262	0.178	0.763	0.081
Wen-NACASI	--	--	--	--	0.544	0.089
Eug-West	0.000	na	0.000	na	0.366	0.130
Eug-East	0.000	na	0.000	na	0.181	0.078
Chetco-PSW	--	--	--	--	0.355	0.205
Coos BLM	0.204	0.102	0.204	0.102	0.477	0.139
Siuslaw	0.167	0.167	0.167	0.167	0.293	0.129
Simpson	0.139	0.042	0.139	0.042	0.414	0.021
LP-Calif.	0.000	na	0.000	na	0.571	0.051

[a] Summarized from annum reports and from information provided by researchers from September to November 1992. Individual study areas are described in Appendix 4-A.
[b] Sample too small to calculate standard error.

The Scientific Analysis Team examined general trends in fecundity on 15 different study areas. Fecundity varied considerably among years on some study areas, while remaining fairly stable on others (Table 4-3), An empirical examination of these data revealed no consistent increases decreases in fecundity over time. Although quantitative information is lacking, we suspect that annual variation in fecundity is strongly influenced by variations in food supply and weather conditions.

Table 4-3 Yearly Variation in Fecundity of Adult Female Northern Spotted Owls on 15 Demographic Study Areas. [a]

Study area	1985	1986	1987	1988	1989	1990	1991	1992
Willow Cr.	0.296	0.350	0. 330	0. 325	0.367	0.306	0.273	--
H.,J. Andrews			0.400	0.486	0.025	0.276	0.250	0.717
Medford	0.234	0.500	0.158	0.457	0.213	0.356	0.344	--
Roseburg	0.196	0.552	0.279	0.300	0.364	0.378	0.240	0.458
Olympic			0.075	0.283	0.548	0.510	0.304	0.653
Simpson-Calif						0.423	0.373	0.445
L.P.-Calif						0.611	0.470	0.630
Coos Bay						0.530	0.141	0.580
Siuslaw						0.460	0.037	0.378
Siskiyou						0.375	0.375	0.316
Wen-USFS					1.000	0.672	0.567	0.814
Wen-NACASI						0.474	0.439	0.722
Eugene West						0.447	0.111	0.539
Eugene East				0.214	0.000	0.450	0.056	0.186
Warm Springs							0.820	

[a] Compiled from progress reports and unpublished data provided by researchers from September to November 1992. Fecundity was defined as the number of female young produced per female owl per year. A 50:50 sex ratio was assumed for juveniles. Study areas are described in Appendix 4-A.

We anticipate that new estimates of population growth rates will be calculated from the 1992 data during 1993 as research scientists complete their analyses of those data. Because our update of demographic rates on four of the five individual study areas indicated little change in estimates of survival and reproduction from Anderson and Burnham (1992), we do not anticipate that the outcome of the new analysis will differ appreciably from the 1992 results. We stress that the reanalysis of the 1992 data on four study areas that we have reported here is preliminary in nature, and that further analysis may result in changes in the estimates of population parameters.

Limitations of Demographic Estimates

Since the results of the Fort Collins workshop were released, there has been considerable discussion within the scientific community concerning possible biases in the demographic data that were used to make assessments of population growth rates. These potential biases were also discussed at length at the Fort Collins workshop and in Anderson and Burnham (1992). Potential sources of bias in the data have also been discussed or reviewed at several scientific meetings, in unpublished manuscripts (Franklin 1992, Forsman 1992a,b), and in a computer simulation model that is in preparation (J. Bart pets. comm.).

The main concern that has been raised regarding the banding data is that emigration of juveniles and adults may result in underestimates of survival rates. In a Jolly-Seber analysis, undetected emigrants are considered to be dead. In fact, some of them are probably still alive. To the extent that banded birds emigrate, survive, and go undetected, Jolly-Seber models will overestimate recapture rates and underestimate survival.

It is known that undetected emigration of banded juvenile owls occurs, based on results of radio-telemetry studies (see the section on Dispersal Studies), and there is evidence that the bias caused by such movements may be greater in some study areas than in others. For example, on the Olympic Peninsula the demographic study area surrounds the Olympic National Park, and is in turn surrounded by extensive private lands. If juvenile owls disperse into the Park or onto adjacent private lands, there is a high likelihood they will go undetected by research scientists. In contrast, the Roseburg Bureau of Land Management study area is surrounded on three sides by other demographic study areas, and bias caused by emigration is likely to be less because emigrants are likely to be detected if they move onto adjacent study areas.

Although there is less evidence to indicate significant emigration by adult owls, this is a matter of concern because estimates of population trends for spotted owls are most sensitive to changes in adult survival rates (Noon and Biles 1990). Even a small bias in estimates of adult survival can have a considerable effect on estimates of population growth. Telemetry studies of adult spotted owls have indicated little emigration of adult owls (Thomas et al. 1990:237), but there are exceptions. For example, (Meslow et al. 1989) noted two radio-marked females that emigrated from the H.J. Andrews study area. Emigration of adult owls will lead to an underestimate of adult survival rates.

Adult and subadult fecundity estimates among the five study areas in Anderson and Burnham (1992) were remarkably similar, ranging from 0.327 to 0.358 for adults and 0.094 to 0.229 for subadults (Appendix 4-C, Table C.3). We believe these estimates are reasonable, although several sources of counteracting bias may be influencing results. For example, breeding pairs may be more readily detected than non-breeding pairs because they tend to be more vocal. If breeding pairs are over-represented in the sample, this would cause an overestimate of fecundity. We believe this source of bias to be slight because a concerted effort was made each year by the research teams on each study area to verify the status of all females, regardless of whether or not they were breeding. The absence of information on the fecundity of non-territorial birds probably had little impact on results of the population trend analysis, as that analysis focused only on territorial females.

Another potential bias in the estimates of fecundity was that broods were rarely located immediately after they left the nest. If some mortality occurred after the young left the nest but before they were observed, this would produce an underestimate of fecundity. Again, because research personnel made a concerted effort to locate broods as soon as possible after the young left the nest, we believe bias from post-fledging mortality to be minor.

Another concern with the accuracy of data from banded birds is that capture and banding of owls could influence survival or fecundity. Based on the experience of the persons on the Scientific Analysis Team who have conducted such studies, and our conversations with other researchers, we do not believe this to be a significant problem. Spotted owls are extremely tame i around humans and, in general, do not seem much disturbed by the banding process or by the bands themselves. Despite the fact that thousands of spotted owls have been banded, we know of no physical wounds or abrasions caused by bands.

Another concern regarding the results of the Fort Collins workshop was that all five of the demographic studies examined had been conducted over relatively short periods of time (5 to8 years), Because the spotted owl is a long-lived species it is not clear that 5-8 years of study is sufficient time to establish population trends.

Probably the most important consideration with the demographic studies (described in Anderson and Burnham (1992)) is that estimates from those studies are derived from data that were collected during a period during which the amount of habitat was gradually declining (see Rates of Habitat Loss). Regardless of whether the estimates of demographic rates are biased, we believe that demographic data collected during a period of declining habitat are likely to reveal little about whether the population will eventually stabilize and remain viable once the amount of habitat stabilizes and is arranged on the landscape in a manner thought to be appropriate to minimize the risk associated with such a level of habitat (Thomas et al. 1990, Lamberson et al. 1992). This limitation is discussed further in the section on Population Thresholds.

DISPERSAL STUDIES

A study of radio-marked juvenile spotted owls was initiated on three study areas within the range of the northern spotted owl in 1991 (Forsman et al. unpub.). Based on the first year study, it appeared that 22 to 45 percent of juveniles that survived the first year of life left the study areas. These birds would not have been detected and would have been presumed to have died had they not been wearing radio transmitters (Table 4-4). It is probable that some of these emigrants from the study areas will be detected by conventional calling and banding techniques as they move around and acquire territories in the future, thus reducing the amount of undetected emigration. Nevertheless, the relatively high proportions of juveniles that emigrated from the demographic study areas do indicate that undetected emigration is causing a negative bias in juvenile survival estimates derived from banding data. Areas that adjoin Congressionally designated Wilderness and National Parks (e.g., the Olympic Peninsula study area) appear to the most likely to be influenced by undetected emigration (Table 4-4).

Table 4-4 Proportion of Radio-Marked Juveniles That Emigrated From Demographic Study Areas, Survived for One Year, and Went Undetected by Conventional Calling and Banding Techniques on Three Study Areas in Oregon and Washington, 1991-1992.[a]

Study area	n	Proportion emigrating
Roseburg BLM	18	0.22
Olympic Peninsula	11	0.45
Wenatchee N.F.	5	0.40

[a] Unpublished data front studies conducted by E. Forsman, Stun Sovern, and Janice Reid at the Forest Service Pacific Northwest Research Station, Corvallis, OR.

Survival estimates based on the radio-marked juvenile owls were considerably higher than the average values estimated from banding data (compare Table 4-5 below with Table C.2 in Appendix 4-C). High survival of the radio-marked cohorts may reflect the reduction of bias caused by emigration, but could also be the result of a particularly mild fall, winter and spring in 1991-1992. It should also be noted that transmitters were not placed on juvenile owls until July or August. Thus, survival estimates are based on the period from July-August of the first summer to July-August of the second summer, and did not include the first 1 to 2 months that young owls spent out of the nest. Forsman et al. (1984) and Miller (1989) reported mortality rates for juvenile owls during the first several months of life. Thus, it is possible that survival estimates based on radio-telemetry results are biased high because they do not include the period of particularly high mortality that immediately follows fledging. It should be noted that this bias also applies to estimates from banding data, since many juveniles are not banded until July or August.

Because of concerns that some types of radio transmitters may lower survival (Paton et al. 1991, Foster et al. 1992), the studies of juvenile dispersal described above used small (6 gram) transmitters mounted on the tail feathers. Even with this precaution, there is no guarantee that the transmitters have no effect on juvenile survival rates.

Because of the above uncertainties, we believe it will require modification of techniques and several more years of study before more accurate estimates of juvenile survival can be acquired.
Table 4-5 Annual Survival Estimates (¢) of Radio-Marked Juvenile Spotted Owls on Three Study Areas in Oregon and Washington, 1991-1992. Estimates from programs SURVIV and MICROMORT are compared. [a]

		Program SURVIV		Program MICROMORT	
Study area	n	($¢_J$)	95% CL	($¢_J$)	95% CL
Roseburg BLM	27	0.70	0.50-0.91	0.66	0.50-0.88
Olympic N.F.	16	0.75	0.51-1.00	0.73	0.54-0.99
Wenatchee N.F.	16	0.31	0.09-0.72	0.24	0.10-0.56

[a] Starting dates for annual estimates were July 1, 1991, for Roseburg Bureau of Land Management and Wenatchee National Forest, and August 1, 1991, for the Olympic Peninsula. Starting dates differed among areas because transmitters were not installed at the same times on all areas. Unpublished data from studies conducted by E. Forsman, Start Sovern and Janice Reid at the Forest Service Pacific Northwest Research Station, Corvallis, OR.

DENSITY STUDIES OF SPOTTED OWLS

Summary of Recent Studies

An alternative method of evaluating population trends is to examine actual changes in the number of territorial owls per unit area over time. A number of demographic studies of spotted owls have included "density study areas" in which research biologists have attempted to locate and band all territorial owls that are present within a prescribed boundary each year. This requires a complete search of the study area, with repeated surveys to ensure that territorial owls do not go undetected. The objective of surveys for owls in density study areas is to monitor trends in the territorial population over time. Trends can be analyzed between time periods in terms of total numbers of owls, numbers of pairs and single owls, or numbers of females per unit area. In the following summary, we present information on the total number of adult and subadult owls detected in each density study area by year. We refer to this estimate as the "crude density" of owls.

We summarized density estimates for 12 density study areas (Table 4-6). An analysis of these data by Franklin and Ward (1992) indicated that of the 10 areas with 3 or more years data, only two areas near Medford, Oregon, appeared to be undergoing significant declines. Crude densities were essentially stable on seven areas, and increasing on one area. However, a meta-analysis of the combined data suggested that the overall population was declining at a rate of 3.2 percent per year (Franklin and Ward 1992).

Table 4-6 Estimates of Crude Density (Number of Individuals/km ^{2}) of Adult and Subadult Owls on 12 Density Study Areas Within the Range of the Northern Spotted Owl. a

Study area	1985	1986	1987	1988	1989	1990	1991	1992
					Year			
Willow Cr	0.232	0.233	0.233	0.246	0.257	0.267	0.243	0.274
H.J. Andrews				0.197	0.200	0.200	0.217	0.223
Medford								
Butte Falls						0.103	0. 093	0.084
Evans Cr						0.107	0.095	0.104
Elk Cr						0.264	0. 253	0. 245
Williams							0. 148	0. 159
Roseburg								
Drain			0.090	0.122	0.112	0.140	0.140	0.137
Cow Cr						0.114	0.108	0.106
Siuslaw NF						0.071	0.084	0.087
Olympic			0.051	0.068	0.070	0.070	0.076	0.068
Eugene BLM						0.078	0.076	0.063
Wenatchee NF							0.117	0.112
Simpson-Calif [b]								0.252

[a] Summarized from annual reports and unpublished data provided by researchers from September to November 1992.
[b] Not initially designed as a density study area but minimum density is presented to indicate comparatively high densities in this area even without complete surveys.

Limitations of Density Studies

Estimates of population trends based on density data are likely subject to a number of biases, and only apply to a certain segment of the population. In particular, studies of spotted owl density apply only to the territorial population, because non-territorial birds cannot be consistently detected. In addition, spotted owls are long-lived animals that may concentrate in the remaining habitat as the amount of habitat declines. This may produce short-term densities that are not sustainable in the long term. This phenomenon is referred to as "packing". Therefore, densities within a density study area could remain inordinately high during a period of habitat decline, thus masking the actual rate of population decline.
Another limitation of density studies is that the number of surveys to count owls were not the same in all studies. In some studies, investigators used a minimum of three surveys per year, whereas others used six. Such differences in survey effort may bias comparisons among study areas, but should not influence estimates of trends within individual study areas, as long as the number of surveys per year remain consistent within each Study area.

Another question regarding density studies is how well they represent the population as a whole. If a density study area does not include habitats and landscapes typical of some larger area, it may not be a good indicator of what is happening to the population in that larger area. If a density study area is not located within a Habitat Conservation Area (Thomas et al. 1990) for example, it may be managed differently than the Habitat Conservation Area, and may, therefore, not represent what is happening there. The density study areas included in this review were selected because they were considered typical of forested areas within the landscapes in which they were located.

However, none of the density study areas were laid out to conform to exact Habitat Conservation Area boundaries. Thus, most density study areas overlap Habitat Conservation Areas and a variety of other land use classifications. At present, data summaries for density study areas have not been subdivided for areas inside and outside Habitat Conservation Areas, so the Scientific Analysis Team can only provide estimates for density study areas as a whole. We do not consider this a serious problem. At this point, the Interagency Scientific Committee Conservation Strategy has been in effect for such a short period of time (3 years) that treatments inside and outside the Habitat Conservation Areas have not diverged appreciably.

Another possible bias associated with density studies of spotted owls is that observers may become increasingly efficient at locating owls as they become more familiar with the study areas and learn more about the distribution of resident pairs. This could mask a decline in numbers of territorial owls or partially explain the gradually increasing number of owls detected on some study areas.

An additional problem encountered with density studies is that very small changes in population size (e.g., 1 to 2 percent per year) are difficult to detect until many years of data have been collected. In short-term studies, variation due to demographic variability, observer effort, differing observers, and other factors can mask gradual changes in population size. Thus, in a gradually declining population it is highly unlikely that a short-term density study will produce a clear picture of long-term trends in the population.

Probably the most significant limitation on the interpretation of the density data is that the density studies have been conducted during a period when the amount of habitat has been gradually declining. For the same reasons described in the discussion of demographic studies, estimates of trends in owl density during a period of gradual habitat loss tell us nothing about whether the population will eventually stabilize at a new equilibrium.

RATES OF HABITAT LOSS

Although it is commonly assumed that spotted owl populations are declining as a result of habitat loss [Thomas et al. 1990, USDI Fish and Wildlife Service 1992], correlations between rates of habitat loss and rates of population decline are poorly understood. To compare rates of habitat loss with rates of population change on the five demographic study areas described by Anderson and Burnham (1992), the Scientific Analysis Team used two methods.

In the first approach, we compiled Forest Service and Bureau of Land Management records of the amount of owl habitat cut each year on Federally administered lands within density study areas. We also examined habitat loss on Forest Service and Bureau of Land Management administered lands within a buffer area around three of the density study areas to determine if harvest rates inside and outside the density study area were similar.

In cases where there were multiple density study areas in the same vicinity (e.g., Medford Study), we examined the density study areas and their corresponding buffer areas as one combined unit. To estimate the amount of habitat present at the beginning of the study period, we estimated the area currently covered by spotted owl habitat, and then added the number of acres of suitable owl habitat cut during the study period.

Average annual rates of habitat removal were estimated by dividing the number of acres of suitable habitat cut during the study period by the calculated amount of habitat present at the beginning of the study period, and then dividing the result by the number of years in the study period.

An additional confounding factor in assessing rates of habitat loss on lands administered by the Bureau of Land Management was that, in southern Oregon, considerable timber cutting involved removal of selected trees rather than clearcutting. This often made it difficult to determine if a stand should still be considered owl habitat after logging had occurred. We relied on the opinion of local biologists as to whether such stands should be considered owl habitat. Although these estimates are crude, we believe them to be reasonable. We stress that this analysis was restricted to Federally administered lands, as harvest records were unavailable for other ownerships.

The team's second method of analysis was to use Landsat imagery (digital satellite photos) examine rates of habitat loss on three of the five demographic study areas from 1977 to 1988. This analysis covered the same geographic areas examined in the harvest records analysis, but included an examination of all lands, not just Federally managed lands. Landsat Multispectral Scanner data was used for the 1977 time period while Landsat Thematic Mapper imagery was used for the 1988 time period.

All image processing was conducted using ERDAS (ERDAS, Inc., Atlanta, GA). The Multispectral Scanner sensor had a nominal resolution of 79x56 meters while the Thematic Mapper imagery had a resolution of 30x30 meters. The Multispectral Scanner data was rectified to the Thematic Mapper imagery and both data sets were resampled to 50x50 meter resolution. Initially, an unsupervised classification approach (ISODATA clustering) was used that defined initial spectral signatures by clustering spectral reflectance values.

Spectral signatures were identified using digital stand information from the Bureau of Land Management (Forest Operations Inventory data), digital habitat data from air photo interpretations, and visual inspection of the imagery. Many of these spectral signatures did not represent a unique informational class (i.e., they lumped young forest pixels with older forest pixels).

New spectral signature files were created by selecting (or combining) the best of the initial spectral signatures that represented four distinct information classes: non-forest, open canopy young forest, closed canopy young forest, and closed canopy mature/old forest. A fifth class (water) was added where large rivers, lakes, or ponds were present. The new spectral signature files were used as input to a maximum likelihood classification algorithm that classified all pixels in the imagery into one of the five classes. Infrared wavelength bands were included in the classification to improve discrimination between vegetated and non-vegetated areas. Classified files were subsetted ('clipped') to the boundaries of the density study area and to the boundary of a buffer area around each density study area. The width of buffer areas was set equal to the average width of spotted owl home ranges in each province (estimates from Thomas et al. 1990). The analysis of records of timber cutting indicated that the amount of spotted owl habitat was declining at a rate of 0.9 to 1.5 percent per year on Forest Service study areas and 1.3 to 3,1 percent per year on Bureau of Land Management study areas (Table 4-7). Analysis of rates of habitat loss using Landsat data indicated rates of habitat loss between 1.1 percent and 5.4 percent per year (Table 4-8). Rates of loss within density study areas and surrounding buffer areas were relatively similar for both the timber cutting analysis and the Landsat analyses except on the Roseburg study area, which had a much higher level of habitat loss in the buffer area than in the density study area (Table 4-8). The highest rate of habitat loss was on the Bureau Land Management Medford District, which was also the area in which spotted owl populations appeared to be declining most rapidly.

Table 4-7 Rates of Removal of Owl Habitat on Five Study Areas Within the Range of the Northern Spotted Owl. All area measurements in hectares (1 hectare = 2.471 acres).

	Willow Creek	Medford [b]	Roseburg [c]	Andrews	Olympic [d]
Density areas					
Total Area	30302	36949	45914	30490	26761
Years examined	82-92	79-92	79-91	82-92	82-92
Starting habitat	12058	19411	28032	18013	14651
Curent habitat [e]	10606	11085	23419	15245	12202
Hectares harvested	1453	8326	4613	2768	2449
Percent change	12. 05	42. 89	16. 46	15. 36	16. 71
Avg. annual loss(%)	0. 86	3. 06	1. 27	1. 40	1.52
Buffer areas [f]					
Starting habitat		86,511		16823	8127
Current habitat		43,259		15120	6965
Hectares harvested		43,252		1704	1162
Percent change		50. 00		10. 13	14.30
Avg. annual loss		4. 55		0. 92	1.30

[a] Unpublished data from studies by M.G. Raphael, J.A. Young, and E.D. Forsman, Pacific Northwest Research Station, Olympia, Washington,
[b] Summarized from harvest records provided by the Forest Service and Bureau of Land Management. Estimates of rates of removal apply to lands managed by both the Forest Service and Bureau of Land Management.
[c] Summarized from harvest records provided by the Bureau of Land Management. Estimated rates apply to lands administered by the Bureau of Land Management.
[d] Estimates apply only to lands managed by the Forest Service.
[e] Estimated by multiplying area of study area by the estimated proportion of study area currently covered by owl habitat.
[f] Width of buffer areas was scaled to correspond to the average diameter of a home range within the study area. Widths were: Andrews -- 4.0 kin, Medford -~ 5.B km, Olympic = 7.2 kin.

Table 4-8 Rates of Removal of 0wl Habitat on Three Study Areas Within the Range of the Northern Spotted Owl, 1977 to 1988a. Estimates based on Landsat imagery. All area estimates in hectares (1 hectare - 2.471 acres).

	Study Area		
	Medford	Roseburg	Andrews
Density Areas			
Size (ha)	90911	105304	30490
Habitat[b] in 1977	45142	48148	16025
Habitat in 1988	18242	42375	13457
total % loss	59.59	11.99	16.02
annual % loss	5.42	1.09	1.46
Buffer areas[c]			
Size (ha)	144195	94031	32262
Habitat in 1977	61095	34893	19449
Habitat in 1988	28955	22383	16054
total % loss	52.61	35.85	17.46
annum % loss	4.78	3.26	1.59

[a] Unpublished data from studies by M.G. Raphael, J.A. Young, and E.D. Forsman, Pacific Northwest Research Station, Olympia, Washington.
[b] Habitat was classified as mature and older, closed-canopy forest as identified from Landsat imagery.
[c] Width of buffer areas was scaled to correspond to the average diameter of a spotted owl home range within the study area. Widths were: Andrews = 4.0 kin, Roseburg = 4.8 km, Medford = 5.6 km.

The two methods used to examine rates of habitat loss are not directly comparable because they measure different things and are subject to different types of bias. For example, the analysis that was based on Landsat data examined all ownerships within the study areas, whereas the analysis that examined cutting rates focused on Federally administered lands. The analysis of cutting records was also influenced by the initial estimate of the amount of habitat currently present.

Although we believe that the analysis of Landsat data was a reasonable first attempt to examine rates of habitat loss, several qualifying statements should be made. These are: (1) the effects deeply shadowed areas were not specifically addressed and may cause an overestimation of the older age classes in areas of high relief, such as the Olympic Peninsula and the H.J. Andrews Experimental Forest, (2)classification was based primarily on unsupervised clustering of spectral values; therefore, some classification error must be expected in classifying different seral stages with similar spectral responses, (3) even though digital habitat information was used to guide the classifications, the results have not been subjected to a detailed assessment of accuracy and some error in classification must be expected, and (4) the wavelength characteristics of each band differ between sensors; therefore, differences in reflectance from objects on the ground may influence comparisons of classifications between years.

Despite these qualifications, the above analyses indicate that rates of habitat loss are considerably lower than rates of population decline estimated from demographic studies (Anderson and Burnham 1992). Conversely, rates of habitat loss on most study areas were greater than rates of population decline based on empirical observations of changes in spotted owl numbers on density study areas (Franklin and Ward 1992). The one exception was the Medford area where both the rate of decline based on changes in owl numbers (4.7 percent) and rate of decline based on Landsat analyses (5.42 percent in density study areas and 4.78 percent in buffer areas) were similar.

It is apparent that demographic studies and density studies suggest quite different relationships between habitat loss and population response. One method (demographic studies) suggests that territorial populations are declining faster than the rate of habitat loss. The other method (population density studies) indicates that populations of territorial birds are either stable declining at about the same rate as habitat loss.

Given that packing may be occurring as the habitat declines, we do not find it surprising or unlikely that the rates of decline in numbers of territorial birds on density study areas might lag behind rates of habitat loss. Conversely, given that banding data may underestimate survival rates, we are also not surprised that estimates of lambda indicate a population declining faster than the rate of habitat loss. Either result could be predicted, given the biases that are likely to influence the different methods of assessing population trends.

POPULATION THRESHOLDS

Population models described by Thomas et al. (1990) indicated that two distinct population thresholds occur, either of which can lead to the eventual extirpation or extinction of a species. One of these thresholds occurs as a result of habitat loss. If the amount of habitat is reduced to an excessively small fraction of the landscape, then (1) it becomes difficult for owls to find suitable territories, and (2) the resulting small populations are subject to random demographic and environmental effects. Both of these factors cause the overall population to exhibit precipitous declines.

The other threshold occurs as a result of the Allee effect. If population numbers fall below a certain level, it becomes so difficult to find a mate that reproductive rates fall below the level needed to maintain a stable population. Thomas et al. (1990:253) emphasized that, although mathematical models indicated the presence of thresholds, knowledge was inadequate to, "accurately predict the population size, suitable habitat, or amount of habitat fragmentation thresholds that, once crossed, would lead to a population crash." This situation has not changed (Lamberson et al. 1992, Carroll and Lamberson [in press]). In all likelihood the exact locus such thresholds will be impossible to predict with accuracy because they are moving targets that change over time and location with a changing environment (Lamberson et al. 1992).

After the release of the Anderson and Burnham report (1992), some observers (e.g., Harrison 1992, Kareiva 1992, Orians 1992) suggested that the declining survival rates of female spotted owls might be indicative of a population that had dropped below a demographic threshold. The testimony and depositions given by these respected scientists in this matter indicated to us that they were unfamiliar with the data and with the possible biases in the data. They also chose not to address one of the key cautions in the report of the Interagency Scientific Committee (Thomas et al. 1990:249) in which the authors stated that "assessing population trends from data collected during periods of declining carrying capacity (for example, the harvest of suitable owl habitat) may be very difficult because of the difficulty of distinguishing a collapsing population ... from one that eventually reaches a long-term stable equilibrium..." This point was also emphasized by Lamberson et al. (1992).

Thus, it is important to realize that a population that declines as its habitat declines is entirely likely to stabilize when the point is reached where habitat recruitment equals or exceeds the rate of habitat loss. The Interagency Scientific Committee proposed its conservation strategy under the assumption that populations would stabilize at a lower population level.

Other data that may provide insights relative to whether the spotted owl population has gone beyond some demographic threshold are estimates of fecundity and density. We have already discussed the absence of significant changes in density on most density study areas. It could be predicted that if the Allee effect was causing a population to fall below a threshold, a reduction in fecundity would be observed as females would have an increasingly lower probability of finding mates as habitat is lost. As described earlier, an examination of fecundity on 14 study areas did not reveal any consistent downward trends in fecundity for adult females (Table 4-3). While this does not indicate evidence of an Allee effect, it cannot be assumed from this that no Allee effect is present. In a long-lived species like the spotted owl it is possible that the Allee effect would not become detectable until some time after a habitat threshold was exceeded. Another method of examining whether the Allee effect is influencing spotted owls would be to examine trends in the proportion of territorial adults that are paired. Data for such an analysis were not available for our review, although we anticipate that such analyses will be conducted by individual researchers in the near future.

POPULATION VIABILITY MODELS AND ASSESSING THE TRANSITION PERIOD

Alternatives in the Final Environmental Impact Statement were ranked using seven biological criteria (Chapter 2). Subsequently, the Forest Service was criticized for not using more quantitative, spatially explicit models to rank alternatives (Doak 1992, Kareiva 1992). agree that the use of quantitative, spatially explicit models to examine alternatives is a good idea. There are several reasons however, why the Forest Service has not done so to date. First, at the time the spotted owl Final Environmental Impact Statement was written, the only spatially explicit owl/habitat model that we are aware of was still in development and not fully tested. Second, and more importantly, the use of a spatially explicit model requires detailed maps of the present and projected future forest conditions, including all successional stages. Geographic Information System maps (i.e., computerized maps) of the current distribution older forest types within the range of the spotted owl have been produced by the Wilderness Society, National Audubon Society, and by Pacific Meridian Resources under contract with the Forest Service. Unfortunately, these maps were produced using different criteria and are in many respects not comparable. Johnson et al. (1991) experienced considerable difficulty resolving differences between these maps when attempting to map late-successional and old-growth forests in the Pacific Northwest (J.W. Thomas, per. comm.). In addition, spatially explicit computer maps of most other forest age classes are incomplete or lacking, as are spatially explicit maps of proposed future harvest patterns, The lack of spatially explicit maps of all forest age classes and of present and projected future forest management activities makes it nearly impossible to project future habitat conditions for spotted owls. Thus, use of spatially explicit models at this point would involve many assumptions about the amount and distribution of habitat and harvest areas that are unsubstantiated by currently available data. In other words, we consider the data available for such an analysis to be of poor quality and inadequate in scope. Because no model is any better than the data fed into it, we believe an extensive modeling effort would be of little, benefit at this time.

Since the release of the Final Environmental Impact Statement, there has been considerable refinement of spatially explicit models designed to examine relationships between spotted owl populations and changes in habitat (e.g., McKelvey et al. 1991, McKelvey et al. 1993, Lamberson et al. 1992, Carroll and Lamberson 1992). Whereas these models are incapable of identifying exact thresholds, they are useful for examining general relationships between spotted owls and their habitat, and for ranking the relative effectiveness of different management alternatives. We encourage the Forest Service to begin as soon as possible to develop: (1) spatially explicit maps of forest age classes and harvest alternatives, and (2) vegetation change and growth models that can be used to assess alternatives for managing habitat for the spotted owl and other species. Although we do not believe that the results of these modeling efforts ca n or should overshadow the judgment of biologists and land managers, the use of spatially explicit models will~ when adequate data is available, undoubtedly provide additional insights into biological processes and will allow the Forest Service to better identify areas that are particularly at risk.

A key point about the Interagency Scientific Committee's proposed strategy that was not addressed in the Final Environmental Impact Statement was the transition period during which habitat in the Habitat Conservation Areas recovers from the present condition to the desired future condition. It was assumed in the Final Environmental Impact Statement that, because of the redundancy of protective measures built into the selected alternative to ensure viability of the owl, and because of the relatively large size of the existing population, owls would persist in adequate numbers during the transition period to eventually reach the projected long-term equilibrium level. Whereas population viability models (e.g., McKelvey et al. 1991) indicate their the transition period is one of risk in terms of population persistence, we believe it is unlikely that spotted owls will reach population levels during the transition period from which they cannot recover, provided that the Bureau of Land Management adopts a management plan that is equal or superior to the strategy proposed by the Interagency Scientific Committee (Thomas et al. 1990), or that the Forest Service adopts measures to mitigate if the Bureau of Land Management adopts a less suitable plan (see Chapter 2).

For the reasons described in previous sections, we do not believe that estimates of crude density or demographic rates shed much light on the issue of whether the spotted owl population will eventually reach equilibrium at the target levels set by the Interagency Scientific Committee and the Forest Service Final Environmental Impact Statement. However, we believe that if Federal land management agencies manage for a network of relatively large blocks of habitat, spaced at relatively close intervals across the range of the spotted owl, as proposed by the Interagency Scientific Committee the owl population will eventually stabilize at a lower equilibrium population level, and will have a high likelihood of long-term viability. We base our opinion on the information that was compiled by Thomas et al. (1990:283-302) on persistence times of small populations, and on the results of models that show that metapopulations of animals distributed in large clusters are likely to remain viable for long periods of time (Thomas et al. 1990, McKelvey et al. 1991). The conclusions of Carroll and Lamberson (in press) are also supportive.

They stated that, "The optima] conservation plan probably results from a reserve philosophy similar to that described by Thomas et al. (1990) in their conservation strategy for the northern spotted owl, which is many moderately large reserves broadly distributed throughout the range of the species with distance between reserves small enough to maintain connectivity."

HYBRIDIZATION WITH THE BARRED OWL

Since 1989, hybrid crosses between barred owls and spotted owls have been confirmed at four widely separated locations within the range of the northern spotted owl (Hamer et al., in press). The four cases included two male hybrids that were found paired with female barred owls, one female hybrid that was found paired with a male spotted owl, and one case in which a l-year-old spotted owl paired with a female barred owl and produced a hybrid offspring.
In all cases, the adult hybrids that were observed were believed to be first generation (F1) crosses based on plumage characteristics. One of the hybrid males that was paired with a female barred owl produced young in at least two separate years, thus demonstrating that first generation hybrid males, at least, are capable of back-crossing. First generation hybrids are characterized by very distinctive plumage and vocalizations, which include attributes of both of the parent species. These observations have been described in a draft manuscript by Hamer et al. (in press) who concluded that the Mayr and Short (1970) classification of the spotted owl and barred owl as~ superspecies (two species that only recently diverged from a common parental stock) is probably correct.

Although records of hybridization between barred owls and spotted owls are an interesting biological phenomenon, we cannot predict the ultimate outcome. Hybridization is common in nature~ having been recorded in about 10 percent of the non-marine bird species in North America (Mayr and Short 1970) and between two other owl species of the genus *Strix* (the same genus as the spotted owl) in Europe (Scherzinger 1983). In most species where hybridization occurs it tends to be an uncommon event, and thus has little effect on the parental species - that is, the species still continue as distinct species for very long periods of time.

We suspect that hybridization between spotted and barred owls is rare for the following reason. During the last 15 years, hundreds of observers have surveyed and banded spotted owls and have confirmed several thousand pairs of spotted owls and hundreds of pairs of barred owls. Despite this massive effort, only four F1 hybrids have been observed. This suggests that the behavioral isolating mechanisms that normally keep the two species from hybridizing are relatively effective. Nevertheless, the barred owl is rapidly invading the range of the northern spotted owl and the incidence of hybridization could increase as the numbers of barred owls increase. We do not know what the ultimate outcome will be. In a recent report prepared for the association of O&C Counties, Vincent (1990:49.) expressed the view that the "...prognosis is poor for the spotted owl to maintain an undiluted gene pool." Although he could be right, we feel his view is conjectural. Even in the absence of interbreeding, the barred owl may represent a serious threat to the spotted owl from the standpoint of competition or displacement. But that is highly uncertain, as discussed by Hamer et al. (1989) and Vincent (1990). At this point, barred owls are relatively uncommon in many upland areas in Washington, Oregon and California, and it remains to be seen whether they will eventually become common enough to displace significant numbers of spotted owls.

Currently, we believe that there is little the Forest Service or other forest management agencies can or should do to influence the eventual outcome of the barred owl range extension. It is not at all clear that the range extension is the result of forest management practices. It is equally unclear whether a change in management practices (e.g., saving all the old-growth forests or stopping M1 timber harvest) will have any effect on the rate or extent of the range extension. In light of this uncertainty, we believe that the most reasonable course of action is to continue to manage habitat for a reasonably large population of spotted owls, widely dispersed within the historical range of the species (as proposed by the Interagency Scientific Committee, the selected alternative in the Final Environmental Impact Statement, and by the Draft Recovery Plan).

OWL NUMBERS AND DISTRIBUTION

Since the release of the Final Environmental Impact Statement, additional surveys of spotted owls have been completed. This information has been summarized by state agencies and by the Northern Spotted Owl Recovery Team, and is briefly summarized below.

Canada

in Canada, the historical range of the spotted owl is limited to the southwest mainland of British Columbia. Dunbar et al. (1991) described results of surveys of spotted owls and barred owls British Columbia from 1985 to 1988. During those surveys, which covered a large portion of the historical range of the northern spotted owl in British Columbia, spotted owls were found at only six locations, including pairs at two sites and single owls at four sites. The authors concluded that the spotted owl was rare in British Columbia, with an estimated population of less than 100 pairs. They also hypothesized that the population had probably declined as a result of habitat loss and displacement by barred owls. Since 1988, additional surveys have been conducted in British Columbia and the total number of sites where spotted owls have been located has increased to 14 pairs and 12 individuals (Blackburn and Bryant 1991, Dunbar pets. comm.).

United States

Numbers of owl pairs located in Washington, Oregon and northwestern California during surveys conducted from 1987 to 1992 are summarized in Table 4-9. These data were summarized from personal communications with persons responsible for maintaining state wildlife agency data bases in the three states, and with Fred Seavey of the Northern Spotted Owl Recovery Team. The total number of owls reported in the three-state area included 3,591 pairs, and approximately 1,000 sites where single owls were observed but status was not confirmed. These counts should not be considered a minimum population estimate because: (1) not all landowners and agencies reported their annual summaries of 1992 data in time to be included in the population estimate; and (2) the counts included only owls located since 1987-88, and undoubtedly did not include some pairs that were still occupying sites not visited since 1986-87. It is also possible that some of the pairs found in 1987-91 may have been displaced by habitat loss.

Table 4-9 Numbers of Spotted Owl Pairs Located Within the Range of the Northern Spotted Owl [a].

Area	USFS[c]	BLM[c]	Private	State or Province	Nat'l Parks	Tribal Lands	Total
California	471	17	414	14	1[c]	37	954
Oregon	1,164	608	128[b]	33	8[b]	36	1,977
Washington	486		45[b]	33	64[c]	32	660
Canada				14			14
Totals	2,121	625	587	94	73	105	3,605

[a]Sunmmrized from personal communications with state biologists and with Fr ed Seavey of the Northern Spotted Owl Recovery Team.
[b]Five-year survey period -- 1988-1992
[c]Five-year survey period -- 1987-1991

Although actual population counts are unknown, data compiled by the Northern Spotted Owl Recovery Team indicate that 40-73 percent of the potential owl habitat on lands administered by both the Forest Service and the Bureau of Land Management was searched for owls between 1987-91 (Table 4-10). The fact that not all habitat has been searched suggests that the actual population is larger than the confirmed population. However, it is also likely that at least some of the owls documented between 87-91 have been displaced by habitat loss. It is also likely that this summary does not include some areas that were surveyed prior to 1987, but that have not been searched in recent years.

Table 4-10 Percent of Spotted Owl Habitat Surveyed for Owls on Lands Administered by Both the Forest Service and Bureau of Land Management Between 1987-91.[a]

Landowner	Washington	State Oregon	California
Forest Service			
Reserved lands	22	46	17
Non-reserved lands	45	77	54
Total FS lands	40	73	44
Bureau of Land Management			
Total BLM lands		61	

[a]These data were obtained from summaries compiled by the Northern Spotted Owl Recovery Team, For purposes of this analysis, habitat is defined as any forested area with trees at least 11 inches in diameter with at least 40 percent canopy closure.

Two points should be emphasized here. First, the increase in the number of confirmed owl pairs should not be interpreted as evidence of a population increase. Data from the density study areas and the demographic studies clearly do not support such an interpretation. The obvious explanation for the increase in the number of known owls is that survey effort has greatly increased during the last 10 years, including: (1) a greatly expanded effort to inventory owls in Habitat Conservation Areas, (2) the initiation of numerous demographic studies across the range of the owl, and (3) increased survey associated with timber sales in order to comply with Section 7 consultation requirements of the Endangered Species Act. Given the dramatic increase in survey effort since 1985, we are not surprised that more owls are being located as new areas are being searched.

The second important point to emphasize is that the total number of owls that exist under current conditions is not particularly relevant in the long term. What is much more important is the total number of owls projected to occur when the selected management plan is fully implemented. The Conservation Strategy proposed by the Interagency Scientific Committee assumed that most pairs of owls outside the Habitat Conservation Areas would eventually disappear as habitat was removed by logging and natural events, eventually resulting in an estimated future population of about 2,200 pairs of northern spotted owls in Habitat Conservation Areas. This estimated number will not likely change very much, regardless of the size of the current population. What does change as a result of the larger current population size is that we are more confident that the population will survive through the short-term transition period during which the plan is implemented.

SUMMARY AND CONCLUSIONS

Analyses of data from ongoing demographic studies of spotted owls suggest that the territorial female population is declining at a rate of 7.5 percent per year (Anderson and Burnham 1992). By comparison, density estimates of spotted owls indicate territorial populations that are either stable or declining slightly. Because of the potential biases that may influence estimates from banding studies and density studies, the Scientific Analysis Team concluded that banding studies are likely to result in overestimates of rates of decline whereas density studies are likely to result in underestimates of rates of decline. Therefore, it is our opinion that the actual rate of decline in the territorial population is intermediate between the estimates produced by the two methods.

A declining territorial population during a period of declining habitat is to be expected. Under these conditions, we also believe that a declining female survival rate (Anderson and Burnham 1992) might also be expected given the density dependent factors (e.g., packing) that might be effect during the transition period.

Regardless of the biases that may effect estimates from demographic studies and density studies of spotted owls, we believe that demographic rates or trends observed during a prolonged period of habitat loss will provide little insight as to whether the population wil] eventually reach a new stable equilibrium when the rate of habitat loss is equaled by the rate of habitat gain (Noon and Biles 1990, Lamberson et al. 1992). For that reason, the Scientific Analysis Team disagrees with those (e.g., Kareiva 1992, Orions 1992, Harrison 1992) who have inferred from the demographic data that the approach proposed by the Interagency Scientific Committee is inadequate. In fact, our review of recent modeling efforts (e.g., Carroll and Lamberson [in press]) leads us to conclude that the strategy proposed by the Interagency Scientific Committee of maintaining a network of large blocks of suitable habitat, distributed across the range of the owl, will have a high likelihood of maintaining a viable population of spotted owls in the long term. This viewpoint reflects our collective professional judgement based on a review of the evidence. There simply are no data that can guarantee that any plan that has never been tried will prove successful. It is well to note that after prolonged deliberation, the Northern Spotted Owl Recovery Team proposed a strategy that is nearly identical with the strategy proposed by the Interagency Scientific Committee.

Using records of timber cutting, we estimated that rates of habitat loss ranged from 0.9 to 3.1 percent per year on five study areas in which densities of territorial spotted owls were being monitored. A different analysis, using Landsat data from three of the same areas, indicated that potential owl habitat declined at rates of 1.1 to 5.4 percent per year. Estimates of rates of decline in the population of territorial female owls based on demographic studies (6-16 percent per year) generally exceeded rates of habitat loss. Estimates of rates of decline in the territorial population based on density studies generally indicated populations that were stable or declining slightly.

Results from population models indicated that population thresholds exist, and that Once the habitat is reduced below a threshold level, the population will eventually decline to extinction (Thomas et al. 1990, Carroll and Lamberson [in press]). Unfortunately, these models cannot tell us where those thresholds are. For reasons stated above, we believe that the Interagency Scientific Committee strategy and the preferred alternative in the Final Environmental Impact Statement will maintain owl habitat above the levels that might be likely to cause a threshold response.

A review of habitat databases indicated that the Forest Service does not have Geographic Information Systems coverage of all forest age classes and of spatially explicit present or future harvest plans. This makes it impossible to use spatially explicit population viability models to compare different alternatives in the Final Environmental Impact Statement without making numerous assumptions about present and future conditions. Although we have no expectations that population viability models will provide exact estimates of thresholds, we do think they are a very useful tool for ranking alternatives and for exploring general relationships between animals and their environment. Therefore, we recommend that the Forest Service begin to develop the Geographic Information Systems databases necessary to conduct such analyses.

Our review of the available information leads us to believe that hybridization between barred owls and spotted owls is uncommon. However, we do not know if hybridization between the two species will increase as the barred owl continues to increase and expand its range. There is no evidence to indicate that saving more old forest will have any effect on the barred range extension, or on the ability of the spotted owl to compete with the barred owl. At this point we feel that there is little the Forest Service can or should do to influence this relationship, except to provide the spotted owl with a network of secure habitat areas like those proposed by the Interagency Scientific Committee strategy.

Recent surveys indicate that the current spotted owl population is larger than was estimated by the Interagency Scientific Committee. We attribute this to a more complete survey, rather than a population increase. It is important to emphasize that the size of the current population is not particularly relevant. What is important is the size of the population that will exist when the proposed management plan is fully implemented, and the population has stabilized at the lower equilibrium target that was established by Interagency Scientific Committee (about 2,200 pairs).

Although the northern spotted owl population in Canada is probably less than 100 pairs, we believe it is important to protect that population for two reasons. First, the risk of extinction to a species is reduced by maintaining the widest possible distribution (Den Boer 1981, Thomas et al. 1990). Second, groups of individuals near the edge of the range are likely to be best adapted to the unique climatic/habitat conditions that prevail in those areas, and could be better able to persist if similar conditions eventually become prevalent in other portions of the range (Peters and Darling 1985:707-717).

We emphasize that a key part of the strategy proposed by the Interageney Scientific Committee and the Final Environmental Impact Statement is to continue to track owl numbers through monitoring, inventory and demographic studies, and to conduct experiments to assess the extent of bias in methods used to assess population trends. And finally, we call for the adoption of an adaptive management process to facilitate the orderly review and synthesis of new information as it becomes available.

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Appendix 4-A

Description of Banding Studies

Appendix 4-A
Description of Banding Studies

This appendix contains a description of banding/demographic studies being conducted on the northern spotted owl. As of the end of the 1992 field season, a total of 4,066 adults/subadults and 2,784 juveniles had been banded.

OREGON

H...J. Andrews -Meslow/Miller/Swindel/DeStefano
A cooperative study between the Oregon Cooperative Wildlife Research Unit and the Pacific Northwest Forest and Range Experiment Station. This study was initiated in 1987. It includes a 116 mi2 (300 km2) density study area encircled by a 655 mi2 (1,696 km2) general study area that includes most of the Blue River and McKenzie Ranger Districts of the Willamette National Forest. The study area includes a variety of forest age classes and landscapes typical of lands managed by the Forest Service on the west slope of the Cascades, including a portion of the Three Sisters Wilderness. A total of 306 adults/subadults and 228 juveniles were banded as of 1992. This was one of the five areas described in the Anderson and Burnham report (1992).

Eugene Bureau of Land Management - Western Side - Thrailkill and Meslow
A cooperative study between the Bureau of Land Management and the U.S. Fish and Wildlife Service Oregon Cooperative Wildlife Research Unit. This study officially started in April 1990. However, Bureau of Land Management personnel had already banded about 40 owls in 1989 before the formal study began. This study includes a 178 mi2 (461 km2) density study area called the "Wolf Creek Density Study Area", as well as a 540 mi2 (1,399 km2) general study area that encompasses the west half of the Eugene District of the Bureau of Land Management (Coast Range and South Valley Resource Areas). The Wolf Creek Density Study Area is included in the general study area. A total of 92 adults, 12 subadults, and 64 juveniles were banded as of 1992.

Eugene Bureau of Land Management - East Side - Irwin/NCASI
A cooperative study between Bureau of Land Management and the National Council for Air and Stream Improvement. This was initially started as a habitat use study in 1988. Following completion of the habitat use study in 1991, the scope of the project was expanded to include a demographic study on private lands and those managed by Bureau of Land Management. The study area includes the east half of the Eugene District, as well as adjacent private lands. A total of 94 adults, 9 subadults, and 23 juveniles were banded as of 1992.

Coos Bay Bureau of Land Management - Pacific Southwest Forest and Range Experiment Station - Noon/Zabel/Brown
A cooperative study between Bureau of Land Management and the Pacific Southwest Forest and Range Experiment Station in Arcata, California. This study was initiated in 1990 on the Coos Bay District of the Bureau of Land Management. However, small samples of owls were also banded on the district from 1986 to 1989, before the formal study began. The study area includes the entire Coos Bay District and intervening private lands. Total area is approximately 400 mi2 (1,036 km2). The study is designed to examine population growth rates from mark-recapture analyses. Although it does not include a density study area, conversations with Barry Noon and Mark Brown indicate that most of the study area is being thoroughly searched for owls. A total of 248 adults/subadults and 153 juveniles were banded as of 1992.

Appendix 4-A
Description of Banding Studies (continued)

Siskiyou National Forest - Ngo~/Zabel/Pacific Southwest Forest and Range Experiment Station
A cooperative study between the Chetco Ranger District of the Siskiyou National Forest and the Pacific Southwest Forest and Range Experiment Station at Arcata, California. Initiated in 1990, this mark-recapture study includes a general study area that encompasses the Chetco Ranger District. It does not include a density study area. A total of 66 adults, 8 subadults, and 30 juveniles was marked as of 1992. The study will likely be discontinued after 1992 because of lack of funding (Zabel pets. comm.).

Siuslaw National Forest - Pacific Northwest Forest and Range Experiment Station - Forsman/Loschl/Forson
A cooperative study between the Siuslaw National Forest and Pacific Northwest Forest and Range Experiment Station. Initiated in March 1990. Includes 1) a 261 mi2 (676 km2) density study area that encompasses the north half of the Mapleton Ranger District, and 2) a general study area that includes the entire Siuslaw National Forest. This study encompasses a broad range of landscapes typical of the Oregon Coast Ranges. A total of 132 adults, 17 subadults, and 62 juveniles was banded as of 1992.

Roseburg Bureau of Land Management- Forsman/Reid/Mires/Oliver/Witt/Foster/Lint/et al.
A cooperative study between Bureau of Land Management and the Pacific Northwest Forest and Range Experiment Station. This mark-recapture study was initiated in 1985 and includes the entire Roseburg District of Bureau of Land Management as well as interspersed private lands (roughly 1,700 mi2 or 4,403 km2). It includes a 390 mi2 (1,010 km2) density study area that encompasses most of the Drain Resource Area. Another 190 mi2 (492 km2) density study area was added in 1991 on the Dillard Resource Area. Includes landscapes typical of three geographic provinces, the Coast Ranges, Western Cascades, and Klamath Mountains. A total of 438 adults, 117 subadults, and 453 juveniles was banded as of 1992. This was one of the five areas described in the Anderson and Burnham report (1992). In addition to banding studies, 37 juvenile owls were fitted with 6 gram tail-mount transmitters on this area in 1991 and 1992 to examine survival rates and dispersal.

Medford Bureau of Land Management - Wagner/Meslow/Harper/Wright/et al.
A cooperative study between Bureau of Land Management, the U.S. Fish and Wildlife Service Oregon Cooperative Wildlife Research Unit, and several National Forests. This mark-recapture study was initiated in 1985. Initially it included only a portion of the Medford District of Bureau of Land Management, but in 1990 it was expanded to encompass most of the Medford District as well as portions of the Winema, Umpqua, Siskiyou and Rogue River National Forests. The study includes four density study areas [Butte Falls = 120 mi^2 (311 km^2), Evans Creek = 126 mi^2 (326 kin^2), Elk Creek = 105 mi^2 (272 km^2), Williams = 119 mi^2 (308 km^2)]. The general study area covers approximately 4,050 mi^2 (10,490 km^2). A total of 803 adults, 108 subadults, and 564 juveniles was banded as of 1992. This was one of the five areas described by Anderson and Burnham (1992).

Salem Bureau of Land Management - Logan/England/Hopkins/Licata

This mark-recapture study was initiated in 1986. It includes a general study area that encompasses the entire Salem District of Bureau of Land Management. It includes two density study areas. Although a few spotted owl responses have been heard in the Nestucca density study area, no owls have been visually located or banded there in three years of surveys (1990-1992). The Nestucca density study area is covered by young and mid-aged forests and cutover areas. A new density study area was initiated in 1992 on Mill Creek, just south of the Nestucca density study area. Both density study areas are located in the Oregon Coast Ranges. The Nestucca density study area will probably be dropped in 1994 assuming that no owls are found there in 1993 (W. Logan pers. comm.). A total of 154 adults/subadults, and 100 juveniles was banded on the district as of 1992.

Warm Springs Indian Reservation - AG Crook Company

The tribe hired the AG Crook Consulting company to mark owls on the reservation in 1992. A total of 47 adults, 4 subadults, and 14 juveniles was banded.

WASHINGTON

Olympic Peninsula- Forsman/Moorehead/Seaman/Anthony

This mark-recapture study was initiated by the Pacific Northwest Forest and Range Experiment Station in 1987 and focuses primarily on Olympic Peninsula lands managed by the Forest Service. Since that time, the Olympic National Park and the Washington Department of Natural Resources have joined in the banding effort, expanding the coverage to portions of the Olympic National Park and to State lands. While the general study area includes the entire Olympic Peninsula, large areas of the Olympic National Park and privately owned forest lands are not surveyed. A 137 mi2 (355 km2) density study area is located on the south half of the Quinault Ranger District of the Olympic National Forest on the west side of the Peninsula. The total study area is roughly 965 mi2 (2,500 km2). As of 1992, a total of 226 adults, 43 subadults, and 223 juveniles were banded. In addition, a sample of 18 juveniles was marked with tail-mount radio transmitters in 1991 and 1992 to examine survival rates and dispersal patterns. This was one of the five study areas examined by Anderson and Burnham (1992).

Wenatchee National Forest - Forsman/Sovern/Taylor/Pacific Northwest Forest and Range Experiment Station

A cooperative study between the Pacific Northwest Forest and Range Experiment Station and the Wenatchee National Forest. Initiated in 1989 on the Cle Elum Ranger District of the Wenatchee National Forest, the study started as a habitat use study and then continued as a demographic study after the habitat use study was completed in 1991. The study includes a 76 mi2 (197 km2) density study area in the Swauk Valley, and a general study area that includes the entire 696 mi2 (1,803 km2) Cle Elum Ranger District and adjacent private lands. The Cle Elum study area includes extensive areas that have been selectively logged or burned during the last 80 years. As of 1992, a total of 121 adults, 26 subadults, and 168 juveniles was banded. In addition, 29 juveniles were radio-marked with tail-mount transmitters in 1991 and 1992 to determine survival rates and dispersal patterns.

Appendix 4-A
Description of Banding Studies (continued)

Wenatchee National Forest - Irwin/Flemming/Martin/NCASI/Pacific Northwest Forest and Range Experiment Station
A cooperative study between the National Council For Air and Stream Improvement and the Pacific Northwest Forest and Range Experiment Station in Wenatchee. Initiated in 1990, this mark-recapture study includes most of the Wenatchee National Forest, with the exception of the Cle Elum Ranger District. It does not include a density study area. A total of 173 adults, 21 subadults and 170 juveniles was marked as of 1992. This study was designed to compare demographic parameters of owls living in managed and unmanaged habitats.

Yakima Indian Nation - Eric Hanson
This study was initiated in 1991 as a habitat use study but also includes a sample of banded owls. The study area includes the forested portions of the Yakima Indian Reservation on the east slope of the Washington Cascades. This study abuts the demographic studies that are being conducted on the Wenatchee National Forest. A total of 26 adults, 2 subadults, and 13 juveniles **was banded as of 1992.**

CALIFORNIA

Willow Creek Study - Franklin/Gutierrez/Noon
A cooperative study between Humboldt State University, the California Department of Fish and Wildlife, and the Pacific Southwest Forest and Range Experiment Station at Arcata, California. This mark-recapture study was initiated in 1985 on the Six Rivers National Forest in northwestern California. It includes a 113 mi2 (293 km2) density study area on Willow Creek as well as a series of smaller density study areas distributed in a satellite network around the Willow Creek area. The study area includes landscapes typical of the Six Rivers National Forest. A total of 254 adults/subadults and 276 juveniles was banded as of 1992. This was one of the five areas examined by Anderson and Burnham (1992).

Simpson Timber Company - Lowell Diller
This study was started as a habitat use study in 1989, then continued as a mark-recapture demographic study after the habitat use study was completed in 1991. The 300 mi2 (777 km2) study area includes primarily Simpson Timber Company lands within the redwood belt of northwestern California. Although not designed as a density study per se, an area of approximately 220,608 acres (893 km2) had been surveyed well enough to estimate minimum density of owls as of 1992. The study area includes mostly young-growth and mid-aged redwood forest and areas that have been recently clearcut: A total of 250 adults, 62 subadults, and 197 juveniles was banded as of 1992.

Appendix 4-A
Description of Banding Studies (continued)

Louisiana Pacific Timber Company - Malcom Pious
This study was started in 1990 as a mark-recapture study. The study area covers approximately 650 mi2 (1,683 km2) of predominantly private land along the northern California coast. Much of which is covered by young to mid-age redwood forest. A total of 154 adults/subadults and 35 juveniles was marked as of 1992.

Hoopa Valley Indian Reservation - Mark Higley
This study was started in 1991 by the Hoopa Valley Tribal Council in mixed-conifer forests in northwestern California. A total of 47 adults, 6 subadults, and 11 juveniles was banded in 1991-92.

Appendix 4-B

Annotated List of Publications and Draft Reports that Provide New Information on the Northern Spotted Owl

Annotated Bibliography of Recent Research Information on Northern Spotted Owls

This annotated bibliography contains references on selected scientific studies that have been published or are still unpublished since the completion of the Final Environmental Impact Statement on Management for the Northern Spotted Owl in the National Forests. References contained within this bibliography became generally available between January 1992 and November 1992. Because additional studies may be in an unpublished form and therefore not readily available, it is probable that some literature relating to this subject and completed within the dates given were not included in this annotated bibliography. Some of the unpublished literature is still in draft form and not ready for public distribution. The Scientific Analysis Team was permitted to review these drafts for the purpose of assessing new data. since the Interagency Scientific Committee report.

The major conclusions of the Interagency Scientific Committee Report regarding spotted owl biology, demography and habitat use have not changed substantially after a review of the literature included here. Research on spotted owl habitat use, particularly for northern California and the east slope of the Washington Cascades should continue to add to the existing information. The review of new studies and the incorporation of information into habitat management planning should continue through accepted scientific research processes, including publication peer review.

This appendix is divided into two sections. The first section is a list of studies that have been published since the Final Environmental Impact Statement. In the second section, unpublished references available since completion of the Final Environmental Impact Statement are listed. For most references, in addition to the literature citation, the abstract is included when available. For annotations which come from author written abstracts, summaries, and conclusions, an index code of (A) is given at the end of the quote. For compiler generated annotations, an index code of (C) is found at the end of the paragraph.

Published Literature

Anderson, D.R.; Burnham, K.P. 1992. Demographic analysis of northern spotted owl populations. Pages 319-328 in: Recovery plan for the northern spotted owl, appendix C-draft. Portland, OR: U.S. Department of the Interior. 662 p.

"The 1990 Status Review Northern Spotted Owl (USDI 19901 provided estimates of the rate of population change for populations of northern spotted owls in northern California (Willow Creek and surrounding regional study area) and southern Oregon (the Roseburg study area). The population of resident female owls in these areas was shown to be declining at a significant rate. By the fall of 1991, there were2 additional years of capture-recapture data on these two populations, and three new areas (Medford in southern Oregon, H.J. Andrews near Corvallis, Oregon and the Olympic Peninsula in northwestern Washington) had sufficient years of capture-recapture data to warrant an intensive analysis (Table C.1). More than 2,000 owls had been marked and the resighting probability for adult females was approximately 0.8 to 0;9 percent."

"This appendix provides estimates for the rate of population change of resident, territorial females in these five large study areas. Analysis methods (e.g., model building, model selection, tests of model fit, parameter estimation, and inference procedures concerning the rate of population change) are those used in USDI (1990) with some extensions. The key references on methodology are Burnham and Anderson (In Press) and Lebreton et al. (in Press). The analyses of data were done during September-October, 1991, during one intensive workshop held in Ft. Collins, Colorado. The analyses were completed by six biologists working on the northern spotted owl - two French scientists, two professors from Colorado State University with special expertise in the analysis of capture-recapture data, and two U.S. Fish and Wildlife Service employees from the Colorado Cooperative Fish and Wildlife Research Unit." (A)

Bart, J.; Forsman, E.D. 1992. Dependence of northern spotted owls *Strix occidentalis caurina* on old-growth forests in the western USA. Biological Conservation. (62): 95-100.

Abstract. "Habitat requirements of northern spotted owls Strix occidentalis caurina have become the focus of a major controversy over how much old-growth forest in the western United States should be preserved. Analysis of three large data sets showed that the subspecies was rare or absent in areas with little older (i.e. > 80-year-old) forest but with extensive stands nearing harvest age. The owls were also rare in areas with the small amount of old-growth typically left after harvest operations. Old-growth stands in Wilderness Areas supported sparse populations of northern spotted owls, and their reproductive success was only about half that of owls outside Wilderness Areas. The results indicate that timber harvest operations, as currently practiced, lead to declines in numbers of northern spotted owls, and that currently protected old-growth stands are unlikely to provide enough high-quality habitat to maintain self-supporting populations of northern spotted owls." (A)

Bias, M.A.; Gutierrez, R.J. 1992. Habitat associations of California spotted owls in the central Sierra Nevada. Journal of Wildlife Management. 56(3): 584-595.

"Abstract: Habitat requirements of spotted owls (*Strix occidentalis*) are controversial, particularly with respect to private lands. Therefore, we studied the distribution and roosting and nesting habitat of California spotted owls (S. o. occidentalis) throughout a 355-km 2 study area in the central Sierra Nevada, Eldorado and Placer counties, California, from May to August 1986 and 1987. Fewer (P < 0.001) owls were detected on private land than expected from its relative land area. Slope; total canopy closure; number of possible nest trees; maximum shrub height; basal areas of old-growth, medium, pole and live trees; percent ground cover by litter; and small and large dead or dying woody vegetation were different (P < 0.05) between public and private land. Habitat types of mixed-conifer, large-tree successional stage, with > 70 percent total canopy closure were most abundant (38.1 percent) on public land; whereas mixed-conifer, pole-medium successional stage with ≥ 70 percent total canopy closure habitat types dominated private land (44.1 percent). Roost sites occurred in habitats with relatively greater total canopy closure, and basal areas of snags, medium, and old-growth trees than found in the abundance of habitat. Twenty-six of 29 observed roosts (89.7 percent) and all 11 owl nests were on public land. Our results provide forest managers with a direction towards appropriate silvicultural and logging practices for the conservation of California spotted owl roost and nest habitats. These include adequate representation of all tree size classes, especially mature and old-growth, combined with essential habitat elements (e.g., nest trees)." (A)

Blakesley, J.A.; Franklin, A.B.; Gutierrez, R.J. 1992. Spotted owl roost and nest site selection in northwestern California. Journal of Wildlife Management. 56(2): 338-392.

"Abstract: We directly observed roost and nest site selection in a population of northern spotted owls (*Strix occidentalis caurina*) in northwestern California during 1985-89. Because of potential biases caused by use of radio telemetry in previous studies, we examined habitat use relative to habitat availability at a level not previously reported for spotted owls. Spotted owls selected coniferous forest characterized by trees >53.3 cm in diameter more often (P<0.05) than it was available. Hardwood stands and coniferous forest dominated by smaller trees were used less than (P<0.05), or in proportion to, their availability. The owls selected forests at 300-900 m elevations for roosting (P<O.05), selected the lower third of slopes within a specific drainage (P<0.05), and avoided the upper third for both roosting and nesting (P<0.05). These observations support the findings of earlier workers who used radio telemetry and to assess habitat selection in the northern spotted owl" (A)

Carey, A.B.; Horton, S.P; Biswell, B.L. 1992. Northern spotted owls: influence of prey base and landscape character. Ecological Monographs. 62(2): 223~250.

"Abstract. We studied prey populations and the use and composition of home ranges of 47 Northern Spotted Owls (*Strix occidentalis caurina*) over 12 mo in five landscapes in two forest types in southwestern Oregon. We measured 1-yr home ranges of 23 owl pairs, 2-yr home ranges of 13 owl pairs, and 3-yr home ranges of 3 pairs. The landscapes differed in the degree to which old forest had been fragmented by wildfire and

logging. Prey populations were measured at 47 sites in southwestern Oregon. Further data on prey populations were gathered on 14 sites on the Olympic peninsula in northern Washington, where owls use large ranges than in Oregon."

Carroll, J.E.; Lamberson, R.H. 1992. [In press]. The owl's odyssey. A continuous model for the dispersal of territorial species. Society of Industrial and Applied Mathematics Journal of Applied Mathematics. 52(6).

"Abstract. In this paper, a composite model is developed that consists of a continuous model for dispersal set within a difference equation model for the life history of territorial species. Two dispersal models are considered: one that assumes that suitable habitat is uniformly or randomly distributed throughout the range of the population, and one that assumes that home ranges are concentrated in clusters of suitable habitat. These models explicitly consider the cost of dispersal by including ongoing rates of mortality due to predation and starvation while birds search for a territory. The cluster model also differentiates between mortality within and outside of clusters. An analysis of the difference equation model demonstrates a threshold for density of suitable habitat below which the population must decrease to extinction, and above which the population tends monotonically to a stable positive equilibrium size. In addition, it is established that the equilibrium size of the population can be increased by consolidating the reserves of suitable habitat into larger clusters:" (A)

Dunbar, D.L.; Booth, B.P.; Forsman, E.D., [and others]. 1991. Status of the spotted owl, *Strix occidentalis*, and barred owl, *Strix varia*, in southwestern British Columbia. Canadian Field Naturalist. 105(4): 464-468.

Abstract. "Calling surveys were used to assess the relative abundance and distribution of Spotted and Barred owls in southwestern British Columbia from lg8S to 1988. Spotted Owls were located at 14 sites, including pairs at 7 sites and single birds at 7 sites. One Spotted Owl nest was located. Barred Owls were located at 57 sites, including pairs at 14 sites and single birds at 43 sites. The average number of individuals responding per km of survey transect was 0.04 and 0.25 for Spotted and Barred Owls, respectively. The low response rate for Spotted Owls indicates that the species is rare in British Columbia. We estimated the population at not more than 100 pairs. Although the Spotted Owl has probably never been abundant in British Columbia, we hypothesize that the population has declined because of habitat loss and displacement by the Barred Owl." (A)

Foster, C.C.; Forsman, E.D.; Meslow, E.C., [and others]. 1992. Survival and reproduction of radio-marked adult spotted owls. Journal of Wildlife Management. 56(1): 91-95.

"Abstract: We compared survival, reproduction, and body mass of radio-marked and non-radio-marked spotted owls (*Strix occidentalis*) to determine if backpack radios influenced reproduction or survival. In most study areas and years, there were no differences ($P<0.05$) in survival of males and female or in survival of radio-marked versus banded owls. There was no difference ($P = 0.31$) in mean mass of owls before and after they had worn radio transmitters. Radio-marked owls produced fewer ($P<0.01$) young than did owls that were not radio-marked. Because of the possible relationship between

lower productivity and large (>19-g) backpack style transmitters, we recommend that researchers consider the use of smaller transmitters mounted on the tail." (A)

Franklin, A.B. 1992. Population regulation in northern spotted owls: theoretical implications for management. Pages 815-827 in: McCullough, D.R.; Barrett, R.H., eds. Wildlife 2001: populations. London, England: Elsevier Applied Science. 1163 p.

"Abstract. A marked population of northern spotted owls was examined within a bounded, 292 km^2 study area in northwestern California over a six-year period (1985-1990). Observed and predicted finite rates of population change (A) for males spotted owls were significantly stable. Predicted A for females indicated a significant decline even though observed A indicated stability. Observed stability in numbers of territorial males was maintained by recruitment, whereas stability in numbers of females was maintained by immigration. Most recruits did not become territory holders until several years after their birth. I hypothesized that the study area population was regulated by territorial behavior. Under this mechanism, spotted owl populations may b< declining even though observed numbers of territorial birds appear to be stable. Using computer model, I examined the effects of "floaters" on the stability of territory holders, and suggest warning signals which may predict imminent instability for the population." (A)

Ganey, J.L. 1992. Food habits of Mexican spotted owls in Arizona. The Wilson Bulletin. 104(2): 321-326.

"Results. - Between May 1984 and August 1990, I identified 1434 prey items from pellets or kills of 34 pairs of spotted owls. The diet included at least 19 species of mammals, seven species of birds, two species of reptiles and an unknown number of insect species. Vertebrates dominated the diet in all five regions, comprising 84-96% of total prey and 99% of prey biomass (Table 1). Mammals accounted for 73-96% of total prey and 91-99% of prey biomass. Owls consumed prey ranging in mass from beetles (Coleoptera) and moths (Lepidoptera) (ca 1 g) adult cottontail rabbits *(Sylvilagus* spp; ca 650 g). Mean prey mass ranged from 63-118 g in various regions."

"Woodrats, white-footed mice (*Peromyscus* spp.), and voles (*Microtus* spp.) accounted for 61-83% of the total prey and 59-88% of total biomass in various regions (Table 1). Cottontails and pocket gophers (*Thomomys* spp.) accounted for another 3-14% of total prey and 7-36% of total biomass. Birds and reptiles contributed little to prey numbers or biomass except in Southeast Arizona. Insects were relatively common in the diet (3-16% of total prey) but contributed little to prey biomass. Diurnally active mammals such as squirrels and chipmunks (Scuridae) accounted for <3% of total prey or biomass." (A)

Ganey, J.L.; Duncan, R.B.; Block, W.M. 1992. Use of oak and associated woodlands by Mexican spotted owls in Arizona. Pages 125-128 in: Ecology and management of oak and associated woodlands: perspectives in the southwestern United States and northern Mexico: Proceedings of a symposium; 1992 April 27-30; Sierra Vista, AZ. Gen. Tech. Rep. RM-218. Fort Collins~ CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 224 p.

"Abstract - Although the spotted owl is often associated with coniferous forests, oak and associated woodlands also provide habitat for spotted owls. In Arizona, Mexican spotted owls are year-round residents in Madrean oak-pine forests, encinal woodlands, and ponderosa pine-Gambel oak forests, while some spotted owls winter in pinyon-juniper woodlands. Oak and associated woodlands present unique management challenges to resource managers charged with maintaining viable populations of Mexican spotted owls." (A)

Johnson, D.H. 1992. Spotted owls, great horned owls, and forest fragmentation in the central Oregon Cascades. Corvallis, OR: Oregon State University. 138 p. M.S, thesis.

"Nocturnal surveys were conducted in February - May 1989 and January - May 1990 to locate great horned owls (*Bubo virginianus*) and northern spotted owls (*Strix occidentalis caurina*)throughout the range of forest fragmentation levels in the Central Cascades of Oregon. Forest fragmentation levels ranged from landscapes (≥ 500 ha in size) containing intact stands of mature/old-growth forest (0% fragmentation) to landscapes containing younger stands with no mature/old-growth forest (100% fragmentation). Six survey visits were made to each of 469 calling stations located along 28 roadside survey routes. Total length of survey routes was 535.8 road km; relative abundance for great horned owls and spotted owls was 0.069 and 0.139 owls/road km, respectively. Owl response rates were examined for differences 1) during the night, 2) moon phase, and 3) by month during the survey period. Great horned owls responded less than expected before midnight and more than expected after midnight, less than expected during full moon and more than expected during new moon phases, and less than expected during January and April of the survey period. Spotted owls responded more than-expected from 1800-1959 hr, more than expected during full moon phases, and generally more than expected during May of the survey period."

"Thirteen habitat/landscape variables within 500-ha circular landscape plots surrounding 77 great horned owl, 103 spotted owl, 70 no-owl and 70 random points were assessed. Significant differences existed between great horned and spotted owl landscapes for 6 variables: great horned owl landscapes contained more shrub/forb and sbelterwood, less mature/old-growth and interior habitat, had a higher linear edge-to-mature/old-growth area ratio, and were higher in elevation than spotted owl landscapes. The amount (χ ± SE) of mature/old-growth forest was 48% ± 2% around great horned owls, 60% ± 2% around spotted owls, 53% ± 3% around no-owl points, and 53% ± 2% around random points. The greatest number of great horned owl responses were associated with landscapes containing 10-20% old forest. Great horned owl responses generally declined with increasing amount of old forest, and few (11%) great horned owls were detected in landscapes containing ≥ 70% old forest. The majority (62%) of spotted owls were detected within landscapes containing ≥ 60% old forest. Spotted owl responses generally declined with declining amounts of old forest, and few (7%) spotted owls were detected within landscapes containing ≤ 20% old forest."

"The spatial distribution of old forest stands was compared to dispersed (checkerboard) and clumped landscapes; 95% of great horned owl, 88% of spotted owl, 89% of no-owl, and 86% of random landscapes were classified as dispersed. Clearly, the forests of the Central Cascades are very highly fragmented. A method for linking owl biology and landscape level plot size is described." (A)

Johnson, D.H.; Miller, G.S.; Meslow, E.C. 1992. Edge effects and the northern spotted owl. Spotted owls, great horned owls, and forest fragmentation in the central Oregon Cascades appendix C. Corvallis, OR: Oregon State University. 138 p. M.S, thesis.

"Distance-to-edge measurements derived from 1,159 telemetry locations and 51 nest sites indicated that owls avoided young stands and preferentially selected locations with,, old forest stands. Owl telemetry and nest locations were consistently farther into old forest stands than were randomly selected points (P < 0.01). Although owls may forage up to an edge, they prefer areas > 90 [m] from an edge during the night. For daytime roost locations and nest sites, owls have indicated a decided preference for location > 100 m from an edge into old forest stands. Based on determinations presented here, researchers and managers concerned with edge should use an "edge effect " distance o! ≥ 100 m for northern spotted owls." (A)

LaHaye, W.S.; Gutierrez, R.J.; Call, D.R. 1992. Demography of an insular population (*Strix occidentalis occidentalis*). Pages 803-814 in: McCullough, D.R.; Barrett, R.H., eds. Wildlife 2001: populations. London, England: Elsevier Applied Science. 1163 p.

"Abstract. We studied the dynamics of an insular California spotted owl (*Strix occidentalis occictentalis*) population in the San Bernardino Mountains of southern California, USA. We located owls at 128 sites and banded 367 individuals between 1987-1990. We captured and color banded at least 70% of the territorial spotted owls in the mountain range. We measured territory occupancy, social status, nesting rate, fledging rate, fecundity, territory turnover and replacement rates, and survivorship. California spotted owls in the San Bernardino Mountains had variable annual reproduction. Survival rates were the lowest yet reported for a spotted owl population. We calculated λ=0.769 using a two stage Leslie projection matrix and this value was significantly different than 1.0. In this paper we assess the effect of sample size on the estimates of vital rates of this owl population. We discuss the relevance of insular studies of spotted owl populations to the understanding of the demographics of continuous spotted owl populations." (A)

McKelvey, K. 1992. A spatially-explicit life-history simulator for the northern spotted owl. USDI Bureau of Land Management Eugene District resource management plan and environmental impact statement, appendix 4-P. Eugene, OR: U.S. Department of the Interior, Bureau of Land Management, Region 1.33 p. 2 vol ± 4 maps.

"A spatial model was created to simulate the impact of forest management on populations of the northern spotted owl. The basic premise of the model is that an organism's survival and reproduction can be linked explicitly to its immediate habitat and that habitat's context within the larger landscape. That is, a population's rates of survival and fecundity will vary based on map configuration. In addition, the model allows for habitat areas that are unsuitable or marginally suitable for nesting. Lastly, the model assumes that each organism must search the landscape to find a mate."

"The model is a single-organism simulator. Each organism is born, moves, attempts to find a mate and breed, and dies. This format allows the behavior of each individual to be simulated by following a series of probabilistic rules rather than through the

abstraction of an equation set. The model is flexible, allowing for the analysis of individual characteristics as well as population dynamics. The average distance moved by individual birds before death or pairing, for example, can be output, and thus compared with data from banding or telemetry studies to determine if the simulated movement produces a path-length similiar in magnitude to the observed behavior." (A)

National Forest Products Association and American Forest Council. I992. A multi-resource strategy for the conservation of the northern spotted owl. Compiled by the Spotted Owl Subgroup of the Wildlife Committee of the National Forest Products Association and the American Forest Council. 60 p. ± 1 map.

"This strategy is offered as a management alternative that we believe can safeguard the long-term survival of the northern spotted owl (*Strix occidentalis caurina* I while simultaneously allowing the sustained yield of forest products. It combines several approaches and defines both public and private landowner roles for the conservation of the northern spotted owl."

"Our strategy was developed to provide technical input to the various processes (critical habitat proposals, recovery plan development, state regulations, etc) surrounding the management of the northern spotted owl in the Pacific Northwest. We relied heavily on the summary of biological information presented in Thomas et al. (19901 and employed many of the same key biological principles (such as a system of protected habitat for multiple pairs and provisions for connectivity between them I. We also incorporated new survey and research information that has become available in the last two years."

"By studying the most recent available data, including land use classification, suitable habitat maps, and owl locations (provided by the U.S. Forest Service and other agencies), we developed a concept that will specify a zone of owl habitat that stretches from British Columbia to northern California." (A)

Murphy, D.D.; Noon, B.R. 1992. Integrating scientific methods with habitat conservation planning: reserve design for northern spotted owls. Ecological Applications. 2(1): 4363-4378.

"Abstract. To meet the requirements of Congressional legislation mandating the production of a 'scientifically credible' conservation strategy for the threatened Northern Spotted Owl (Strix occidentalis caurina), the Interagency Spotted Owl Scientific Committee employed scientific methods to design a habitat reserve system. Information on the current and historical distributions of the owl and its habitats was reviewed in light of economic, political, and legal constraints; results were used to develop a preliminary reserve system of habitat 'polygons'. A map representing these polygons and their attendant properties served as a set of hypotheses that were tested. Statistical analyses of empirical data, predictions from ecological theory, predictions from population dynamics models, and inferences drawn from studies of related species were used to test properties of the preliminary map, including the number and sizes of habitat conservation areas (HCAs), their distribution, configuration, and spacing, and the nature of the landscape matrix between Habitat conservation areas. Conclusions that failed to confirm specific map properties were used to refine the reserve system, a process that continued iteratively until all relevant data had been examined and all

map properties had been tested. This conservation planning process has proven to be credible, repeatable, and scientifically defendable, and should serve as a model for wildlife management, endangered species recovery, and national forest planning." (A)

Simpson Timber Company. 1992. Habitat conservation plan for the northern spotted owl on the California timberlands of Simpson Timber Company. Arcata, CA: Simpson Timber Company. Addendum. 323 p.

"Simpson Timber Company (Simpson), a privately held corporation, is seeking permit from the U.S. Fish and Wildlife (USFWS) for the incidental take of northern spotted owls (*Strix occidentalis caurina*) in connection with timber harvesting on the properties of its California subsidiaries, Arcata Redwood Company and Simpson Redwood Company. This habitat conservation plan (HCP) has been prepared as part of the application for that permit, pursuant to Section 10(a)(1)(B) of the Federal Endangered Species Act (ESA) of 1973 as amended. Upon approval of the permit, the plan also will be used to demonstrate compliance with the current spotted owl provisions of California's Forest Practice Rules." (A)

Thomas, J.W.; Verner, J. 1992. Accommodation with socio-economic factors under the Endangered Species Act - more than meets the eye. Proceedings of the 57th North American wildlife and natural resource conference. 627-641 p.

"We intend to explore myths and realities about how much attention is paid to socio-economic consequences when applying the Endangered Species Act (ACT) of 1973 (U.S. Laws, Statutes, etc. Public Law 93-205). We will examine the circumstances surrounding the development and adoption of a conservation strategy for the northern spotted owl (5trix occidentalis caurina) and other activities, including the listing of the subspecies as "threatened," delineation of critical habitat, development of a recovery plan, development of Habitat Conservation Plans (HCPs) and other actions (Corn and Baldwin 1990). Our objective is to point out that what is perceived many as relentless and inexorable process solely based on biology to protect imperiled species without consideration of socio-economic impacts is, in fact, a procedure subject to repeated accommodation between the listed species welfare and the associated socio-economic consequences."

"This analysis is based on our experiences as members of the Interagency Scientific Committee to Address the Conservation of the Northern Spotted Owl (ISC)." (A)

USDA. 1992. Final environmental impact statement on management for the northern spotted owl in the National Forests, Portland, OR: U.S. Department of Agriculture, Forest Service, National Forest System. 2 vol.

"The Forest Service has prepared an environmental impact statement to disclose the environmental consequences of five different management alternatives to provide habitat for the northern spotted owl in National Forests. Four of these alternatives would amend the Regional Guides and approved Forest Plans for the Pacific Northwest Region and the Pacific Southwest Region of the Forest Service."

"The proposed action is to manage National Forests within the range of the northern spotted owl in accordance with the Interagency Scientific Committee's report 'A Conservation Strategy for The Northern Spotted Owl'. This proposed action would apply only to lands administered by the Forest Service" (A)

USDI 1992. Recovery plan for the northern spotted owl - draft. Portland, OR: U.S. Department of the Interior. 662 p.

"The northern spotted owl draft recovery plan provides a comprehensive basis for management actions to be undertaken by forest landowners and wildlife agencies to alleviate conditions threatening the species. Primary actions will be taken by Federal land management agencies in the Pacific Northwest - the U.S. Forest Service, the U.S. Bureau of Land Management, and the National Park Service. The U.S. Fish and Wildlife Service will oversee implementation of the plan through its authorities under the Endangered Species Act."

"State forest management and wildlife agencies in Oregon, Washington, and California also will take actions that contribute to recovery under the plan. These state agencies have an important role in managing state forests and in regulating forest practices on private land within their jurisdiction, Contributions from habitat on Indian lands also were considered in formulating the draft plan." (A)

USDI Bureau of Land Management. 1992a. Coos Bay District resource management plan and environmental impact statement. Coos Bay, OR: U.S. Department of the Interior, Bureau of Land Management, Region 1.2 vol. ± 4 maps.

"Abstract: This Draft Resource Management Plan/Environmental impact Statement addresses resource management on 329,583 acres of Federal land and 12,152 acres of reserved mineral estate administered by the Bureau of Land Management in its Coos Bay District. Seven alternatives including no action (no change in the existing plan) are analyzed. These alternatives range in emphasis from high production of timber and economically important values to management and enhancement of values such as biological diversity, spotted owl habitat, old-growth forests, dispersed recreation opportunities, and scenic resources. The preferred alternative would: provide for a planned annual timber sale level of 20.1 MMCF (124 MMBF) from 309,000 acres of commercial forest land; maintain air quality, water quality, and long term soll productivity; retain 52,400 acres of old-growth forest; provide habitat to support a carrying capacity of 16to 24 pair of northern spotted owls and provide for protection of other Federally listed animal species; designate eight new Areas of Critical Environmental Concern on 7,490 acres; provide opportunities to develop 27 recreation areas/sites or trails; designate five Back Country Byways; provide for visual resource management on 7,200 acres; and provide for mineral exploration and development on 322,200 acres. No rivers would be found suitable for designation under the Wild and Scenic Rivers Act. Long term management (100 years) under the Preferred Alternative would increase the amount of old-growth to 56,300 acres and increase the carrying capacity for the northern spotted owl to between 41 and 58 pair." (A)

USDI Bureau of Land Management. 1992b. Eugene District resource management plan and environmental impact statement. Eugene, OR: U.S. Department of the Interior, Bureau of Land Management, Region 1.2 vol. ± maps.

"Abstract: This Draft Resource Management Plan/Environmental Impact Statement addresses resource management on 316,592 acres of Federal land and 1,299 acres of reserved mineral estate administered by the Bureau of Land Management in its Eugene District. Seven alternatives including no action (no change in the existing plan) are analyzed. These alternatives range in emphasis from high production of timber and economically important values to management and enhancement of values such as biological diversity, spotted owl habitat, old-growth forests, dispersed recreation opportunities, and scenic resources."

"The Preferred Alternative would: provide for a planned annual timber sale level of 19.9 mmcf (119 mmbf, Scribner Short Log) while maintaining water quality in all watersheds. Old-growth forest acreage would be reduced by about 2,700 acres (7%) the short-term, five additional Areas of Critical Environmental Concern (ACECs) would be designated, and three segments of river would be found suitable for designation under the Wild and Scenic Rivers Act." (A)

USDI Bureau of Land Management. 1992c. Medford District resource management plan and environmental impact statement. Medford, OR: U.S. Department of the Interior~ Bureau of Land Management, Region 1.2 vol. ± 4 maps.

"Abstract. "This Draft Resource Management Plan/Environmental Impact Statement addresses resource management on 866,300 acres of Federal surface estate and approximately 4,700 acres of reserved mineral estate administered by the Bureau of Land Management in its Medford District. Seven alternatives including the No Action alternative (no change from the existing plan) are analyzed. These alternatives range emphasis from high production of timber and other commodity values to management and enhancement of values such as biological diversity, spotted owl habitat, old growth forests, dispersed recreation opportunities, and scenic resources. The Preferred Alternative would provide for a planned annual timber sale level of about 18 mmcf (105 mmbf) on a sustained yield basis while maintaining water quality in all watersheds and long-term biological diversity. Old growth forest acreage would be increased by about 4,000 acres (4%), 22 additional areas of critical environmental concern would designated, and 5 stretches of river would be found suitable for designation under the Wild and Scenic Rivers Act." (A)

USDI Bureau of Land Management. 1992d. Roseburg District resource management plan and environmental impact statement. Roseburg, OR: U.S. Department of the Interior, Bureau of Land Management, Region 1.2 vol. ± 4 maps.

"Abstract: This draft resource management plan/environmental impact statement addresses resource management on 419,400 acres of Federal land administered by the Bureau of Land Management in its Roseburg District. Seven alternatives including no action (no change in the existing plan) are analyzed. These alternatives range from management of timber and other resources vital to the economy, to management and enhancement of values such as biological diversity, spotted owl habitat, old-growth

forests, recreation opportunities, and scenic resources. The preferred alternative would provide a planned annual timber sale level of 15.3 mmcf (105 mmbf), while meeting established water quality criteria in all watersheds. Also, 91,700 acres of old-growth forest would be retained at the end of the first decade; three additional areas of critical environmental concern would be designated; and no river segments would be found suitable for designation under the Wild and Scenic Rivers Act." (A)

USDI Bureau of Land Management. 1992e. Salem District resource management plan and environmental impact statement. Salem, OR: U.S. Department of the Interior, Bureau of Land Management, Region 1.2 vol. ± 4 maps.

"Abstract: This draft resource management plan/environmental impact statement addresses resource management on 393,600 acres of Federal land and 27,800 acres of reserved mineral estate administered by the Bureau of Land Management in its Salem District. Seven alternatives including no action (no change in the existing plan) are analyzed. These alternatives range from management of timber and other resources vital to the economy, to management and enhancement of values such as biological diversity, spotted owl habitat, old-growth forests, recreation opportunities, and scenic resources. The preferred alternative would provide a planned annual timber sale level of 21.5 mmcf (136.5 mmbf), while meeting established water quality criteria in all watersheds. Also, 28,000 acres of old-growth forest would be retained at the end of the first decade; seven additional areas of critical environmental concern would be designated; and two river segments would be found suitable for designation under the Wild and Scenic Rivers Act. " (A)

USDI Fish and Wildlife Service. 1992f. Endangered and threatened wildlife and plants: determination of critical habitat for the northern spotted owl; final rule. Washington, DC: Federal Register. 50(17): 1795-1838.

"The Fish and Wildlife Service (Service) designates critical habitat for the northern spotted owl (*Strix occidentalis caurina*), a subspecies Federally listed as threatened under the Endangered Species Act of 1973, as amended (Act). The northern spotted owl, referred to herein as spotted owl or owl, is a forest bird that inhabits coniferous and mixed conifer-hardwood forests over a range that extends from southwestern British Columbia through western Washington western Oregon, and northwestern California south to San Francisco Bay."

"This critical habitat designation provides additional protection requirements under section 7 of the Act with regard to activities that are funded, authorized, or carried out by a Federal agency. As required by section 4 of the Act, the Service considered the economic and other relevant impacts prior to making a final decision on the size and scope of critical habitat. The Service excluded some areas from designation due to economic and other relevant information. Final critical habitat units are designated solely on Federal lands." (A)

USDI Fish and Wildlife Service. 1992g. Protocol for surveying proposed management activities that may impact northern spotted owls. trey. 2nd ed. Portland, OR: U.S. Department of the Interior, Fish and Wildlife Service, Region 1. 17 p.

"The enclosed protocol was designed for surveying areas where Federal or non-Federal activities may remove or modify northern spotted owl habitat. The U.S. Fish and Wildlife Service (Service) endorses the use of this protocol for gathering information spotted owl occupancy in proposed project areas for assessing affects of the proposed actions. Note that any information on owl presence within and/or adjacent to the proposed planning or activity areas is important, even if it does not meet the guidelines described below. However, if the only information available for a particular activity was acquired through less intensive surveys, the Service must conservatively assess (i.e. worst-case analysis) the impacts of the action on northern spotted owls. It is always useful to document reasons for not adhering to the recommended protocol."

"This protocol is based on several existing protocols and, when implemented, should serve two primary purposes: (1) provide adequate coverage and assessment of the area for the presence of spotted owls, and (2) ensure a high probability of locating resident spotted owls and identifying owl territories that may be affected by a proposed management activity, thereby minimizing the potential for unauthorized incidental take. It is not appropriate to use this protocol to monitor yearly trends of spotted owls or for many other research applications."

"In this document, management activities are defined as those activities which may impact northern spotted owls. The most common activity is harvest or modification of spotted owl habitat. Also included under management activities are various types of disturbance not necessarily associated with timber harvest activities."

"This protocol was peer-reviewed by scientists, biologists, and managers who work on various issues pertinent to the ecology and management of northern spotted owls." (A)

Zabel, C.J.; Steger, G.N.; McKelvey, K.S., [and others]. 1992. Home-range size and habitat-use patterns of California spotted owls in the Sierra Nevada. Gen. Tech. Rep. PSW-GTR-133. U.S. Department of Agriculture, Forest Service. 141-155 p.

"Estimates of home range size among California spotted owls are extremely variable. An~ available data indicate that they are smallest in habitats at relatively low elevations that are dominated by hardwoods, intermediate in size in conifer forests in the central Sierra Nevada, and largest in true fir forests in the northern Sierra Nevada." (A)

Anderson, D.R.; Burnham, K.P. 1992. Model building and statistical inferences for adult female northern spotted owls. Proceedings of the 62nd annum meeting of the Cooper Ornithological Society symposium; 1992 June 22-28; Seattle, WA.

"Inference concerning population parameters of the northern spotted owl from capture-recapture data rests on the proper analysis of multiple data sets. The primary methodological issue is one of intense model building and model selection. Given a model, maximum likelihood provides a framework for optimal inference, at least for large samples."

"This paper stresses the importance of a global model for the analysis of capture-recapture data, Akakie's Information Criterion (AIC) provides a useful method for proper selection within the Principle of Parsimony. Goodness-of-fit must be evaluated

and quasi-likelihood methods are often used to obtain good estimates of sampling variances and covariances."

"An example is given for the northern spotted owl whereby 64 interrelated models are considered for the analysis of female data collected on five large study areas. The paper emphasizes analysis philosophy, model selection and statistical inference." (A)

Anthony, R.G.; Desimone, S.E.; Apfelbeck, K., [and others]. October 1991. Patterns of distribution and abundance of small mammals in old- and second-growth Douglas-fir forests in the Central Cascades. Pages 1-4 in: Wildlife habitat relationships in western Washington and Oregon. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Wildlife Ecology Team; annum report. 119 p.

"Study Objective(s): a. Compare small mammal abundance in old- and second-growth Douglas-fir forests, b. Describe the population dynamics of flying squirrels in old-growth Douglas-fir forests, c. Relate spotted owl reproduction to prey abundance, d. Collaborate with other researchers in the spotted owl RDR, A Program in synthesizing the results of the owl prey ecology studies across the Pacific Northwest." (A)

Anthony, R.G. 1992. Single-species versus ecosystem management: lessons for the future. Raptor Research Foundation 1992 annual meeting: Proceedings of a spotted owl symposium; 1992 November 11-15; Bellevue, WA.

"The spotted owl/old-growth issue has often been portrayed by the news media as owls versus people or jobs versus conservation of older coniferous forests. Actually, the spotted owl serves as an indicator species for late-successional forests to many environmentalists and managers. However, we know from basic ecological principles that different species occupy different ecological niches, therefore a single species can not possibly represent all the requirements of a host of other species. Such is true for the spotted owl."

"The Northern Spotted Owl Recovery Team was charged with considering other species and older-forest ecosystems in developing a recovery plan for the northern spotted owl in fulfilling this charge, we emphasized species that were listed Federally as threatened of endangered, candidates for Federal listing, state sensitive or species of special concern, and those associated with older forests. A list of 3S0+ species of plants and animals that occur within the range of the northern spotted owl was assembled. This list is comprised of 24 species of birds, 18 mammals, 26 amphibians and reptiles, 28 fish, 58 mollusks, 59 arthropods, 144 vascular plants, and 8 fungi and lichens. Five species are listed Federally as threatened or endangered, and 155 species are candidates for Federal listing. At the state level, over 100 species are listed as threatened or endangered, or designated as sensitive or species of special concern. More than 100 species are narrowly or broadly endemic to the Pacific Northwest and 190+ are associated with older forests. This effort also substantiated the importance of riparian ecosystems as approximately one third (130+) of the species are associated with riparian areas. In addition, the species of fish include approximately 800 stocks that are considered at risk and may become candidates for listing. Eighteen priority species were identified, of which the marbled murrelet and the numerous fish stocks were considered the highest priority."

"Information on the distribution, biology, and habitat relationships of the priority species and the ecology of riparian ecosystem were used to influence the location of some of the conservation areas for the owl. However, the extent to which this exercise could be carried out was influenced by economics and the preponderance of non-biologists on the recovery team. Consequently, the recovery plan for the northern spotted owl can not be portrayed as a conservation plan for late-successional forests in the Pacific Northwest." (A)

Bart, J.; Holthausen, R. 1992. Listing, critical habitat designation, and development of the northern spotted owl recovery plan. Raptor Research Foundation 1992 annual meeting: Proceedings of a spotted owl symposium; 1992 November 11~15; Bellevue, WA.

"The northern spotted owl (Strix occidentalis caurina) was listed as a threatened species by the U.S. Fish and Wildlife Service in 1990. Following the listing, the Fish and Wildlife Service, acting under court order, designated critical habitat for the species."

"Concurrently, the Department of the Interior named a team to begin work on a Recovery Plan for northern spotted owls. This Recovery Plan was published as a draft in May 1992, and a final is expected in early 1993. The basic principles underlying the Plan are based on the 1990 report of the interagency Scientific Committee. It recommends the establishment of 196 Designated Conservation Area (DCAs) on Federal lands, and contains guidelines for silviculture and salvage operations within those Designated Conservation Areas. It also contains a series of recommendations to provide dispersal habitat in the Federal forest matrix between Designated Conservation Areas. It recognizes the contribution that can be made to recovery by private lands, and suggests ways for the contribution to be made more effective."

"Major issues that must be dealt with before publication of the final Plan includes: (1) consideration of demographic data which indicate an accelerating decline in the spotted owl population; (2) a review of models that might be used to evaluate the Recovery Plan and other options; and (3) a detailed description of the procedures that could be used to continually update the Plan based on new information. Success of the final Plan will depend on close coordination among Federal and state agencies." (A)

Buchanan, J.B.; Irwin, L.L. 1992. Variation in spotted owl nest site characteristics within the Wenatchee National Forest. Raptor Research Foundation 1992 annual meeting: Proceedings of a spotted owl symposium; 1992 November 11-15; Bellevue, WA.

"Spotted Owls (5trix occidentals caurina) nest in a broad range of forest stand conditions in the Wenatchee National Forest (WNF). Nearly half of the known nests occur in evenaged patches or stands 65-135 years old, and 21 percent of the nest sites were partially harvested several decades prior to our study. A predictive model developed to distinguish between nest and random sites at the stand level correctly identified 70 percent of the study sites. Diagnostic evaluation of the model indicated that the low classification rate reflected variation in habitat conditions with the WN F. To identify factors that could improve the model, we developed pairs of predictive models based on north- and south-facing slopes and on sites with and without evidence of previous partial harvest. The aspect and harvest models correctly classified 65-93 percent of the sites; however, none of the models were stable, as determined by cross-validation. Following

this we examined variation among nest sites within the WN F by comparing mean habitat values among 4 of the 5 Fire Management Analysis Zones (FMAZ) identified by the Forest Service for fire control purposes. The FMAZ areas were defined primarily in terms of topography, annual precipitation, and estimates of fuel loading and fire frequency. We found significant differences among the FMAZ for nearly half of the 60 habitat features we compared at nest sites, it may be possible to develop predictive models within each FMAZ using the original or other models. For example, the harvest model (with a larger sample) may be useful to researchers and managers who wish to conduct adaptive management experiments in stands managed for timer and/or fire protection. The use of such models within the FMAZ framework would likely be more powerful and allow better management throughout the region." (A)

Carey, A.; Biswell, B.; Brown, B., [and others]. October 1991. Patterns of spotted owl prey abundance in the Oregon Coast Ranges and western Washington. Pages 5-9 in: Wildlife habitat relationships in western Washington and Oregon. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Wildlife Ecology Team; annual report.

"Study Objective(s): a. Determine pattern of abundance of flying squirrels and woodrats in the types of forest stands found within the home ranges of spotted owls, particularly young Douglas-fir stands, old-growth Douglas-fir stands, and riparian hardwood or mixed hardwood and conifer stands, b. Determine structural features of the environment that account for significant amounts of the variation in flying squirrel and woodrat abundance within and among stands, c. Determine seasonal changes (fall vs. spring) in patterns of flying squirrel and woodrat abundance, d. Relate flying squirrel patterns of abundance to spotted owl foraging (as measured in a companion study) and relative abundance to spotted owl reproductive efforts (as measured in a companion study of owl demographics), e. Determine the patterns of abundance exhibited by ancillary prey species, especially deer mice and red-backed voles, f. Explore additional techniques to study the abundance and habitat use patterns of bushy-tailed and dusky-footed woodrats." (A)

Carey, A.B.; Miller, R.E.; Wunder, L., [and others]. October 1991. Experimental manipulation of managed stands to provide habitat for spotted owls and to enhance plant and animal diversity. Pages 10-11 in: Wildlife habitat relationships in western Washington and Oregon. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Wildlife Ecology Team; annum report. 119 p.

"Study Objective(s): a. Determine the feasibility of accelerating development of spotted owl habitat in managed forests, by increasing plant and animal diversity, and the abundance of spotted owl prey. b. Determine if populations of flying squirrels can be increased by increasing the number of cavities available, c. Determine if thinning can increase the abundance and diversity of food available to flying squirrels." (A)

Carey, A. 1992. Prey ecology and northern spotted owl diet. Raptor Research Foundation 1992 annum meeting: Proceedings of a spotted owl symposium; 1992 November 11-15; Bellevue, WA.

"Mammals constitute 90 percent of the spotted owl's diet; diets vary locally and

seasonally, but are consistent annually at larger geographic scales. *Glaucomyx sabrinus* (GLSA) is the single most important prey, accounting for 16-46 percent of the prey items consumed. GLSA is the only species to occur with frequency of >15 percent in all parts of the owl's range. In western hemlock and Douglas-fir forests, GLSA constitutes 47-58 percent of the biomass consumed. In fall and winter, GLSA comprises 60-72 percent of the biomass consumed. *Peromyscus* spp. and juvenile lagomorphs are 12-18 percent and 7 percent respectively, of summer diets, in mixed-conifer forests in the southern part of the owl's range, *Neotoma fuscipes* may be up to 70 percent of the biomass consumed, and GLSA as little as 14 percent. Other species (percent items consumed) are important locally: *Phenacomys longicaudus* (0-25 percent), *Neotoma cinerea* (0-15 percent), *Lepus americanus* (0-10 percent), *Clethrionomys* spp. (0-21 percent), Peromyscus spp. (5-31 percent), and *Thomamys mazama* (0-10 percent). There appears to be definite selection of prey based on (1) nocturnality - otherwise *Tamiasciurus* and *Tanias* would be common prey; (2) mass of 100-400g-aduh - lagomorphs are generally not taken and shrews, voles, and mice are low in frequency in diets relative to their abundance in forest; (3) arboreality - GLSA is arboreal, Neotoma spp. are semi-arboreal, and *Phenacomys longicaudus* (27 g) is strictly arboreal and more frequently taken when available than the semi-arboreal Peromyscus (20 g) and the terrestrial Clethrionomys (23 g); arboreality probably relates to detectability of the prey; and (4) social behavior - colonial N. f*uscipels* is locally concentrated in large numbers whereas the funle-harem N. *cinerea* is locally concentrated in small numbers; P. *longicaudus* is also colonial, whereas *Peromyscus, Clethrionomy*, and GLSA are not. These characteristics seem to outweigh abundance: GLSA densities (mean number per ha -I- standard error) in old growth are 0.21 ± 0.09 in the North Cascades of Washington, 0.5 ± 0.2 on the Olympic Peninsula, 2.3 ± 0.3 in the Western Cascades in Oregon, and 1.9 ± 0.1 in the Oregon Coast Ranges and Klamath Mountains, yet GLSA constitutes a greater percentage of the diet in Washington than in southwestern Oregon. But GLSA is probably the most consistently available nocturnal species weighing 100-300g in old-growth western hemlock and Douglas-fir forests. GLSA reaches its highest densities in old growth (3.7/ha) and is more than twice as abundant in old forest than other types in Washington and southwestern Oregon. The amount of old forest encompassed by spotted owls in their home ranges reflects the biomass of the medium-sized prey (GLSA and Neotoma spp.) in old growth. Spotted owls can depress GLSA population densities by almost 50 percent in areas intensively used for foraging." (A)

Diller, L.V. 1992. A private landowner's habitat conservation plan: the Simpson Timber Company HCP. Raptor Research Foundation 1992 annual meeting: Proceedings of a spotted owl symposium; 1992 November 11-15; Bellevue, WA.

"In July, 1990 the listing of the northern spotted owl (*Strix occidentalis caurina*) as threatened under the Federal Endangered Species Act prohibited "taking" of the species. In response to this listing, the California Board of Forestry adopted regulations to avoid a take of the owls. Among other things, these regulations required retention of 500 acres of spotted owl habitat within a 985-acre (0.7-mile) circle centered on a known pair. High densities of owls (gross density approximately 1 pair/1000 acres) in and adjacent to a situation in which continuing timber harvest and avoiding a take were not possible. This prompted Simpson to seek a permit from the U.S. Fish and Wildlife Service to allow take of spotted owls incidental to its timber harvest operations. As part of the permit application, the company draft a Habitat Conservation Plan (HCP) for the owl."

"Intensive surveys and analysis of nesting sites and stands indicated that spotted owls on and adjacent to Simpson property were recolonizing and successfully reproducing in stands as early as 35-45 years following harvest. The results of these studies were used to project future owl habitat and develop the major premise of the HCP: that even when timber harvest was accounted for, potential owl habitat would more than double over a 30-year planning period. In addition, the plan included several other conservation strategies including setting aside 39 areas totalling 13,000 acres where timber harvest would not occur, establishing a 35,000 acre 'Special Management Area' that would maintain at least 20 pairs of owls and where 'no take' of owls would occur, continuing the spotted owl research program, and managing stands to accelerate the development of future owl habitat." (A)

Dippon, D. 1992. Linking the BLM's RMP planning process with a spatial demographics model for the northern spotted owl. 26 p.

"While the Noon/McKelvey Owl Model is at the heart of the BLM's analysis of alternatives, the development of the necessary input data can be just as important to the model's simulations. Spatially accurate renditions of the expected vegetation dynamics associated with any given plan must be projected if the model is to perform properly."

"This information memorandum will focus on the procedure used to project the pattern of habitat change as input to the Noon/McKelvey Owl Model used in the BLM's analysis of effects." (A)

Folliard, L.B.; Diller, L.V.; Reese, K.P. 1992. Occurrence and nesting habitat of northern spotted owls in managed young-growth forests in northwestern California. Raptor Research Foundation 1992 annum meeting: Proceedings of a spotted owl symposium; 1992 November 11-15; Bellevue, WA.

"From 1989 through 1992, approximately 120,000 ha of managed, young-growth forests were surveyed for northern spotted owls (Strix occidentalis caurina) in coastal northern California. To date, 169 owl sites have been identified and over 500 birds banded (including 197 juveniles). The relative density of owl sites was greatly influenced the amount of acreage of forest greater than 45 years old. The region with the highest density (about 0.46 owl sites/km 2) had 37 percent of the landscape in this older age class. Habitat analysis of 60 nesting pairs revealed that owls nested in stands that varied from pure conifer to those dominated by hardwoods, with no apparent selection for a particular cover type. The median nest stand age was 59 years, with 83 percent of pairs nesting in stands 35-80 years old. On average, Conifer nest stands were dominated by trees 53-90 cm dbh in size. Although the density was low, there was a higher density of large (greater than 90 cm dbh) conifers (P - 0.010) in nest stands in comparison with randomly selected stands. In general, hardwood nest stands had smaller trees than conifer stands. In comparison with old-growth forest structure, the most distinctive difference was the low density of trees greater than 90 cm dbh in these managed stands. Favorable conditions in the redwood (*Sequoia sempervirens*)/Douglas-fir (*Pseudotsuga menziesii*) coastal region such as rapid tree growth rates and an abundant prey base, make these second-growth forests suitable spotted owl habitat at an early age. Development of spotted owl habitat in this region can occur at an accelerated rate following timber harvest in comparison with other regions of the species' range." (A)

Forsman, E.D. 1992a. Demographic studies of northern spotted owls. Raptor Research Foundation 1992 annum meeting: Proceedings of a spotted owl symposium; 1992 November 11-15; Bellevue, WA.

"Between 1985 and 1987, 5 different demographic studies were initiated to determine population parameters of northern spotted owls. These studies include the Willow Creek Study in northwestern California, Medford BLM Study in southwestern Oregon, Roseburg BLM and H. J. Andrews Studies in western Oregon, and the Olympic Peninsula Study in western Washington. All five studies used mark-recapture techniques to assess age and sex-specific survival rates. Fecundity was assessed by counting the numbers of young that left the nest. Population growth rates (lambda) were calculated based on birth and death rates of females." (A)

"Estimates of lambda indicated that populations in all 5 study areas were declining. Furthermore, a meta-analysis in which estimates form all 5 areas were examined together, indicated a decreasing trend in annual adult female survival. This suggested that the rate of population decline was accelerating."

"Although the results of these analysis are alarming, I believe that they should be viewed with caution. A number of potential biases exist that could make things look worse than they really are. Probably the biggest concern is that survival rates may be underestimated if significant undetected emigration occurs. Emigration is probably most problematic with respect to juvenile survival estimates because juveniles disperse

considerable distances from their natal sites. It is also likely that some emigration of adults and subadults occurs as well.

"To better understand population trends of spotted owls, we need more years of data and we need to develop methods to test the magnitude of possible biases in mark-recapture estimates. One way to determine the extent of undetected emigration is to compare survival estimates from radio-marked and color-banded samples. This will be very expensive and time-consuming as it will involve radio-marking large samples of owls." (A)

Forsman, E.D. 1992b. Life history characteristics of the spotted owl. Proceedings of the 62nd annual meeting of the Cooper Ornithological Society symposium; 1992 June 22-28; Seattle, WA.

"The Spotted Owl is a medium-sized Strigid that occupies forested areas along the Pacific Coast, the southwestern United States, and Mexico. This paper describes the life history characteristics of the species, focusing primarily on the northern subspecies, which occupies coniferous forests from southwestern British Columbia south to northwestern California."

"Spotted Owls are unique in that they occupy very large home ranges, and show little fear of humans. They nest primarily in trees in either large cavities or on platforms. They typically lay 2 eggs (range -- 1-4). Nesting is sporadic, and is not synchronous across the range. The young leave the nest in May or early June, and are fed by the adults until August or September. The young disperse in the fall (September-November). Most do not disperse more than 40 kin, although distances up to 120 km have been recorded. Subadults may breed at 1 year of age, although most do not breed until they are 2-3 years old."

"The diet of the northern spotted owl is dominated by medium-sized arboreal mammals, especially Flying Squirrels and Woodrats. Other prey include a variety of small mammals, birds, and insects." (A)

Forsman, E.D.; Forson, R.; Grayson, S., [and others]. October 1991a. Habitat use and home range characteristics of spotted owls on the Olympic Peninsula, Washington. Pages 12-16 in: Wildlife habitat relationships in western Washington and Oregon. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Wildlife Ecology Team; annual report. 119 p.

"Study Objective(s): a. Determine characteristics of spotted owl home ranges, including total area, seasonal changes, and amount of overlap between paired individuals and their neighbors, b. Compare home range characteristics of nesting and non-nesting owls. c. Describe the diet of the radio-tagged owls. d. Determine types of vegetation structure selected for foraging and roosting, e. Describe foraging behavior (frequency of foraging by type of stand, distance traveled to forage, etc.) and changes in foraging behavior with breeding status and season, f. Explore the usefulness of a variety of home range and habitat selection models for evaluating home ranges and habitat use. g. Relate owl use of home range and stand types to information collected in prey base studies." (A)

Forsman, E.D.; Forson, R.; Hearty, M.; Loschl, P. October 1991b. Demographic characteristics of spotted owls on the Siuslaw National Forest. Pages 45-54 in: Wildlife habitat relationships in western Washington and Oregon. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Wildlife Ecology Team; annual report. 119 p.

"Study Objective(s): Elucidate the population ecology of the spotted owl on the Siuslaw National Forest, to include population age structure, and age and sex specific birth and death rates." (A)

Forsman, E.D.; Lowell, R.; Maurice, K., [and others]. October 1991c. Demographic characteristics of spotted owls on the Olympic Peninsula, Washington, 1987-1991. Pages 17-23 in: Wildlife habitat relationships in western Washington and Oregon. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Wildlife Ecology Team; annual report. l19p.

"Study Objective(s): a. Elucidate the population ecology of the spotted owl on the Olympic Peninsula, to include population age structure, and age specific birth, death, and reproductive rates, b. Compare survival and reproductive rates of color-banded and radio-tagged owls." (A)

Forsman, E.D.; Maurice, K.; Otto, I., [and others]. 1992. Demography of spotted owls on the Olympic Peninsula, Washington. Proceedings of the 62nd annual meeting of the Cooper Ornithological Society symposium; 1992 June 22-28; Seattle, WA.

"A capture-recapture study of spotted owls was conducted on the Olympic Peninsula in 1987-1991. The study population included owls located on commercial forest lands, wilderness areas, and the Olympic National Park. The sample of owls marked during the study period included 182 adults (89 males, 93 females), 39 subadults (13 females, males) and 156 juveniles. Sex and age-specific models indicated no significant differences in male and female survival rates. Analysis of time-specific models indicated little annual variation in survival rates, and a slight time effect on recapture probabilities. The selected time-specific model (0, Pt) produced survival rates of 0.8820 (s.e. -- 0.033) for females, 0.9351 (s.e. = 0.02410) for males, and 0.9124 (s.e. -- 0.0197) for both sexes combined. Juvenile survival rates could not be estimated because of low recapture rates. Average fecundity was 0.344 (s.e. = 0.086) for adult females and 0.134 (s.e. = 0.009) for subadult females. Mean life span for adults was 10.6 years, conditional on surviving to age 1."

"Estimated population growth rate (A) was 0.-. This estimate was based on the assumption that juvenile survival rates were comparable to rates in our other study area in Oregon, where , = 0.-, s.e. = 0.-) This estimate also assumed that subadults and adults had similar survival rates. Although our analysis indicated a declining population, we are concerned that our estimate of the rate of decline may be biased. Until we obtain better estimates of juvenile and subadult survival rates, and assess the impact of emigration on adult and subadult survival rates, we feel that our analysis should only be used to indicate the direction of the population growth rate rather than an exact estimate." (A)

Forsman, E.D.; Reid, J.; Horn, R., [and others]. October 1991d. Demographic characteristics of spotted owls on the Roseburg District of the Bureau of Land Management, Roseburg, Oregon: 1985-1991. Pages 33-44 in: Wildlife habitat relationships in western Washington and Oregon. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Wildlife Ecology Team; annual report. 119 p.

> **"Study Objectives: a. Elucidate the population ecology of the spotted owl in the Oregon Coast range, to include population age structure, and age specific birth; death, and reproductive rates, b. Compare survival and reproductive rates of color-banded and radio-marked owls." (A)**

Forsman, E.D.; Sovern, S.; Taylor, M., [and others]. October 1991e. Demography of spotted owls on the east slope of the Cascade Range, Washington. Pages 27-32 in: Wildlife habitat relationships in western Washington and Oregon. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Wildlife Ecology Team; annual report. 119 p.

> **"Study Objective(s): Determine demographic characteristics of spotted owls in forests on the east slope of the Cascade Range." (A)**

> **Forsman, E.D.; Sovern, S.; Taylor, M., [and others]. October 1991f. Habitat use and home range characteristics of spotted owls on the east slope of the Cascade Range, Washington. Pages 22-26 in: Wildlife habitat relationships in western Washington and Oregon. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Wildlife Ecology Team; annual report. 119 p.**

> **"Study Objective(s): a. Determine characteristics of spotted owl home ranges in forests on the east slope of the Cascade Range, including home range area, seasonal changes, and amount of overlap between paired individuals and their neighbors, b. Determine forest types selected for foraging and roosting, c. Describe the diet of radio-tagged owls, to include seasonal changes in diet." (A)**

Forsman, E.D.; Sovern, S.; Taylor, M., [and others]. October 1991g. Demography of spotted owls on the east slope of the Cascade Range, Washington. Pages 27-32 in: Wildlife habitat relationships in western Washington and Oregon. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Wildlife Ecology Team; annual report. 119 p.

> **"Study Objective(s): Determine demographic characteristics of spotted owls in forests on the east slope of the Cascade Range." (A)**

Franklin, A.B. 1992a. Future direction in spotted owl population biology. Proceedings of the 62nd annual meeting of the Cooper Ornithological Society symposium; 1992 June 22-28; Seattle, WA.

> **"Sampling of northern spotted owl populations has increased substanstially since the inception of the 5 study areas discussed in this symposium. It is critical that future study designs incorporate the lessons learned from previous research. We discuss considerations in designing studies, the need for integrating demography and population ecology, and the need for understanding how spotted owl populations are regulated. We also discuss important features of spotted owl population biology which we feel should be emphasized in future studies." (A)**

Franklin, A.B.; Ward, J.P. 1992b. Density of northern spotted owls. Raptor Research Foundation 1992 annual meeting: Proceedings of a spotted owl symposium; 1992 November 11-15; Bellevue, WA.

"Density is a useful measure for estimating population size, monitoring spatial and temporal population trends, and examining mechanisms of population regulation. We examine density estimates for northern spotted owls from 10 study areas on public lands distributed throughout northern California, Oregon and Washington. Density was estimated based on banded individuals on these study areas which ranged from 300 to 1000 km2 in size. Densities on individual study areas were measured over periods ranging from 2 to 8 years. Crude density (number of owls/km 2 of total area) ranged from 0.067 to 0.250 owls/km 2. We tested hypotheses concerning temporal and spatial trends in density estimates. Trends in density appeared stable while there appeared to be geographic differences. We also evaluated density estimates from public lands with those form private land managed for timber production. We discuss the problems inherent in estimating density and the utility of density in monitoring programs. We also discuss considerations for estimating density such as sampling design, study area size, and survey effort." (A)

Franklin, A.B.; Ward, J.P.; Gutierrez, R.J. 1992c. Demography of spotted owls in northwestern California. Proceedings of the 62nd annual meeting of the Cooper Ornithological Society symposium; 1992 June 22-28; Seattle, WA.

"A central question in management of northern spotted owl populations concerns the current stability of these populations. We tested the null hypothesis that local and regional populations are stable by 1) estimating age- and sex-specific survival and fecundity rates, 2) incorporating these estimates in a modified Leslie matrix to estimate the finite rate of population change (λ) and 3) testing against population stability (λ = 1). Based on this analysis, we found that females were significantly declining (λ = 0.9146, s.e.= 0.0374) whereas males were not (λ = 0.9938, s.e. = 0.0472). further examined demographic parameters in terms of factors such as age-structure and movements to evaluate whether key parameters such as juvenile and adult survival were adequately estimated." (A)

Fredrickson, R.J.; Seaman, D.E.; Moorehead, B.B.; Houston, D.B. 1992. Northern spotted owl inventory and monitoring in Olympic National Park. Port Angeles, WA: U.S Department of the interior, National Park Service, Olympic National Park; progress report. 7 p.

"Progress is reported on northern spotted owl (*Strix occidentalis caurina*) inventory and monitoring in Olympic National Park during 1992. Field work was completed in Year 1 of a 3-Year research project to estimate spotted owl densities in the park. Intensive surveys were conducted by a crew of 17 persons on off-trail transects that were established across 5 randomly located census blocks (totaling 4947 ha) in the park interior. Thirty-four "historic" sites where owls had previously been banded elsewhere in the park were also monitored."

"A total of 96 spotted owls were detected, including 28 pairs, 15 single birds, and 29 juveniles. Forty owls were also newly banded. Eight owl pairs, 5 single birds and 4 juveniles were found within the census blocks. Crude density estimates in the census blocks suggested a mean pair density of 0.18 owl pairs/kin 2 and a mean total density (pairs and single birds) of 0.49 owls/km^2. Such estimates are preliminary, representing

only 1 year of data and a portion of the habitat that will be surveyed during the project. A reproduction rate of 0.50 female offspring per adult or subadult female spotted owl was estimated for 28 pairs that were located. Twenty-two barred owls (*S. varia*) were also detected, including 8 birds in the census blocks."

"A separate technical report is also in preparation for a peer-review of the project's research design and methods by an independent panel of experienced research scientists in December 1992. A number of timely administrative recommendations are proposed for future project work (see pp. 11-12)." (A)

Ganey, J.L.; Balda, R.P. 1992. Habitat selection by Mexican spotted owls in northern Arizona. Raptor Research Foundation 1992 annual meeting: Proceedings of a spotted owl symposium; 1992 November 11-i5; Bellevue, WA.

"Although the Spotted Owl (*Strix occidentalis caurina*) has been the object of considerable attention in the Pacific Northwest, little is known about the habitat requirements of the Mexican Spotted Owl (*S.o. lucida*). We compared use of broad habitat types to availability of those types within the home ranges of eight radio-tagged Mexican Spotted Owls in northern Arizona. When all habitat types were considered, no owls used these types in proportion to availability. Use patterns differed among individuals and by activity type. All owls roosted primarily in virgin mixed-conifer and ponderosa pine (*Pinus ponderosa)* forests and less than expected in managed forests. Mature forests appear to be important to Spotted Owls in this region and different forest types may be used for different activities; Consequently, managers should retain virgin stands of both mixed-conifer and ponderosa pine forest where these owls occur, to provide both roosting and foraging habitat." (:A)

Hamer, T.E,; Forsman, E.D.; Fuchs, A.D.; Waters, M.L. 1992. Hybridization between barred and spotted owls. Raptor Research Foundation 1992 annual meeting: Proceedings of a spotted owl symposium; 1992 November 11-15; Bellevue, WA.

"We present the first records of interspecific hybridization between the Northern Barred Owl (*Strix varia varia*) and Northern Spotted Owls (:5. occidentalis caurina). Two hybrid owls in Washington and two in Oregon were confirmed during lg8g-92. One of the hybrids paired with a Barred Owl and produced young in 1990 and 1991. In addition, we confirmed the pairing of a female Barred Owl to a one-year-old male Spotted Owl, which produced at least one young in 1992. Hybrids were identified by their unique plumage, unusual vocalizations, and morphological measurements. All three adult hybrids had similar plumage characteristics and vocalizations. Body measurements of hybrids were intermediate between Barred and Spotted Owls, and sonograms of vocalizations displayed attributes of both species. Although genetic comparisons have not yet been conducted, we believe the three adult specimens we observed were all F1 crosses between Barred and Spotted Owls. Hybridization between these species and successful back-crossing by hybrids indicates that the designation of the Barred and Spotted Owl as a superspecies is appropriate." (A)

Hessburg, P.F.; Everett, R.L. 1992. Forest pathogens as catalysts of change in fire-restricted northern spotted owl landscapes. Wenatchee, WA" U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, Forestry Sciences Laboratory; draft report. 66 p.

"Conclusions. Landscape-level analysis, planning, and management are needed to

diminish the risk of catastrophic fire to spotted owl landscapes. This analysis and planning would strive to determine the amount of current risk, and the amount and distribution of stand-level fire risk that is manageable through time. Such analyses may well reveal that there is a greater probability of achieving the goal of maintaining viable owl populations in perpetuity when current owl population levels and current habitat abundance or quality are somewhat reduced. Future success in providing suitable habitat on a sustainable basis will likely be the result of interdisciplinary planning and active management of habitats as dynamic and movable locations within the forest, rather than the result of long term protection strategies." (A)

Irwin, L.L. March 1992. Relations among suitable habitat, fire management analysis zones, and demographic patterns of northern spotted owls on the east slope of the Cascade mountains, Washington. Corvallis, OR: NCASI. 11 p. Unpublished manuscript.

"Summary-. An updated analysis is reported for habitat conditions at 84 Spotted Owl sites where data on owl occupancy and reproduction are available." (A)

Irwin, L.L. 1992. Management activities on private timberlands and industry-supported research on northern spotted owls. Raptor Research Foundation 1992 annual meeting: Proceedings of a spotted owl symposium; 1992 November 11-15; Bellevue, WA.

"Private timberlands owners in the Pacific Northwest and northern California have developed various approaches to managing their lands relative to legal obligations and voluntary contributions for protecting the northern spotted owl as a Federally listed threatened species. Such activities depend upon the size and community of the private forests as well as the owner's objectives. Many private owners contract for annual surveys to locate owls, and some companies evaluate nest-site conditions and monitor reproduction success on their lands. Such activities may be used to schedule timber harvests to avoid locations with owls, or they may support development of habitat conservation plans or HCP's. For example, one company in northern California (Simpson) recently had and HCP approved by the Fish and Wildlife Service for operations on their lands. Another company maintains a computerized database of the status of all owls on their lands or on adjacent lands that may affect their operations. The same company is developing a (IS-based process for predicting other owl locations based upon conditions of known sites in managed forests. In many other cases, private companies survey their lands to determine if planned timber operations do not contain spotted owls. Several private companies support research on their lands to learn more about owl habitat requirements, and some have implemented case-history experiments with innovative forestry practices or special techniques (e.g. nest boxes) that may accommodate owls. In addition, a consortium of companies that purchase Federal timber support cooperative research on owl populations and habitat relationships. The goal of much of the industry supported research is to develop new technology that may support forest management alternatives that account for habitat needs of the owl while minimizing costs to wood production. Examples of topics that are being investigated in cooperation with Federal agencies will be presented." (A)

Irwin, L.L.; Martin, S.K.; Fleming, T.L.; Buchanan, J.B. March 1992. Demography of spotted owls in managed and unmanaged forests on the east slope of the Cascades Mountains, Washington. Corvallis, OR: NCASI; 1991 annual report. 34 p.

"We describe demographic information and habitat relations in 1990 and 1991 for

Northern Spotted Owls (*Strix occidentalis caurina)* on the eastern slope of the Cascade mountains in Washington. Over the 2 years 125 Spotted Owl sites were examined for occupancy and reproduction by owl pairs. Field crews located 93 pairs, 55 of which .... produced young. Of the 125 sites, 92 were surveyed sufficiently to determine occupancy by owls in both 1990 and 1991. Of the 92 sites, 84 were occupied by at least 1 owl (91.3 percent), and 71 were occupied by pairs (77.2 percent) at least 1 of the 2 years. Forty-five sites contained pairs both years, 19 of which (27 percent of all pairs) produced young both years. In 1990, 32 (55.2 percent) of the 58 pairs produced and fledged young (0.95 fledglings/pair), for a rate of 1.72 fledglings per reproductive pair, In 1991 44 (55 percent) of 80 pairs reproduced and fledged 71 young (0.89 fledglings/pair), for a rate of 1.61 fledglings per reproductive pair. Reproductive rates did not differ (P<0.05) between years or between managed forests and reserved locations (wilderness, National Parks, roadless area, etc.). Occupancy by a pair in one or both years was correlated with acreage of suitable habitat within 0.5-, 1.0-, 1.5-, and 2.1 miles of a nest or site-center. Reproductive success was not correlated with acreage of suitable habitat. Partial-correlation analysis revealed that the number of young produced declined with increasing latitude and with increasing distance from the crest of the Cascades, after effects of suitable habitat were removed. Field observations indicated that reproduction was generally highest on the Naches District, which is located in the southern- and western most part of the study area. Since 1989 field crews have banded 112 Spotted Owls, including 51 in 1991." (A)

Johnson, D.H. 1992. Predators, competitors, and mobsters: interspecific interactions involving northern spotted owls. Raptor Research Foundation 1992 annum meeting: Proceedings of a spotted owl symposium; 1992 November 11-15; Bellevue, WA.

"Interactions, between spotted owls and other wildlife species can be placed into four main groups: prey, predators, competitors, and species which are involved in mobbing behaviors ("mobsters"). This presentation offers a review of the latter three groups and offers results of my recently completed study on spotted owls, great horned owls, and forest landscape patterns in the Central Oregon Cascades."

"Predators on spotted owls include the great horned owl, goshawk, red-tailed hawk, and common raven. Although cooper's hawks have been observed in unsuccessful predation attempts, it seems possible that juvenile owls may be taken. Spotted owl mortality caused by avian predation is significant: a query of researchers has indicated that 40 percent of 91 adult/subadult and 25 percent of 60 juvenile radio-marked spotted owl deaths were attributable to avian predation; an additional 25 percent of adult/subadult and 37 percent of juvenile owls died of undetermined causes; it seems likely that avian predation was involved in at least some of these deaths as well."

"The primary competitor with spotted owls is the barred owl. The barred owl outcompetes spotted owls in several different ways. For example, barred owls are slightly heavier in body mass than spotted owls, take a wider variety of prey, have smaller home ranges which they defend more rigorously, and are more diurnal in their activity patterns. Barred owls seldom "lose" in territorial interactions with spotted owls. Barred owls have continued to expand their range in the Pacific Northwest and now can be found in several hundred locations in Washington, some 260 locations in Oregon, and 17 locations in California."

"A wide range of species have been observed to mob spotted owls. Mobbing species may

frequently make physical contact with spotted owls, ruffling the owl's feathers or, in some instances, knocking spotted owls from their perches. The following species have been observed to mob spotted owls: hermit thrush, Swainson's thrush, varied thrush, Cooper's hawk, black-capped and mountain chickadees, red-breasted nuthatch, rufous hummingbird, dark-eyed juncos, hermit warbler, golden-crowned kinglet, Steller's jay, gray jay, northern pygmy owl, and sharp-shinned hawk. The latter four species have more commonly been observed making physical contact with spotted owls."

"Great horned owls have been identified as the primary predator of spotted owls. As old-growth forests become fragmented through logging or natural processes, it is hypothesized that great horned owls becomes established and increase in numbers as this new niche is created. I conducted a nocturnal survey in 1989 and 1990 to locate great horned owls and spotted owls throughout the range of forest fragmentation levels in the Central Cascades of Oregon. Forest fragmentation levels ranged from landscapes (≥500 ha in size) containing intact stands of mature/old-growth forest (0 percent fragmentation) to landscapes containing younger stands with mature/old-growth forest (100 percent fragmentation). Six survey visits were made to each of 46g calling stations located along 28 roadside survey routes. Relative abundance for great horned owls and spotted owls was 0.069 and 0.139 owls/road km, respectively. Thirteen habitat/landscape variables within 500-ha circular landscape plots surrounding great horned owl, spotted owl, and random points were assessed. Significant differences existed between great horned owl and spotted owl landscapes for six variables: great horned owl landscapes contained more shrub/forb and shelterwood, less mature/old-growth and mature/old growth interior habitat, had a higher linear edge-to-mature/old growth area ratio, and were higher in elevation than spotted owl landscapes. The greatest number of great horned owl responses were associated with landscapes containing 10-20 percent old forest. Great horned owl responses generally declined with increasing amounts of old forest, and few (11 percent) great horned owls were detected in landscapes containing ≥ 70 percent old forest. The majority (62 percent) of spotted owls were detected within landscapes containing ≥ 60 percent old forest. Spotted owl responses generally declined with declining amounts of old forest and few (7 percent)spotted owls were detected within landscapes containing < 20 percent the variation in habitat pattern. We suggest the percentage of area in owl habitat, an isolation index, and the CV of patch area are useful measures of owl habitat pattern in spotted owl home ranges. Our results support the use of circular areas on the order of 3,200 ha for assessment of northern spotted owl habitat on the Olympic Peninsula." (A)

Lint, J.R. 1992. Inventorying and monitoring programs for northern spotted owls. Raptor Research Foundation 1992 annual meeting: Proceedings of a spotted owl symposium; 1992 November 11-15; Bellevue, WA.

"The annual inventory and monitoring of northern spotted owls has become a tradition for many wildlife biologists working for Federal and state agencies, universities, private consultants and private timber companies in the Pacific Northwest. Current survey programs are founded on the efforts of biologists that began the search for owls over two decades ago. Pioneer work by Eric Forsman in Oregon and Gordon Gould in California was instrumental in developing and refining standard survey techniques essential to conducting an inventory."

"In the 1970s, the Forest Service and Bureau of Land Management took the inventory lead by surveying for spotted owl occurrence on lands they administered. This provide d

the first operational extension of the work of Forsman and Gould. Through the 1970s and early 1980s, agency surveys focused on locating territorial owls to provide basic information for planning timber sales and making land use planning decisions. Survey work for the 1980s decade turned to monitoring owl response to land use decisions and incremental inventory of lands not previously surveyed. During this time period, the use of offered prey called "mousing" and the implementation of banding added new dimensions to the inventory and monitoring program."

"The listing of the spotted owl as a Federal threatened species in 1990 accentuated the importance of ongoing work and set in motion intensive efforts by government and private interests to inventory proposed timber sale areas to ensure compliance with the Endangered Species Act. Through inventory and monitoring, knowledge has been gained on the distribution, of owls, the relationship of occurrence to forest condition, dispersal movements and reproductive success. The programs, although productive, were not without shortcomings. Some local programs were keyed to finding owls, but lacked clear objectives and plans for data analysis. On a regional scale, poor coordination between agencies, lack of a central data storage and retrieval system and inconsistent formats for data recording were detractions. Fortunately these problems have been identified. The future affords the opportunity to learn form past experience and to establish a single, cooperative spotted owl inventory and monitoring program with common goals and objectives." (A)

McKelvey, K. June 1992. A spatially-explicit life-history simulator for the northern spotted owl. Arcata, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Experiment Station, Redwood Sciences Laboratory. 55 p.

"A spatial model was created to simulate the impact of forest management on populations of the northern spotted owl." (A)

McKelvey, K.; Noon, B.R.; Lamberson, R.H. 1992. [In press]. Conservation planning for species occupying fragmented landscapes: the case of the northern spotted owl. Arcata, CA: U.S Department of Agriculture, Forest Service, Pacific Southwest Experiment Station, Redwood Sciences Laboratory. 50 p.

"In the case of the northern spotted owl, concerns over the reduction and fragmentation of habitat were translated into a specific plan for the subspecies conservation (Thomas et al. 1990). In this paper we report some of the models that were used to guide decisions and thinking about the size and geometry of the proposed reserve design. We would like to emphasize that we are reporting only a small fraction of the studies and analyses that have been pursued to help maintain spotted owl populations, and that our results represent the synthesis of a massive team effort." (A)

Meslow, E.C. 1992. Northern spotted owl management, 1972-1992. Proceedings of the 62nd annual meeting of the Cooper Ornithological Society symposium; 1992 June 22-28; Seattle, WA.

"The top level administrators of the responsible Federal Agencies were made aware of the potential impact of the Northern Spotted Owl (5trix occidentalis caurina) on timber harvest in 1972. This paper traces the succession of spotted owl management plans/proposals that have evolved in the ensuing 20 years. Current direction continues to emphasize management of the spotted owl rather than the old-growth forests of the

Pacific Northwest for which it is the surrogate." (A)

Meslow, E.C.; Bruce, C.R.; Marcot, B. 1992. History of conservation planning for the northern spotted owl. Raptor Research Foundation 1992 annual meeting: Proceedings of a spotted owl symposium; 1992 November 11-15; Bellevue, WA.

"Conservation planning for the Northern Spotted Owl began in 1973 when the bird was given top priority by the newly formed Oregon Endangered Species Task Force. In 1977 the Task Force recommended maintaining 400 pairs on public lands in the state with 300 acres of old forest reserved per pair. Washington (1978) and California (1981) joined in conservation planning efforts. While the acreage reserved per owl pair increased with time, the operative paradigm remained focused on 1-3 pair management units until 1988. In 1989, the Interagency Spotted Owl Scientific Committee was jointly established by the directors of the four Federal wildlife/land managing agencies and charged with developing a scientifically credible Northern Spotted Owl management plan. The committee's product provided for a series of 20 pair conservation areas spaced to facilitate dispersal, with intervening "forest matrix" lands managed to provide habitat sufficient to support dispersal. The draft Northern Spotted Owl Recovery Plan utilizes the same basic construct." (A)

Meslow, E.C.; Forsman, E.D.; Swindle, K.A., [and others]. October 1991. The ecology of spotted owls on the Willamette National Forest: habitat use and demography. Pages 55-61 in: Wildlife habitat relationships in western Washington and Oregon. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Wildlife Ecology Team; annum report. 119 p.

"Study Objective(s): a. Elucidate the population biology of the spotted owl on portion of the Willamette National Forest by banding adult and fledgling owls, and documenting age-specific reproductive parameters, b. Determine home ranges and habitat use by spotted owls, using radio-telemetry, c. Determine the diet and prey preferences of spotted owls by collecting and analyzing regurgitated pellets, d. Determine patterns of abundance of primary prey species using live-trapping and other techniques as appropriate (see companion report on prey ecology study), e. Relate owl foraging behavior and reproduction to prey abundance, f. Collaborate with other researchers in the Spotted Owl RD&A Program in synthesizing the results of the owl ecology studies across the Pacific Northwest." (A)

Meslow, E.C.; Forsman, E.D.; Thrailkill, J., [and others]. October 1991. Demographic characteristics of spotted owls on the Eugene BLM District, Central Coast Range, Oregon. Pages 62-68 in: Wildlife habitat relationships in western Washington and Oregon. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Wildlife Ecology Team; annual report. 119 p.

"Study objective(s): a. Satisfy Eugene Bureau of Land Management District spotted owl monitoring needs (Coast Range province), b. Elucidate the population ecology F the spotted owl on the Eugene Bureau of Land Management District (Coast Range province), to include population age structure and age specific birth, death, and reproductive rates, c. Determine total density of adult/subadult spotted owls within an intensive study area." (A)

Meslow, E.C.; Wagner, It.; Bennett, G., [and others]. October 1991. Spotted owls in managed forests: identification and evaluation of non old-growth cover types for use in habitat management on the Medford District of the Bureau of Land Management, Oregon, Pages 69-75 in: Wildlife habitat relationships in western Washington and Oregon. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Wildlife Ecology Team; annual report. 119 p.

"Study Objective(s): a. Describe habitat use by spotted owls - especially the use of non old-growth cover types, b. Determine population parameters of spotted owls, including comparative density and annual rates for occupancy, turnover, and productivity, c. Identify and evaluate potential management options which utilize non old-growth cover types within spotted owl habitat management." (A)

Meyer, J.S.; Irwin, L.L.; Boyce, M.S. January 1992. Influence of habitat fragmentation on spotted owl site location, site occupancy, and reproductive status in western Oregon. Corvallis, OR: NCASI; progress report. 165 p.

"Our objectives were to (1) estimate several habitat indices, including measures of forest fragmentation, at known Spotted Owl sites; (2) test the null hypothesis of no difference between habitat indices at randomly-selected landscape locations; and (3) test the null hypothesis of zero correlation between habitat indices and occupancy or reproduction at Spotted Owl sites for which adequate occupancy surveys were conducted for 5 years from 1985 to 1989." (A)

Miller, G.; Forsman, E.D.; Johnson, D.H. 1992. Dispersal and survival of juvenile northern spotted owls. Raptor Research Foundation 1992 annual meeting: Proceedings of a spotted owl symposium; 1992 November 11-15; Bellevue, WA.

"With the Federal listing of the spotted owl as a threatened species, highlighted by the Interagency Scientific Committee's Conservation Strategy for the Northern Spotted Owl and the Spotted Owl Recovery Planning process, the importance of juvenile dispersal information has become much more apparent. Prior to 1982, information on the dispersal ecology of juvenile northern spotted owls was limited. Since that time, three general 'sources' of study can be identified that have addressed the dispersal topic. (1) In 1982, radio-telemetry studies, using back-pack transmitters, were initiated in Washington, Oregon and California to gather information on juvenile dispersal. Between 1982 and 198S, 6 juveniles in Washington, 32 in Oregon and 23 in California were followed during dispersal. A summary of first-year survival, distance dispersed, and habitat use is provided. (2) Between 1985 and 1987, intensive banding studies were initiated in Washington, Oregon and California, providing the opportunity to band several hundred juvenile spotted owls. A summary of dispersal distances and survival estimates obtained from the band return (resighting) data is also provided. (3) In 1991, a radio-telemetry study, using tail-mounted transmitters, was initiated in Oregon and Washington to provide additional information on juvenile survival estimates. Preliminary results from that study for 1991 and 1992 are reported. A comparison of the three sources of information is discussed."

"An overview of how all the information on juvenile dispersal and survival has been incorporated into the Interagency Scientific Committee's Conservation Strategy for the

Northern Spotted Owl and the Northern Spotted Owl Recovery Planning process is also discussed." (A)

Miller, G.S.; DeStefano, S. 1992a. Field and analysis methods for spotted owl demographic studies. Proceedings of the 62nd annual meeting of the Cooper Ornithological Society symposium; 1992 June 22-28; Seattle, WA.

"Spotted Owls were located on each study area using calling surveys (vocal imitations and playback) conducted both during the day and at night. Spotted owls were captured using a noose or snare pole and banded with USFWS lock-on bands and a colored plastic leg band. Reproductive status was determined by mousing the birds. Sites where spotted owls had been banded in previous years were resurveyed each year to confirm bands and band new birds. Capture history arrays of l's and O's were developed for all banded birds, where a 1 indicated that a marked bird was seen >1 times during the year and a 0 indicated that the individual was not observed for that year. Survival estimates and resighting probabilities were calculated using capture-recapture methodology. We used programs RELEASE and SURGE for data summarization, model selection and fit, and parameter estimation." (A)

Miller, G.S.; DeStefano, S.; Brown, M.T., [and others]. 1992b. Demography of spotted owls in the central Cascades, Oregon. Proceedings of the 62nd annual meeting of the Cooper Ornithological Society symposium; 1992 June 22-28; Seattle, WA.

"Demographics of the northern spotted owl were studied in the central Cascades of western Oregon between 1987 and 1991. A total of 358 individual owls were banded over the S-year period with yearly surveys conducted to re-sight marked birds. Re-sighting rates were high, especially for the adult age class. Mean fecundity for adult females was 0.30. Survival was higher for adults than juveniles and for adult males vs. adult females. The rate of change in territorial adult females/year was calculated, with lambda significantly less than 1. Population dynamics and the significance of the lambda calculation are discussed." (A)

Montgomery, C.A.; Brown, G.M.; Adams, D.M. 1992. The marginal cost of species preservation: the northern spotted owl. Missoula, MT: University of Montana, School of Forestry; draft. 35 p.

"Because species survival is not certain, the decision to "save " a species is not an all-or-nothing choice but rather a marginal one. The appropriate unit for both benefit and cost functions is like the likelihood of survival and the appropriate question is how certain we want to be of species survival. The intensity of the species preservation debate is also fired by strong equity concerns. We illustrate these points for the case of the northern spotted owl by constructing a marginal cost curve for its survival and by disaggregating welfare loss by region and by market level." (A)

Reid, J.A.; Forsman, E.D.; Lint, J.B. 1992. Demography of spotted owls in west central Oregon. Proceedings of the 62nd annual meeting of the Cooper Ornithological Society symposium; 1992 June 22-28; Seattle, WA.

"A capture-recapture study of northern spotted owls (*Strix occidentalis caurina*) began on the Roseburg District of the Bureau of Land Management in west-central Oregon in 1985. The study area is commercial forest land of alternating sections of Federal

and private ownership. The sample of marked owls included 469 adult/subadults (207 females, 262 males) and 239 juveniles. Sex and age specific models indicated similar survival rates of males and females. The preferred model produced a survival estimate of 0.857 (s.e.= 0.0211 for females and 0.846 (s.e. = 0.017) for males. Juvenile survival varied depending on the model used. The preferred model produced a juvenile survival estimate of 0.405 (s.e. = 0.136). There was no time effect on survival or recapture probabilities for either females or juveniles. The preferred model indicated a time dependence on survival rates for males. An average fecundity rate was 0.330 (s.e.= 0.039) for adult females and 0.094 (s.e. = 0.055) for subadult females. Mean lifespan for adults/subadults was 6.5 years contingent upon the individual reaching one year of age."

"Estimated population growth rate (lambda) was 0.0964 (s.e.= 0.037). This indicates a declining population of resident owls. However, the estimate of lambda is not significantly different from 1 (p = 0.168). Future years of study will provide more precise estimates." (A)

Rinkevich, S.E. 1992. Distribution and habitat characteristics of Mexican spotted owls in Zion National Park, Utah. Raptor Research Foundation 1992 annual meeting: Proceedings of a spotted owl symposium; 1992 November 11-15; Bellevue, WA.

"Distribution, habitat characteristics, and food habits of the Mexican spotted owl (*Strix occidentalis lucida*) were investigated in Zion National Park. Two hundred and twenty-nine surveys were conducted in canyon and plateau habitat between May-August 1989 and April-August 1990. I located owls in nine different locations; each owl was associated with narrow canyons, "hanging" canyons, and cliff sites. The minimum estimated density in Zion National Park was 0.02 owls/kin^2 in 1989 and 0.03/kin^2 in 1990. Spotted owls were widely distributed and coincident with discontinuous habitat within the park."

"I used stepwise discriminate analysis to examine the habitat differences between (1) observed owl microsites and available microsites and (2) observed owl canyon habitat and available canyon habitat. Spotted owl microsites had higher humidity, more vegetation strata, narrower canyon widths, and higher percentage of ground litter than available microsites. Habitat within owl use canyons had higher humidity and higher total snag basal area than available canyon habitats. Owls may be selecting canyon habitat not only for the structural habitat features but also for the microclimate. The presence of canyons and cliffs may provide necessary refuge from high daytime temperatures that occurred in the study area. Mexican spotted owls do not appear to depend on extensive stands of old-growth forests as do northern spotted owls (*S. occidentalis caurina*) because this type of habitat is lacking in Zion Park. Seventy-one prey items were identified from 60 pellets collected from two owl territories. Mammals comprised 99.9 percent of estimated biomass and 80.3 percent of the total diet composition. Bushy-tailed woodrats (Neotoma cinerea) were the primary prey taken by owls. They comprised 67.3 percent of the estimated biomass and 40.3 percent by frequency of the diet. Further studies are needed to investigate the habitat requirements of spotted owls in the northern region of its range." (A)

Rowland, M.J. 1992. Northern spotted owl litigation review. Raptor Research Foundation 1992 annual meeting: Proceedings of a spotted owl symposium; 1992 November 11-15; Bellevue, WA.

"Principal court cases affecting the northern spotted owl will be reviewed. These cases include: <u>Northern Spotted Owl v. Hodel</u>: A suit against the US Fish and Wildlife Service for failure to list the spotted owl under the Endangered Species Act (ESA) and failure designate critical habitat for the owl. The agency was ordered to reconsider its failure to list the owl, and the owl ultimately was listed. The court also ordered the agency to designate critical habitat."

"<u>Seattle Audubon Society v. Robertson</u>: A suit challenging the US Forest Service's spotted owl management plan for failure to comply with the National Forest Management Act (NFMA) and the National Environmental Policy Act (NEPA). court ruled that the Forest Service's plan did not meet the requirements of either law, ordered the agency to prepare another plan, and enjoined further timber sales in spotted owl habitat until a legally adequate plan is in place."

"<u>Bureau of Land Management v. US Fish and Wildlife Service</u>: A petition by the Bureau of Land Management (BLM) for an exemption for 44 timber sales in Oregon from the requirements of the Endangered Species Act. The Endangered Species Committee granted an exemption for 13 of the sales, the first exemption ever granted under the Endangered Species Act after a full hearing."

"<u>Portland Audubon Society v. Bureau of Land Management</u>: A suit against the Bureau of Land Management for failure to follow National Environmental Policy Act requirements in managing the spotted owl. The court found that the BLM had violated National Environmental Policy Act and enjoined timber sales in spotted owl habitat pending the agency's compliance with National Environmental Policy Act." (A)

Steger, G.N.; Munton, T.E.; Verner, J. 1992. Preliminary results from a demographic study of spotted owls in Sequoia and Kings Canyon National Parks, 1990-1991. Proceedings of the National Park Service fourth conference on research in California's National Parks. San Francisco, CA: U.S. Department of the Interior, National Park Service; draft.

"In a study area of approximately 343 km2 (132 mi2) in Sequoia and Kings Canyon National Parks, 54 adult and subadult and 21 fledgling California spotted owls were located in 1990 (crude density = 0.157 owls per square kilometer). Comparable numbers in 1991 were 60 adults and subadults and one fledgling (crude density = 0.175 owls per square kilometer). Thirteen of 22 pairs in 1990 were found with young and one of 23 pairs was found with young in 1991. The reproductive rate (the proportion of pairs checked for reproduction that fledged young) was 0.88 in 1990 ad 0.08 in 19gl; the combined turnover rate for 1990 and 1991 was 19.5 percent." (A)

Timber Association of California. California timberland wildlife habitat study. Redding, CA: Vestra Resources, Inc.; interim report. 51 p.

"The WHS uses state of the art capabilities in terms of data collection, computer generated mapping, and management prescription information to analyze the status of wildlife habitat in all of California's forests."

"At present this interim report covers the presumed range of the northern spotted owl." (A)

USDA Forest Service. September 1991. Spotted owl inventory and monitoring program. San Francisco, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Region; annual report. 24 p.

"This report summarizes Spotted Owl (Strix occidentals) survey and inventory data collected during 1991 on U.S. National Forest Service lands in the Pacific Southwest Region of the Forest Service (hereafter Region 5). For the purposes of this report, the Region has been divided into three provinces: the Klamath Province in northern California, the Sierra-Nevada Province spanning the length of the Sierra-Nevada mountain range, and the Southern California Province. In Region 5, there are 18 National Forest units, and survey or inventory data were reported from each of the 18 units in 1991."

"In Region 5, the populations of the Northern Spotted Owl are found on the Klamath, Mendocino, Modoc, Shasta-Trinity, and Six Rivers National Forests, as well as the portion of the Lassen National Forest north of the Pit River." (A)

Wagner, F.F.; Meslow, E.C.; Bennett, G.M.; Small, S. 1992. Demography of spotted owls in southern Cascades and Siskiyou Mountains, Oregon. Proceedings of the 62nd annual meeting of the Cooper Ornithological Society symposium; 1992 June 22-28; Seattle, WA.

"We estimated the finite rate of population change for northern spotted owls in the southern Cascades and Siskiyou Mountains of Oregon for the period 1985 though 1991. Survival probabilities were estimated with capture-recapture methods by annually resighting uniquely color-banded spotted owls. We used programs RELEASE for data summary and goodness-of-fit tests and SURGE for model selection and fit. Fecundity was estimated annually according to a standardization field protocol. The finite rate of annual population change indicates that the population of resident females declined significantly over the observed time period." (A)

Young, K.E.; Franklin, A.B.; Ward, J.P. 1992. infestation of northern spotted owls by Hippoboscid (Diptera) flies in northwestern California. 17 p.

"ABSTRACT - Hippoboscid flies were found on 62 (16.7 percent) of 382 northern spotted owls (Strix occidentalis caurina) captured between April and September, 1986 through 1990. Two species of hippoboscids were identified: *Icosta American and Ornithomya anchineuria*. Male and female adult spotted owls had similar prevalences and relative densities of hippoboscid flies. Juvenile owls had lower prevalences and relative densities than adults. There were no significant differences in mean intensity of hippoboscids on adult male, adult female and juvenile spotted owls. Relative densities of flies infesting adult owls were significantly greater during years of increased fall temperatures, decreased winter precipitation, and decreased summer temperatures." (A)

Zabel, C.; McKelvey, K.; Paton, P., [and others]. July 1992. Home range size and habitat use patterns of northern spotted owls in northwestern California and southwestern Oregon. [In preparation]. 40 p.

"Abstract - Home range sizes were estimated for northern spotted owls at 3 study sites in northwestern California and southwestern Oregon. We found significant positive correlations between the number of days an owl was radio tracked and home range size, indicating home ranges may shift or expand over time. Differences in home range sizes

corresponded to differences in the primary prey of owls in different locations. We tested whether owls used habitat types within their home range in proportion to availability, and determined which habitat types were used more or less than expected. Patterns of selectivity were similar to those found in earlier studies on spotted owls , but our results were weaker. We suggest that it is difficult to show selection for mature trees when most of the available habitat consists of mature trees. Our study areas were located where higher proportions of the landscape were mature forest compared to earlier studies. Use of suitable/unsuitable edges by owls was examined by comparing distance distributions of radio locations from the nearest edge to random locations. Where owls were preying predominantly on woodrats, they showed a preference use for edges. Where owls were preying predominantly on northern flying squirrels, they showed neither preference nor avoidance for edges. We tested the hypothesis that owls use suitable or unsuitable habitat exclusively within their home ranges and that the patterns of use we observed were due to telemetry error. Random points were displaced from either habitat type by distances equal to our estimated telemetry error. Distributions between displaced random points and owl locations differed significantly, indicating the patterns we observed could not be produced by our error distribution. Power of our Chi-square tests of habitat selection is presented, and factors that influence power are discussed." (A)

Zabel, C.J.; Noon, B. 1992. Demographic parameters of the northern spotted owl on the Coos Bay Bureau of Land Management District and Siskiyou National Forest, southwestern Oregon. Arcata, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Region; draft annual report. 9 p.

Tables on survival and reproductive rates of populations of spotted owls on the Coos Bay BLM District and Siskiyou National Forest in Oregon. (C)

Appendix 4-C

Anderson and Burnham Report - Demographic Analysis of Northern Spotted Owl Populations

This report is reproduced here exactly as it appeared in Appendix C of the Draft Recovery Plan for the Northern Spotted Owl (USDI).

Appendix C
Demographic Analysis of Northern
Spotted Owl Populations

1. Introduction

The 1990 Status Review Northern Spotted Owl (USDI 1990) provided estimates of the rate of population change for populations of northern spotted owls in northern California (Willow Creek and surrounding regional study area} and southern Oregon (the Roseburg study area). The population of resident female owls in these areas was shown to be declining at a significant rate. By the fall of 1991, there were 2 additional years of capture-recapture data on these two populations, and three new areas {Medford in southern Oregon, H.J. Andrews near Corvallis, Oregon, and the Olympic Peninsula in northwestern Washington) had sufficient years of capture-recapture data to warrant an intensive analysis {Table C. I). More than 2,000 owls had been marked and the resighting probability for adult females was approximately 0.8 to 0.9 percent.

This appendix provides estimates of the rate of population change of resident, territorial females in these five large study areas, Analysis methods (e.g.. model building, model selection, tests of model fit, parameter estimation, and inference procedures concerning the rate of population change} are those used in USDI {1990) with some extensions. The key references on methodology are Burnham and Anderson (In Press) and Lebreton et al. In Press). The analyses of data were done during September-October 199 I. during two intensive workshops held in Fort Collins, Colorado, The analyses were completed by six biologists working on the northern spotted owl--two French scientists, two professors from Colorado State University with special expertise in the analysis of capture-recapture data, and two U.S. Fish and Wildlife Service employees from the Colorado Cooperative Fish and Wildlife Research Unit.

2. Results and Discussion

Two parameters are of critical interest; λ = finite {i.e., annual) rate of change in the size of the population of females, and ø = annual probability of survival of adult females. Maximum likelihood estimates of these parameters are shown as λ and ø, respectively, along with estimates of their precision (i.e., se (λ) se (ø)). If the number of resident females is “stationary" then λ = I, while if population is declining, then $\lambda < 1$. Thus, there is interest in testing the null hypothesis $\mathbf{H_o}$: $\lambda \leq \mathbf{1}$ against the alternative hypothesis $\mathbf{H_o}$: λ **< 1.** Proper estimation of λ answers the critical question, "Have the resident, territorial females replaced themselves?"

Table C.1. Summary information on the five demographic study areas.

Name of Study Area	Total Approximate Size	Years of Marking	Individuals Marked
Northwest California	4,000	1985-91	400
H.J. Andrews (western Oregon)	116	1987-91	358
Medford (southwestern Oregon)	4,050	1985-91	703
Roseburg (southwestern Oregon)	1,700	1985-91	589
Olympic Peninsula (northwestern Washington)	965	1987-91	3O2

Parameter Estimates for Individual Study Areas

The estimation of λ was based on the Leslie-Lefkovitch approach summarized in USDI (1990). Under this method, estimates of age-specific survival and fecundity are needed for the female component of the population, Model selection for the estimation of survival probabilities relied on the Akaike Information Criterion (AIC), however some use of likelihood ratio tests was made, Data from the five study areas supported only two age-classes for annual survival estimates {juvenile and all older classes = "adults"). Estimates of these parameters and measures of their precision are presented in Table C.2.

Estimates of age-specific fecundity of females also followed the procedures ha USDI (1990), and these are summarized In Table C.3. with a measure of the precision of the estimates.

Estimates of λ, computed from the estimates in Tables C.2. and C.3., estimated precision, and test statistics related to the null hypothesis (above) appear Table C.4. While there are several potential biases in these estimates, it is clear from Table C.4, that the population of resident, territorial females has declined in each of the five study areas. The simple average of the estimates was λ = 0.9022 which indicates a rate of decline of approximately I0 percent per year during 1985-199 I. Thus. the resident population was not replacing itself in any of the five large study areas. This is a critical finding. In each case, λ is significantly less than 1 (see test statistics and P-values in Table C.4.}. No statistical inference is made concerning λ prior to these years of study or in the future. These estimates of λ represent a 5- or 6-year "snapshot" of the average annual change in the female component of these five populations.

The t-test is based on the empirical variance among the five independent estimates, of λ, while the z-test is based on the theoretical standard error of λ (i.e., $\sqrt{\sum \text{var}(\lambda_1)/5}$). The t-test allows for significant variation in λ within the five study areas, however, a test for such variation was not significant (K^2=5.1409, 4 df, P=0.2731, (see Burnham et al. 1987:264-269). The estimated standard

Table C.2. Estimates of age-specific annual survival rates for female northern spotted owls.

Study Area	First Year		All Later Years	
	$ø_j$	$se(ø_j)$	$ø_j$	$se(ø_j)$
Northwest California	0.1946	0.0509	0.8507	0.0224
H.J. Andrews (western Oregon)	0.3112	0.1033	0.8365	0.0312
Medford (southwestern Oregon)	0.2002	0.0513	0.7854	0.0258
Roseburg (southwestern Oregon)	0.2829	0.0366	0.8583	0.0131
Olympic Peninsula (northwestern Washington) [a]	0.0707	0.0282	0.8603	0.0264

[a] No sex-specific differences in adult survival were detectable, thus, the estimate of adult female survival includes adult males.

Table C.3. Estimates of age-specific fecundity (b) for female northern spotted owls (number of juvenile females/female of age x).

Study Area	Subadult I (12 mos.)		Subadult 2 (24 mos.)		Adult (36 mos.)	
	(b_1)	$se(b_1)$	(b_2)	$se(b_2)$	(b)	$se(b)$
Northwest California	0.1154	0.0576	0.2286	0.0659	0.3576	0.0245
H.J. Andrews (western Oregon)	0.1430	0.0780	0.1430	0.0780	0.3270	0.0500
Medford (southwestern Oregon)	0.1110	0.0386	0.1110	0.0386	0.3233	0.4880
Roseburg (southwestern Oregon)[a]	0.0938	0.0547	0.0938	0.0547	0.3304	0.0385
Olympic Peninsula (northwestern Washington)[a]	0.1000	0.0667	0.1000	0.0667	0.3327	0.0784

[a] Year-specific differences in (b).

error of the true λ across the five study areas (σ_λ) was 0.0267 {95 percent confidence interval is 0.0 to O. 1073). Both tests indicate a strong rejection of the null hypothesis, and one must conclude that these populations are declining.

Capture-recapture methods allow estimates, of the number of new entries into the population of resident, territorial females (standard Jolly-Seber estimates, see USDI(1990:35-36)). Estimates of this quantity, averaged over years, are

Table C.4. Estimates of the finite rate of annual population change (λ) for female northern spotted owls in five independent study areas throughout their range. Also shown are test statistics and P values for the test of the null hypothesis that λ> 1 vs. λ < 1.

Study Area	λ	se(λ)	t or z	P
Northwest California	0.9153	0.0433	-1.9561	0.0252
H.J. Andrews (western Oregon)	0.9276	0.0437	-1.6567	0.0488
Medford (southwestern Oregon)	0.8444	0.0304	-5.1184	0.0000
Roseburg (southwestern Oregon)	0.9405	0.0182	-3.2692	0.0005
Olympic Peninsula (northwestern Washington)	0.8828	0.0280	-4.1857	0.0000
Simple average and t-test	0.9021	0.0173	-5.7532	0.0024
Simple average and z-test	0.9021	0.0153	-6.4155	0.0000

provided in Table C.5. Study of the results of these analyses indicated that statistically significant immigration had occurred each year in all five study areas. The estimates of the number of new entries (B^) provide insight into how populations in each area have been augmented by immigration from outside the study areas. These findings are consistent with those in the 1990 Status Review (USDI).

b. Meta-analysis

The majority of the capture-recapture data comes from adult birds (i.e., nonjuveniles) and therefore a sophisticated attempt was made to model and understand these data for each of the five study areas. Models of capture-recapture data must properly treat two types of parameters; conditional survival probabilities (ø) and conditional recapture probabilities (p) and these vary across study areas (g). Age was not a factor in this analysis as only adults were treated, and sex was not a factor as only females were of particular interest. For theoretical reasons, much of the analysis was done on logit(ø) and logit(p), where, in general, $logit_e(\theta) = log(\theta /(1- \theta))$. The parameters R and vary by year (t). and models were derived to allow for this effect. Time (t) years was considered in two ways. First. the notation t denoted any significant variability in $ or p over years. Second, T was used to denote a linear trend in time in either logit(θ) or logit(p). Thus, a model allowing survival probabilities to vary across areas (g) and recapture probabilities to vary across years was denoted as $(ø_g,P_T)$.

More complex models allowed several effects to be considered in a likelihood framework. An asterisk (*) denoted independent factors (e.g., g*t indicated that year-dependent parameters were incorporated in a model separately for each study area}. Models employing a logit-linear structure were denoted by a "+" (e.g., g + t would indicate a model whereby study area was indexed by dummy variables, and parameters across time would be parallel on a logit scale) (see Hosmer and Lemeshow 1989). In all models, a log-likelihood ($log_e(L)$) was as the basis for statistical inference and estimation of model parameters was based on Maximum Likelihood methods. The model selection method (AIC) was objective; neighboring models were explored using likelihood ratio tests.

Table C.5. Estimates of the average annual number of new entries (B) into the adult population and the estimated average population size (Ň) of northern spotted owls. [a]

Study Area	B	se(B)	Ň	se(Ň)
Northwest California	14.76	0.84	49.71	2.46
H.J. Andrews (western Oregon)	15.57	1.48	60.06	4.15
Medford (southwestern Oregon)	54.97	3.26	91.80	7.87
Roseburg (southwestern Oregon)	36.69	2.21	99.68	7.57
Olympic Peninsula (northwestern Washington)	24.44	1.06	51.20	3.56

[a] The estimates of B and R and measures of precision were made using program JOLLY (see Pollock et al, 1990).

Using the conventions above, either ø or p could be modeled in eight ways, g*t, g + t, t g*T, g + T, T, g or the null case, denoted -. Combinations of these eight structures for ø and p lead to 64 models of the five data sets on adult females. Table C.6. presents the number of model parameters, $-2.1og_e(L)$, and AIC for each of the models considered.

While the AIC-selected model was $(ø_T, P_{g*T})$, some neighboring models were tested to allow a deeper understanding of the data. These tests retain a very general model structure for the recapture probabilities. Three tests were of particular interest:

Test 1. (ø, P_{g*T} vs. (ø $_t$, Pg_{*T}), χ^2 = 11.9666, 5 df, P = 0.035.
Here, one concludes that there is significant year-specificity in adult female survival.

Test 2. (ø, P_{g*T}) vs. (ø $_t$, Pg_{*T}), χ^2 = 4.930, 1 df, P = 0.026.
Here, one concludes that there is a significant linear trend in logit(ø).

Test 3. (ø, P_{g*T}) VS. (ø $_t$, Pg_{*T}), χ^2 = 7.036, 4 df, P=0.134.
Here, one concludes that there is no reason to use four additional parameters to let R vary by year, when a linear trend is satisfactory.

Finally, a Wald test (2-sided) of the significance of the slope in the relationship between logit(~) vs. T is,

z = -2.287, P = 0.01 I. Thus, one concludes that the slope is significant.

This comprehensive analysis indicated a decreasing trend in annual adult female survival rate for the populations In the five study areas (Table C.7.). This finding is important because λ is critically influenced by the adult female survival (i.e., juvenile survival and fecundity are relatively less important in their influence on X). Because the evidence strongly indicates that R decreased during the 1985-91 period, one must infer that k also decreased over this period. That is, the rate of population decline was accelerating during the study period.

Biases in λ

Estimates of juvenile survival have been contentious because estimates are biased low if some juveniles leave the study area, survive a full year, and never return to the study area. To the extent that these three events happen, juvenile survival is underestimated, and estimates of λ, are too low (i.e., the true value of λ, is probably larger than estimated).

Two approaches were employed to obtain more reasonable estimates of juvenile survival. $ø_J$. First, the maximum estimate of juvenile survival from the five study areas ($ø_J$ = 0.311, sse = 0.103) was used (cases 1 and 2 in Table C.8.). Second, data on juvenile survival from the best production year for the Medford and Roseburg areas were pooled to obtain a maximum estimate ($ø_J$ = 0.3065. he = 0.0764) and this was used (cases 3 and 4, in Table C.8.). The Medford and Roseburg areas are large in size and adjacent to each other. Thus. the number of dispersing juveniles that survived and never returned is minimized in this approach. In each of the four cases, an attempt was made to use a realistic estimate of juvenile survival as one of the estimates affecting λ. Cases 1 and 3 allowed adult female survival to decline, while Cases 2 and 4 used an estimate of the average adult female survival from the pooled data. Table C.2. provides estimates of λ = 1. In each of the four cases, there was strong statistical evidence of a declining population.

Table C.6. Summary of statistics related to model selection, based on 64 models. For each model the three table entries are number of model parameters, -2-1og$_e$(L), and AIC. The best model is indicated by the box.

	Recapture Rate, p							
Survival Rate Φ	g*t	G+t	t	g*T	g+T	T	g	-
g*t	47	36	31	36	32	28	31	27
	1664.54	1681.92	1700.07	1674.01	1683.27	1701.75	1686.76	1705.23
	1758.54	1753.92	1762.07	1746.01	1747.27	1757.35	1748.76	1759.23
g+l	36	20	16	20	16	12	15	11
	1672.76	1694.44	1713.53	1689.23	1698.32	1715.82	1703.46	1719.62
	1744.76	1734.44	1745.53	1729.23	1730.32	1739.82	1733.48	1741.61
t	31	16	11	16	12	8	11	7
	1673.82	1702.36	1721.30	1691.92	1705.49	1722.69	1708.83	1725.85
	1735.82	1734.36	1743.30	1723.92	1729.49	1738.69	1730.83	1739.85
g*T	36	20	16	20	16	12	15	11
	1674.09	1696.86	1714.06	1690.32	1698.65	1717.14	1701.63	1720.15
	1746.09	1736.88	1746.06	1730.32	1730.65	1741.14	1731.63	1742.15
g+T	32	16	12	16	12	8	11	7
	1677.43	1705.04	1719.75	1696.17	1706.46	1723.24	1710.89	1726.14
	1741.43	1737.04	1743.75	1728.17	1730.46	1739.24	1732.89	1740.14
T	28	12	8	12	8	4	7	3
	1678.54	1711.22	1725.85	1698.96	1714.22	1730.82	1716.35	1732.83
	1734.54	1735.22	1741.85	1722.96	1730.22	1738.82	1730.35	1738.83
g	31	15	11	15	11	7	10	6
	1678.39	1708.71	1721.44	1701.81	1714.77	1729.76	1715.12	1729.90
	1740.39	1738.71	1743.44	1731.81	1736.77	1743.76	1735.12	1741.90
-	27	11	7	11	7	3	6	2
	1679.11	1712.14	1726.42	1703.89	1719.31	1735.57	1719.33	1735.60
	1733.11	1734.14	1750 42	1725.89	1733 31	1741.57	1731.33	1739.60

An additional perspective concerning this source of potential bias can be gained by examining the value for juvenile survival necessary to force λ = I (with the same adult survival and fecundity values). The large increases estimated juvenile survival, shown here, seem unfounded.

Study	$\Phi_j l\lambda = 1$	% increase
Northwest California	0.49	151
H.J, Andrews	0.60	93
Medford	0.89	345
Roseburg	0.53	87
Olympic Peninsula	0.52	632
Average	0.61	190

In summary, even with optimistic assumptions about juvenile survival rates, the best information suggests that the population of resident, territorial owls has declined, on average, at an estimated rate of 7.5 percent each year during the 1985-91 period and that this rate of decline probably has accelerated in recent years.

Senescence is another potential problem; unaccounted for senescence leads to overestimation of λ. Likewise, it seems clear that fecundity is overestimated each year and this overestimation is more severe in years of poor production.

Table C.7. Estimates of average adult female survival (Φ) during 1985-91 for the northern spotted owl, based on the best model out of 64 for the pooling of data across the five study areas.

Year	Φ	se(Φ)
1985-86	0.8880	0.0242
1986-87	0.8727	0.0202
1987-88	0.8556	0.0157
1988-89	0.8367	0.0124
1989-90	0.8158	0.0146
1990-91	0.7929	0.0231

Table C.8. Estimates of the finite rate of annual population change(λ) for the northern spotted owl obtained by pooling all the data across the five study areas. Cases (explained in the text) make differing assumptions about juvenile survival rates.

Case	Years	Female Survival Rate	Φ_j	λ	se(λ)	Z	P
1	1985-86	Declining	Φmax1[a]	0.9813	0.0373	-0.4879	0.3128
1	1990-91	Declining	Φmax1[a]	0.8857	0.0362	-3.1575	0.0008
2	1985-91	Constant	Φmax1	0.9259	0.0312	-2.3750	0.0088
3	1985-86	Declining	Φmax2[b]	0.9805	0.0322	-0.6056	0.2724
3	1990-91	Declining	Φmax2[b]	0.8844	0.0312	-3.7051	0.0001
4	1985-91	Constant	Φmax2	0.9246	0.0251	-3.0040	0.0013

[a] The survival rate of juveniles was used for the area with the highest survival rate.

[b] The year with the highest survival was used for the Medford and Roseburg areas, thus the emigration was lowest.

This source of bias in λ, also tends to overestimate X.

Sandland and Kirkwood (1981) noted that the recapture probabilities can correlated and this leads to biases in the estimate of survival. This effect was tested, but no evidence of this effect was found. This effect is a minor problem when recapture probabilities are so high (i.e., 0.80-0.90).

3. Conclusions

Populations of resident, territorial females in all five large study areas have declined significantly, at an estimated average rate of 7.5 percent per year during the 1985-91 period. The parameter most important in ~. is the annual survival rate of adult females and this parameter has decreased significantly during the 1985-91 period. Thus, the rate of population decline has probably accelerated.

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