Studies in Avian Biology No. 17:31–36, 1996.

DEMOGRAPHY OF NORTHERN SPOTTED OWLS ON THE SALEM DISTRICT OF THE BUREAU OF LAND MANAGEMENT IN NORTHWESTERN OREGON

D. Scott Hopkins, Wayne D. Logan, and Eric D. Forsman

INTRODUCTION

Analysis of Northern Spotted Owl (*Strix occidentalis caurina*) populations in northwest Oregon is of particular interest because this area includes portions of the northern end of the Oregon Coast Ranges, an area where historical surveys have generally found low owl densities and poor habitat conditions (Forsman et al. 1977, Forsman 1988, Salem Bureau of Land Management, unpublished data). In one of the few published reports from this area, Forsman (1988) reported finding lower numbers of owls than reported for other regions, and he noted the rate of owls responses during surveys, and presumably owl numbers, had declined between 1976 and 1986.

Since 1974, the Salem District of the Bureau of Land Management (BLM) has conducted surveys for Spotted Owls in both the northern portion of the Coast Ranges and in the northern portion of the Western Cascades in northwest Oregon. Initial survey efforts varied from year-to-year and focused on known locations of Spotted Owl pairs on BLM lands. No attempts were made to mark owls. In 1986, the surveys became more consistent, study area boundaries were expanded, and a banding study was initiated. The primary objective of the study was to provide quantitative information that could be used to assess the condition of the owl population in northwestern Oregon. Data from 1986–1993 on the Salem District were first analyzed at a Spotted Owl Demographic Workshop in Fort Collins, Colorado in December 1993 and were summarized in Burnham et al. (1994b). This paper presents an expanded analysis and discussion of the demographic data collected on Northern Spotted Owls on the Salem District.

STUDY AREA

The Salem Study Area is approximately 3844 km^2, encompassing most of the BLM lands in the Salem District of the Bureau of Land Management as well as interspersed sections of nonfederal land (Fig. 1). The study area includes portions of the Coast Ranges Province and the Western Cascades Province, both of which are located in northwest Oregon (Franklin and Dyrness 1973). The study area is composed of several separate survey blocks, reflecting the dispersed pattern of BLM land ownership in northwest Oregon (Fig. 1).

The majority of BLM lands in the study area occur in a checkerboard ownership pattern of alternating mi^2 (259 ha) sections (Fig. 1). Intervening sections are owned primarily by private timber companies and to a lesser extent, by state agencies or the U. S. Forest Service. Of the 159,300 ha of forest lands administered by the BLM within the study area, 57% (90,800 ha) is in the Coast Ranges Province and 43% (68,500 ha) is in the Western Cascades Province. These two provinces are separated by the Willamette Valley, a predominantly agricultural, urban, and residential region.

Forests within the study area are dominated by western hemlock (*Tsuga heterophylla*), Douglas-fir (*Pseudotsuga menziesii*), and western redcedar (*Thuja plicata*). Red alder (*Alnus rubra*) and bigleaf maple (*Acer macrophyllum*) are common hardwoods, and are often intermixed with conifers, or in some cases occur in pure hardwood stands. Sitka spruce (*Picea sitchensis*) occurs in some low-lying areas along the coast. Silver fir (*Abies amabilis*) and noble fir (*Abies procera*) are present in a few areas at elevations >1000 m.

As a result of wildfires, wind storms, and extensive timber cutting, forests in the Coast Ranges are dominated by young conifer forests or conifer/hardwood forests interspersed with recent clear-cuts covered by grasses, brush, and conifer seedlings (Morris 1934, Teensma et al. 1991). Only about 3% of the forested habitats on BLM lands in the Coast Ranges are old-growth conifer stands (≥200 years old); the majority of these stands occur in patches of ≤40 ha (USDI-BLM 1992b).

The portion of the study area in the Western Cascades is also characterized by a mosaic of young forests, recently harvested patches, and older forests. However, less of this region has been harvested, and large blocks of mature forest (80–199 years old), and old-growth forest (≥200 yrs old) are more common than in the Coast Ranges. Old-growth stands currently comprise approximately 14% of the forest habitat on BLM lands in the Western Cascades portion of the study area.

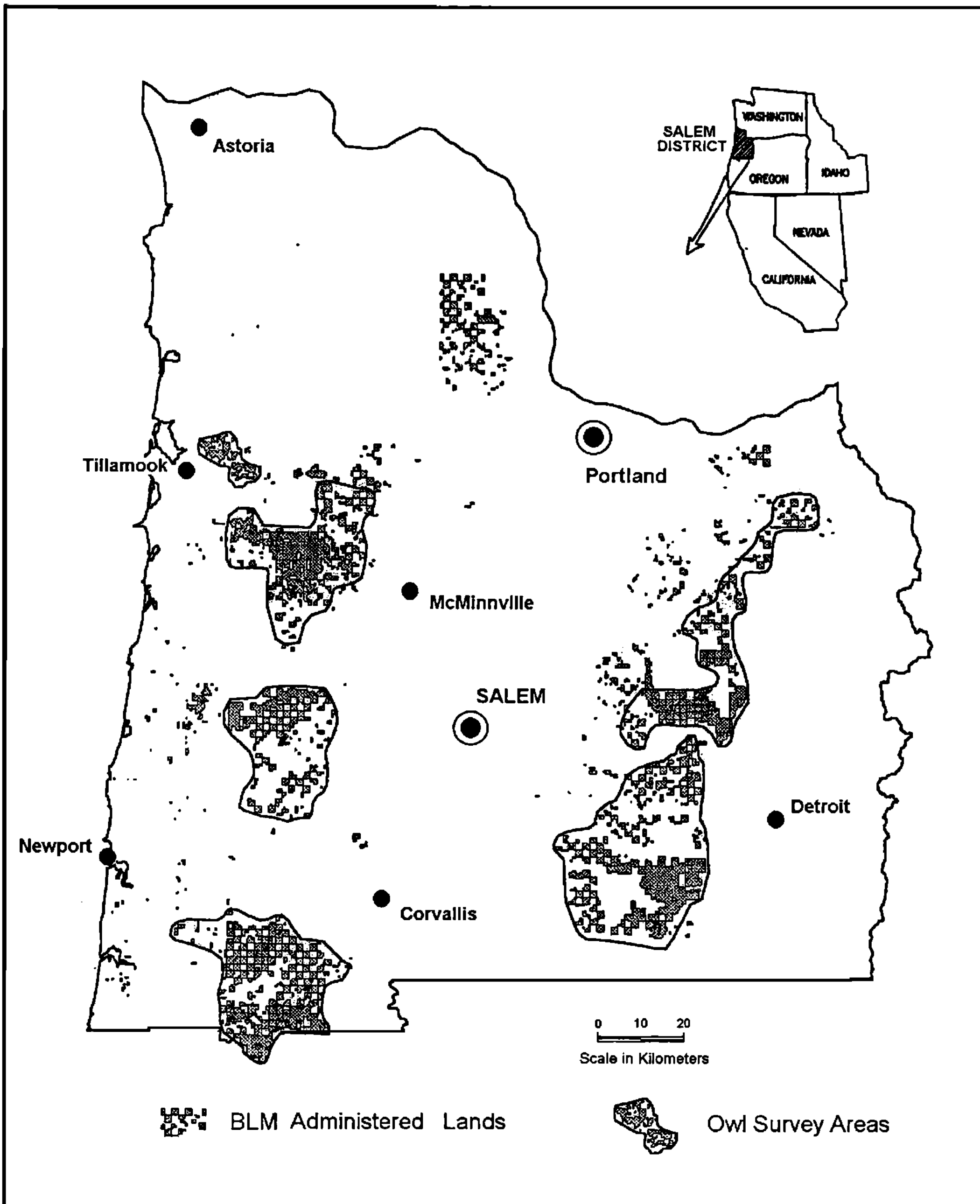

FIGURE 1. Salem District Study Area in northwest Oregon, showing Bureau of Land Management lands, and areas consistently surveyed for Northern Spotted Owls, 1986–1993.

METHODS

Data were collected from pairs or single owls at 123 sites within the study area, including 116 sites on BLM-administered lands and 7 sites on other ownerships. An owl site was defined as a location where Spotted Owls exhibited territorial behavior on at least two occasions ≥2 weeks apart within a given year (Franklin et al. *this volume*). Fifty-four of these owl sites were in the Coast Ranges, and 69 were in the Cascades.

TABLE 1. Numbers of Northern Spotted Owls by Age-class and Year Captured, That Were Used in Capture-recapture Analysis for the Salem District Study Area in Northwest Oregon, 1986–1993

Year	≥3 yrs old[a] M	≥3 yrs old[a] F	1 or 2 yrs old M	1 or 2 yrs old F	Juveniles
1986	13	9	2	0	9
1987	4	7	3	1	13
1988	3	2	2	2	12
1989	8	5	1	0	11
1990	10	11	0	0	14
1991	13	9	1	1	3
1992	17	20	1	1	37
1993	16	5	2	0	2
Totals	74	68	12	5	101

[a] M = male, F = female.

Surveys and banding followed protocols described in Franklin et al. (*this volume*). Survey efforts were consistent at all owl sites, across all survey blocks, and across both physiographic provinces. A capture-recapture data set was compiled from banding and reobservation records of 260 owls from 83 sites where survey efforts over the study period were consistently high (≥3 complete visits per season following initial marking of an owl).

Age or group-specific survival was estimated with Cormack-Jolly-Seber open population models in Program SURGE (Lebreton et al. 1992, Franklin et al. *this volume*). Goodness of fit of the data to the assumptions in the global capture-recapture model was examined with Tests 2 and 3 in Program RELEASE (Burnham et al. 1987). Capture-recapture models were constructed for two different data sets, one which included only ≥3-yr-old owls, and another that included 2 age groups (juveniles and non-juveniles). The non-juvenile age group included all owls ≥1-yr-old. Selection of models that best fit the data was based on Akaike's Information Criterion (AIC, Akaike 1973, Anderson et al. 1994) and likelihood ratio tests (LRT, Burnham et al. 1987).

Age-specific fecundity of territorial females was assessed from 161 records at 58 owl sites where a female was confirmed, and where survey efforts met protocol for determining the number of young produced as described in Franklin et al. (*this volume*). Fecundity was defined as the number of female young fledged per female owl and was estimated by dividing the number of young fledged by two, which assumes that owlets that left the nest had a 50:50 sex ratio (Franklin et al. *this volume*). The finite rate of population growth (λ) was estimated from the age-specific estimates of fecundity and model generated estimates of survival as described in Franklin et al. (*this volume*).

RESULTS

Sample Size and Goodness of Fit

Two hundred eighty-two Spotted Owls were banded during the study. After excluding owls that were radio-marked or that occupied sites that were not consistently surveyed, we used 260 owls in the capture-recapture analysis (142 ≥3-yr-old owls, 17 1- and 2-yr-old owls, and 101 juveniles) (Table 1). Most of these owls (74.2%) were from the Western Cascades Range. The small size of the sample from the Coast Ranges precluded separate goodness-of-fit analyses of the Coast Ranges and Cascades Range data. Results of the overall goodness-of-fit tests on non-juveniles (all owls ≥1 year old) revealed no lack of fit to the assumptions in the capture-recapture models (Table 2). However, many components of these tests did not have sufficient data, which was not unexpected considering the relatively small sample size. Goodness-of-fit tests of the juvenile data provided no meaningful insights because the number of recaptures was small (N = 15).

Model Selection

The capture-recapture model that best fit the data from ≥3-yr-old owls included a negative linear time trend on survival (Fig. 2) and a sex-

TABLE 2. Results of Goodness-of-fit Tests From Program RELEASE (Burnham et al. 1987) for Capture-recapture Data From Northern Spotted Owls on the Salem District Study Area in Northwest Oregon, 1986–1993

Age and sex	TEST 2 + 3 χ^2	TEST 2 + 3 df	TEST 2 + 3 P	TEST 2 P	TEST 3 P
≥3-yr-old females	14.121	16	0.590	0.904	0.324
≥3-yr-old males	12.625	14	0.556	0.142	0.837
≥1-yr-old females	14.075	16	0.593	0.843	0.361
≥1-yr-old males	12.511	14	0.565	0.178	0.798

TABLE 3. CAPTURE-RECAPTURE MODELS FOR NORTHERN SPOTTED OWLS ON THE SALEM DISTRICT STUDY AREA IN NORTHWEST OREGON: 1986–1993. MODELS THAT BEST FIT EACH DATA SET ARE INDICATED BY LOWEST AIC VALUES (AKAIKE'S INFORMATION CRITERION, AKAIKE 1973). LIKELIHOOD RATIO TESTS (LRT) INDICATE COMPARISONS BETWEEN THE MODEL WITH THE LOWEST AIC VALUE AND COMPETING MODELS WITHIN 2 AIC UNITS.

			LRT		
Model[a]	K[b]	AIC	χ^2	df	P
≥3-yr-old owls					
$\{\phi_T, p_s\}$	4	501.465			
$\{\phi_T, p\}$	3	502.268	2.803	1	0.094
$\{\phi, p_s\}$	3	502.286	2.821	1	0.093
$\{\phi_T, p_{s+T}\}$	5	502.793	0.671	1	0.412
$\{\phi, p_{s+T}\}$	4	504.256			
2-age-class models					
$\{\phi_{a2+T}, p_{a4'+s}\}$	8	721.077			
$\{\phi_{a2}, p_{a4'+s}\}$	7	721.588	2.511	1	0.1130
$\{\phi_{a3+T}, p_{a4'+s}\}$	9	721.974	1.103	1	0.2936
$\{\phi_{a2}, p_{a4'}\}$	6	726.067			
$\{\phi_{a2+T}, p_{a3'+s}\}$	7	728.953			

[a] Subscripts associated with ϕ (survival) and p (capture probability) indicate these parameters have a linear time trend (T), or a variable time trend (t), or a difference between sexes (s), or a difference between two or more age classes (a2, a3, a4), or some additive combination of factors. Models of ϕ and p without subscripts indicate that there were no sex, age or time effects on survival or recapture rates. Age effects on capture probability (denoted as a3' or a4') relate specifically to birds first captured as juveniles, since age of birds first captured as adults was unknown.
[b] Number of estimable parameters in model.

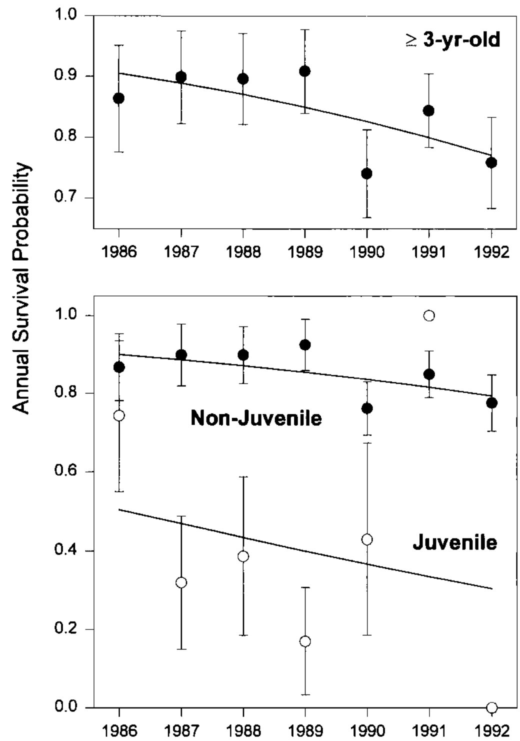

FIGURE 2. Estimates of annual survival for Northern Spotted Owls in the Salem District Study Area in northwest Oregon, 1986–1993. Solid lines represent linear declining survival estimates obtained from the most parsimonious capture-recapture models. Estimates of annual survival (and associated SEs) obtained from models with variable time trends are shown for comparison.

effect on recapture (model $\{\phi_T,p_s\}$, Table 3). Likelihood ratio tests indicated that three other models fit the data nearly as well as the model with the lowest AIC (Table 3).

The model that best fit the 2-age-class data (juveniles and non-juveniles) included an age effect plus a negative linear time trend on survival, and an age and sex effect on recapture (model $\{\phi_{a2+T},p_{a4'+s}\}$, Table 3, Fig. 2). Likelihood ratio tests indicated that two other models fit the data nearly as well as the selected model (Table 3). All 2-age-class models had age-specific recapture probabilities for juveniles only. This is because the exact age of juveniles at first capture (and all subsequent recaptures) was known. In contrast, the exact age of owls first captured as adults (≥3 year old) was unknown. The best 2-age-class models included 4 age classes on recapture probability (denoted *p*a4'), suggesting that recapture probabilities gradually improved for owls banded as juveniles, up to age 3 yrs. The age-effect on recapture rates of juveniles appeared to be strongly influenced by the 1986 juvenile cohort, which made up only 9% of all juveniles banded in the 1986–1992 cohorts, but accounted for 33% of all juvenile recaptures.

SURVIVAL ESTIMATES

The estimate of apparent annual survival from the most parsimonious model for ≥3-yr-old owls was 0.844 (SE = 0.026). For the best fitting 2-age-class model, estimates of apparent annual survival were 0.851 (SE = 0.022) for non-juveniles and 0.402 (SE = 0.105) for juveniles. Standard errors for estimates of survival from models that included a linear time effect on survival were approximations based on SEs of models with similar AIC values and no time effects on survival.

FECUNDITY ESTIMATES

Estimated mean annual fecundity was 0.3810 for ≥3-yr-old owls (SE = 0.036, N = 147). Estimated fecundity for 1- and 2-yr-old females was 0.500 (SE = 0.236, N = 3), but the sample for this estimate was so small that we had little confidence in it. Mean annual fecundity for all females combined, including 11 individuals whose age could not be determined, was 0.370 (SE = 0.034, N = 160). Fecundity of ≥3-yr-old owls varied among years, ranging from a low of 0.021 in 1993 to a high of 0.714 in 1986 (Fig. 3).

Rate of Population Change

Using survival estimates for juveniles and non-juveniles from the selected age-class model, and separate estimates of adult and subadult fecundity, the estimated rate of population growth ($\hat{\lambda}$) was 1.019 (SE = 0.073), indicating a population that was increasing by 1.9% per year. A one-tailed test of the null hypothesis that $\lambda \leq 1.0$ indicated that λ did not differ from 1.0 ($z = 0.26$, $P = 0.397$). This inference to the rate of population change relates primarily to the population of territorial females in the study area, as has been noted by Anderson and Burnham (1992) and Burnham et al. (1994b, *this volume*). A power analysis indicated that there was only an 8.5% chance of detecting a significant trend given the estimated rate of change (i.e., the power of the test was low).

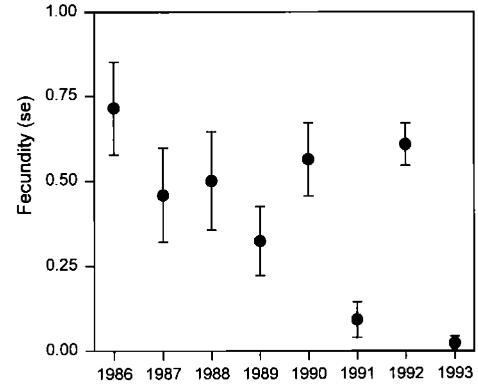

FIGURE 3. Annual fecundity estimates for ≥3-yr-old female Northern Spotted Owls on the Salem District Study Area in northwest Oregon, 1986–1993. Error bars indicate SE. Fecundity was defined as the mean number of female young fledged per female owl detected on the study area.

DISCUSSION

Although our estimate of λ was partially based on vital rates calculated from small samples for some age groups (namely, juvenile survival and subadult fecundity), we have no reason to reject the overall inference of a non-declining population from the data presented. This outcome was surprising considering that the northern Oregon Coast Ranges have been consistently identified as having little suitable habitat and few Spotted Owls (Forsman et al. 1977, Forsman 1988, Thomas et al. 1990, USDI FWS 1992, USDA and USDI 1994a). Because our sample was dominated by banded owls from the Western Cascades, a stationary population in that Province may have obscured a declining population in the Coast Ranges. But this explanation seems unlikely considering that a nearby study in the Western Cascades also found a declining population (Miller et al. *this volume*).

Because of the considerable uncertainty regarding possible biases in estimates of birth and death rates of Spotted Owls (Noon and Biles 1990, Anderson and Burnham 1992, Thomas et al. 1993, Burnham et al. 1994b, USDA and USDI 1994a, Franklin et al. 1995, Bart 1995, Raphael et al. *this volume*), we believe estimates of λ should be viewed with caution. However, the negative linear trend in adult survival during the study period is cause for concern, in that we know of no methodological biases that would cause such a trend. Burnham et al. (*this volume*) reported a similar trend on adult female survival from their meta-analysis of data from 12 demographic study areas.

Our sample of recaptured juveniles was small and dominated by a small cohort from 1986. Recognizing that both positive biases (temporary emigration) and negative biases (permanent emigration) could be effecting our estimates of juvenile survival, we believe that our estimate 0.402 for juvenile survival may be biased high as a result of the predominant influence of the 1986 juvenile cohort. The prospect of obtaining a large enough sample of capture-recapture data to adequately assess juvenile survival may be rather unlikely for the Salem Study Area, given the relatively low number of owls present, low reproductive output, and dispersed nature of sampling areas. For this reason, other methods (e.g., radiotelemetry of juveniles) may afford better estimates of juvenile survival than can currently be obtained using capture-recapture methods.

Given larger samples, it would also be more appropriate to evaluate the Salem data in two separate samples, because the data come from two physiographic provinces with markedly different amounts of suitable owl habitat (Raphael et al. *this volume*). A separate analysis of the Coast Ranges data will likely be possible only if we combine our data with data from other studies in the Oregon Coast Ranges, which we hope to do in future analyses.

Estimates of adult survival in the Salem Study Area were near the mean (0.844) reported for 11 study areas in Burnham et al. (1994b). We did not attempt to adjust estimates of juvenile survival to account for permanent emigration as did Burnham et al. (1994b), because no estimates of emigration were available for our study area. It is also likely that some adults occasionally emigrate. To the extent that adults and juveniles emigrated, survived, and went undetected, our estimates of adult and juvenile survival are biased low (Burnham et al. 1994b).

Although a number of biases could effect estimates of fecundity (Bart 1995), we were most concerned about differences in detectability of birds that nested successfully vs. pairs that either did not nest or that failed at nesting. In many cases where we were relatively certain that pairs of owls did not nest or failed at nesting, we could not find the birds enough times to meet the protocol for determination of numbers of young produced (Franklin et al. *this volume*). We were concerned that this could have caused a positive bias in estimates of fecundity, since pairs that nested successfully were usually fairly easy to locate. If we had included cases where we could not relocate pairs enough times to meet survey protocol, but where we were reasonably certain that they had produced no young, our estimate of fecundity for ≥3-yr-old females would have decreased by 1.5%. However, because of other factors that could cause positive or negative bias in estimates of fecundity (Reid et al. *this volume*, Raphael et al. *this volume*), we were reluctant to make adjustments to estimates of fecundity based on an analysis of only one source of possible bias.

Although our analysis indicated a stationary population, we urge caution in interpretation of our results. We are particularly concerned that potential biases affecting the data have not been fully resolved (e.g., Bart 1995, Raphael et al. *this volume*). In addition, our analysis was based on a combined data set from the Coast Ranges and Cascades Mountains Provinces. Thus, while our analysis may represent overall conditions for the entire study area, it may not represent specific conditions within the individual Provinces. Until these concerns are addressed, we believe that management agencies like the BLM would be well-advised to adopt a cautious approach to management of Spotted Owls.

SUMMARY

We estimated age-specific birth and death rates and population growth rates of Spotted Owls based on a sample of banded owls from the Coast Ranges and Western Cascades Ranges in northwest Oregon. Data were collected from 1986–1993. Most (74%) of the banded sample was from the Western Cascades Range Province. Juvenile and non-juvenile survival estimates from the best age-specific capture model were 0.402 (SE = 0.105) and 0.851 (SE = 0.022), respectively. Fecundity of ≥3-yr-old owls was 0.381 (SE = 0.036). The estimated finite rate of population change ($\hat{\lambda}$) was 1.019 (SE = 0.073), which did not differ from a stationary population ($P = 0.397$). Although our analysis did not indicate a significant decline in the population during the period of observation, the analysis did indicate that the adult survival rate was declining. Given the declining trend in adult survival and uncertainty regarding bias in demographic estimates we suggest that managers should continue to take a cautious approach regarding management of Spotted Owls in Northwestern Oregon.

ACKNOWLEDGMENTS

For assistance with field surveys and banding we thank S. Bahe, C. J. Beyer, M. Brown, C. A. Cooper, K. J. D'Angiolillo, S. Dowlan, J. S. England, J. N. Irving, D. Larson, L. Larson, M. K. Lohr, A. E. McCaull, R. W. Monthey, R. Pace, G. R. Ross, and L. Scofield. We also thank A. E. McCaull, J. Ponzetti, D. Larson, L. Larson and J. Zeyen-Hall for assistance with data verification and compilation. Special thanks to J. Alegria for statistical assistance. Analytical assistance was provided by D. R. Anderson, K. P. Burnham, J. Clobert, J. E. Hines, J. D. Nichols, R. Pradel, E. Rexstad, T. Shenk, G. C. White, and K. R. Wilson. Reviews by M. J. Conroy, D. W. Holt, T. Stevens, M. G. Raphael, and S. DeStefano improved the manuscript. Any errors in interpretation are our own.

Key words: demography, fecundity, mark-recapture, Northern Spotted owl, Oregon Cascades, Oregon Coast Ranges, population growth, *Strix occidentalis caurina*, survival.