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DEMOGRAPHY OF NORTHERN SPOTTED OWLS ON THE EUGENE DISTRICT OF THE BUREAU OF LAND MANAGEMENT, OREGON

JAMES A. THRAILKILL, E. CHARLES MESLOW, JOHN P. PERKINS, AND LAWRENCE S. ANDREWS

INTRODUCTION

Subsequent to a Status Review (Anderson et al. 1990), the Northern Spotted Owl (*Strix occidentalis caurina*) was listed as a federally threatened species. The review team concluded that the Spotted Owl population was at risk in significant portions of its range, primarily due to loss of habitat caused by logging. The review team also identified the central Coast Ranges of Oregon, as an "Area of Special Concern" because this region had been particularly heavily impacted by timber harvest.

In 1989, we initiated a demographic study of Northern Spotted Owls on the western half of the Eugene District of the Bureau of Land Management (BLM), which is located in the central portion of the Oregon Coast Ranges. The primary objective of the study was to provide information on Spotted Owl population trends within the highly modified forest environment that typifies the Oregon Coast Ranges. We also believed that this information would be useful for evaluating the effects of forest management practices on the species (Thomas et al. 1993).

Specific objectives of the study were to estimate age-specific birth, death, and reproductive rates of territorial Spotted Owls. Thomas et al. (1990) argued for the use of demographic parameter estimates to infer the rate and direction of population change for Spotted Owls. We also monitored changes in numbers of territorial owls detected within a smaller portion of the study area.

STUDY AREA

The 1,432 km² study area is located in the central Coast Ranges, 30 km west of Eugene, Oregon (Fig. 1). Contained within the larger surrounding study area is the 425 km² Wolf Creek Density Study Area (DSA). Throughout the study area, intermingled land ownership produces a checkerboard pattern of alternating square mile sections (2.6 km²) that are administered or owned by BLM (44%), the State of Oregon (2%), private industrial timber companies (43%), or "other" landowners (11%) (Fig. 1). Historically, the majority of federal and privately owned lands were managed for timber production, with clear-cutting the dominant harvest method. Topography is characterized by steep mountain slopes with narrow ridges and elevations ranging from 120 to 870 m.

The study area is bounded on the north, west, and south by four other Spotted Owl demographic study areas (Franklin et al. *this volume*), which facilitates the reobservation of dispersing owls. East of the study area is the south terminus of the Willamette Valley, a non-forested agricultural and urban/suburban valley.

Located within the western hemlock (*Tsuga heterophylla*) vegetation zone, the study area is dominated by forests of Douglas-fir (*Pseudotsuga menziesii*) and western hemlock (Franklin and Dyrness 1973). Based on air-photo interpretation, we mapped and calculated that 11% of the study area is covered by old forests in which the dominant overstory trees are >200 years old. Thomas et al. (1990) considered old forest as "superior" Spotted Owl habitat because radiotelemetry studies indicated that Spotted Owls consistently used older forests in excess of availability. On our study area, two percent of old forest habitat is located on privately owned lands, while 98% is on lands managed by BLM.

We classified an additional 13% of the study area as "suitable" habitat (generally mixed-aged forest between 51–199 years old) which meets some or all of the life history needs of the owl. The majority of suitable habitat is also located on BLM lands. Currently, 76% of the study area is covered by young forests (generally < 50 years old) that we consider as "unsuitable" for Spotted Owls because of deficiencies in tree size, canopy closure, and/or stand decadence. Most of the latter stands occur on areas that were cut and replanted.

Forest composition within the DSA was similar to the surrounding study area landscape based on our analysis of available Spotted Owl habitat. Old forest covered 14% of the DSA vs 11% of the surrounding study area.

METHODS

FIELD DATA COLLECTION

Personnel on the Eugene BLM District began a spotted owl monitoring and banding program

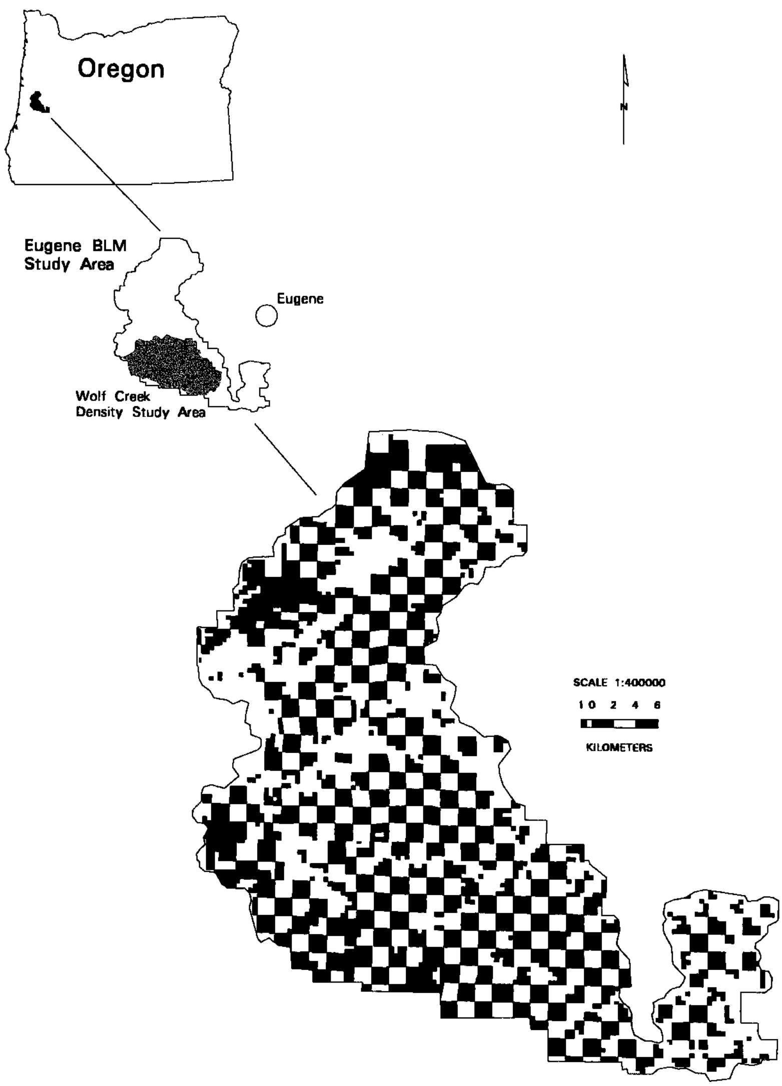

FIGURE 1. Northern Spotted Owl demography study area on the Eugene District of the Bureau of Land Management in the Coast Ranges of western Oregon, 1989–1993. Shaded subplot indicates location of the Wolf Creek Density Study Area (DSA) within the larger study area. Land ownership pattern is indicated by black BLM sections interspersed with white sections of non-federal ownership.

in 1986. Although our study did not formally begin until 1990, we included the cohort of owls banded by district personnel in 1989 (28% of our total sample) in our estimates of survival and fecundity. In 1990 we began annual surveys (April–August) on BLM and privately owned industrial forest lands within the study area with the intent of encountering "new" unbanded owls and reobserving previously banded owls. Field methods used for surveying, locating, determining sex, capturing, reobserving, banding, and determining owl reproductive status followed Franklin et al. (*this volume*) and Forsman (1983). Four Spotted Owl age-classes were distinguished: juveniles (J), 1-yr-old owls (S1), 2-year-old owls (S2), and ≥3-yr-old owls (A) (Forsman 1981, Moen et al. 1991).

Survey effort on the Wolf Creek Density Study Area was consistent from 1990–1993 and consisted of complete coverage with 6 replicate nighttime surveys each year during the nesting season (March–August). Within the study area (DSA excluded), we surveyed all known (historic) owl territories each year, to confirm and band any owls that were present and to determine their nesting status and numbers of young fledged. We defined an owl territory as a 2.4 km radius centered on an owl nest tree. This distance corresponded to the computed minimum convex polygon annual home range size of an owl pair within the study area (Thomas et al. 1990). The survey was consistent each year and included six replicate nighttime surveys before concluding a territory was unoccupied in a given year.

In addition, we conducted surveys in owl habitat located between owl territories (DSA excluded). The number of replicate surveys in habitat located between territories differed by year (0–3 nighttime surveys in 1990, and 5–6 nighttime surveys in 1991–1993). In 1991, the surveys resulted in an 18% increase in the number of territories that were located and incorporated into our sample. This increase in sample size was due primarily to an increase in the number of field biologists and resulting survey effort, not to an increase in the number of owls on the study area.

Data Analysis

Chi-square tests were used to assess annual variation in the proportion of pairs nesting during 1990–1993 (calculated by dividing the number of pairs nesting by the total number of pairs checked for reproductive activity before 1 June). Confidence intervals (95%) around mean proportions were calculated following Zar (1984:378–379). Fecundity was estimated for each age-class as the average number of female young produced per female each year. We assumed a 1:1 sex ratio and included all young located during the breeding period in fecundity estimates (Franklin et al. *this volume*). Annual variation in fecundity was analyzed using ANOVA (Zar 1984:162–170).

Goodness-of-fit tests 2 and 3 in program RELEASE were used to determine if the capture-recapture data met the assumptions underlying the global Cormack-Jolly-Seber capture-recapture model (Pollock et al. 1985, Burnham et al. 1987, Franklin et al. *this volume*). TEST 2 examines across recapture occasions for independence and heterogeneity. TEST 3 examines capture histories within release occasions and tests whether previously released individuals have the same future fates as newly released individuals. Survival and recapture rates were estimated from models produced in program SURGE (Lebreton et al. 1992). Notation of capture-recapture models included subscripts that indicated if a particular model included sex effects (s), age effects (a), non-linear time effects (t), or linear time trends (T) (Franklin et al. *this volume*). Akaike's Information Criterion (AIC) (Akaike 1973) was used to identify the most parsimonious model for each data set (Burnham and Anderson 1992, Lebreton et al. 1992, Franklin et al. *this volume*).

TABLE 1. Number of Northern Spotted Owls Banded and Used in Capture-recapture Analyses on the Eugene BLM Study Area in the Central Coast Ranges of Western Oregon, 1989–1993

	≥3 yrs old		1 or 2 yrs old			
Years	Female	Male	Female	Male	Unknown	Juveniles
1989	16	21	1	1	2	8
1990	4	5	3	4	1	13
1991	20	16	1	1	0	6
1992	8	3	0	1	0	30
1993	4	4	1	0	0	2
Total	52	49	6	7	3	59

The estimated annual rate of population change ($\hat{\lambda}$) during the period of study was computed from age-class estimates of annual survival (juvenile and nonjuvenile) and the mean estimate of fecundity for all females ≥1 yr old (Franklin et al. *this volume*). Estimates of the rate of population change referred to the resident territorial population, containing several age classes, and their recruitment (Franklin et al. *this volume*).

We used regression analysis to assess annual trends in the number of owls detected in the Wolf Creek Density Study Area. A power analysis was applied to the regression (Gerodette 1987).

RESULTS

Capture-Recapture Population

We banded 176 owls from 1989–1993, including 101 that were ≥3 yrs old, 16 that were 1 or 2 yrs old, and 59 juveniles (Table 1). The sample also included 3 owls that were banded as juveniles on adjacent study areas and subsequently immigrated to our study area.

Goodness-Of Fit and Model Selection

Goodness-of-fit tests 2 and 3 in program RELEASE indicated no lack of fit for the capture history data from ≥3-yr-old owls (males χ^2 = 0.85, df = 4, P = 0.932; females χ^2 = 3.30, df = 7, P = 0.855), suggesting that Cormack-Jolly-Seber open population models were appropriate for use with those data. For TEST 3, this indicated that owls within a released cohort had similar future expected fates. For TEST 2, this indicated that data for the various age and sex classes were statistically independent. We had so few recaptures of owls banded as juveniles or as 1- or 2-yr-olds that we could not conduct meaningful goodness-of-fit tests for those age groups.

The capture-recapture model that best fit the data from ≥3-yr-old owls had a non-linear time effect on survival, with the additional constraint that survival probabilities were equal in periods 1 and 2 (Table 2). In this model, there was also

TABLE 2. THE "BEST CANDIDATE" CAPTURE-RECAPTURE MODELS FOR NORTHERN SPOTTED OWLS ON THE EUGENE BLM STUDY AREA, OREGON, 1989–1993, AS DETERMINED BY AIC VALUES (AKAIKE 1977, FRANKLIN ET AL. *THIS VOLUME*). ONE ANALYSIS INCLUDED OWLS THAT WERE ≥3 YEARS OLD. THE OTHER ANALYSIS INCLUDED TWO AGE GROUPS, JUVENILES AND NONJUVENILES (≥1 YR OLD)

Model[a]	Deviance	K[b]	AIC[c]	ϕ[d]
≥3-yr-old owls				
$\{\phi_{t1=t2,t3,t4}, p_{t+s}\}$	235.630	8	251.630	0.860
$\{\phi_{T}, p_{s+T}\}$	244.739	5	254.739	0.846
$\{\phi, p_{s+T}\}$	253.537	4	261.537	0.854
Two-age-class models				
$\{\phi_{a2+T}, p_{a2+s*T}\}$	363.223	8	379.223	0.853
$\{\phi_{a2*T}, p_{a2+s*T}\}$	362.664	9	380.664	0.855
$\{\phi_{a2+T}, p_{a2+s+T}\}$	368.035	7	382.035	0.848

[a] Parameters are subscripted s for sex, t for time (year) with no linear trend, and T for time as a linear trend. An asterisk (*) indicates interactions. Additive effects in models are denoted with a "+".
[b] K is the number of estimable parameters from the model.
[c] AIC (Akaike's Information Criterion) is used to select objectively an appropriate "best" model.
[d] ϕ = estimate of survival for ≥3-yr-old owls or nonjuvenile owls.

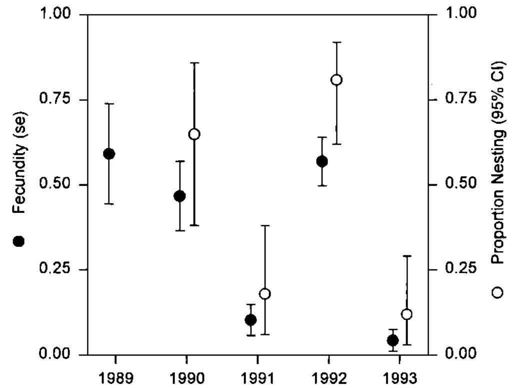

FIGURE 3. Reproductive statistics for female Northern Spotted Owls monitored on the Eugene BLM Study Area, Oregon, 1989–1993. Solid circles with associated SEs indicate mean annual fecundity, defined as the number of female young fledged per female owl. Open circles with associated 95% confidence intervals indicate the proportion of females nesting.

a non-linear time effect and a sex effect on recapture probabilities (Table 2).

The most parsimonious model for the two-age class data (juveniles and non-juveniles) included a linear time effect (T) on survival and a sex effect with an interactive linear time effect (s*T) on recapture probabilities (Table 2). A likelihood ratio test indicated that a competing model with the next lowest AIC value (Table 2) did not differ from the most parsimonious model ($\chi^2 = 0.559$, df = 1, P = 0.454).

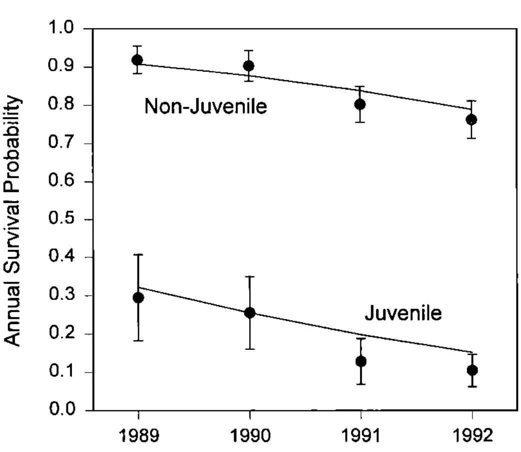

FIGURE 2. Estimates of annual survival probabilities of non-juvenile (≥ 1 yr old) and juvenile Northern Spotted Owls on the Eugene BLM Study Area, 1989–1993. The solid lines indicate nearly linear time trend in annual survival estimates from the selected two-age-class capture-recapture model ($\{\phi_{a2+T}, p_{a2+s*T}\}$). Point estimates and SEs of annual survival from a variable time model ($\{\phi_{a2+t}, p_{a2+s+t}\}$) are shown for comparison with the linear trend model.

ESTIMATED SURVIVAL RATES

Mean annual survival estimates from the selected 2-age-class model ($\{\phi_{a2+T}, p_{a2+s*T}\}$) were 0.232 (SE = 0.078) for juveniles and 0.853 (SE = 0.026) for non-juveniles (Fig. 2). Estimated survival rates were similar from several competing models with low AIC values (Table 2).

FECUNDITY

The proportion of pairs nesting varied among years ($\chi^2 = 67.00$, df = 3, P < 0.001), ranging from a high of 0.81 in 1992 to a low of 0.12 in 1993 (Fig. 3). Fecundity averaged 0.290 (SE = 0.036) for ≥3-yr-old females, 0.077 (SE = 0.077) for 1- and 2-yr-old females, and 0.272 (SE = 0.033) for all females combined. Successful reproduction by a 1- or 2-yr-old female occurred only one time during this study. Fecundity of all females combined varied among years (F = 28.29, df = 3, P < 0.001), ranging from a high of 0.583 in 1989 to a low of 0.038 in 1993 (Fig. 3).

RATE OF POPULATION CHANGE

The estimated annual rate of population change on the study area was 0.9134 (SE = 0.031), which was < 1.0 (z = 2.76, P = 0.003). This suggested an average annual decline in the territorial population of 8.7% over the study period.

Owl Abundance

The number of territorial owls detected on the Wolf Creek Density Study Area declined by 17% from 1990 to 1992 but, the decline was not significant ($r^2 = .702$, df = 3, P = 0.118). The power to detect a decline over the interval studied was relatively low (0.47). The number of owls detected ranged from a high of 36 in 1990 to a low of 29 owls in 1992 (1991 = 35, 1993 = 30).

DISCUSSION

Juvenile Survival

Banded juveniles that permanently emigrated from the study area, survived, and that were not reobserved, would cause a negative bias in estimates of juvenile survival, which would also result in an underestimate of the annual rate of population change (Burnham et al. *this volume*, Bart 1995). Of the 59 juvenile owls banded on the study area, 78% were not reobserved during the study period. We recaptured 7% of the banded juveniles on our study area while 15% were recaptured on adjacent study areas by other investigators.

If we assume that our estimates of fecundity and non-juvenile survival are accurate, then juvenile survival would have to be 0.603 to achieve $\lambda = 1.0$. A juvenile emigration rate (individuals that leave the study area, survive, and go undetected) of 0.61 would increase the observed juvenile survival rate of 0.23 to 0.603. An average annual juvenile survival rate of 0.603 for this area is possible but, seems biologically unrealistic. If the juvenile survival rate was 0.603, we believe more juveniles would have been reobserved, given the amount of survey area covered by our study and adjacent study areas (Franklin et al. *this volume*). However, one must consider two factors influencing juvenile recapture rates: (1) duration of study, and (2) juvenile dispersal behavior. Juvenile survival may be underestimated in short-term studies ($\leq$ 5 years) like ours simply because not enough years of data have been collected on recaptured owls marked as juveniles (Burnham et al. *this volume*). In addition, non-territorial subadult owls probably move throughout the landscape until they encounter a territorial vacancy or can replace a territory holder. During this time they do not readily vocalize; therefore, probability of recapture is low.

Adult Survival

Estimates of survival probabilities derived from the age-specific data (juvenile and nonjuvenile age groups) declined linearly during this study. We do not know if this trend is indicative of some underlying factor such as habitat loss, or is simply a short-term fluctuation. We know of no methodological bias that should have caused a trend in survival rates of non-juvenile owls.

In most capture-recapture studies of Spotted Owls, it is assumed that permanent emigration of territorial adults is relatively uncommon and that estimates of survival for adult owls are, therefore, reasonably accurate. This assumption seems to be supported by data from radiotelemetry studies in which only one occurrence of permanent emigration was observed in >100 owl years of study (Thomas et al. 1990). However, based on observations during our study, we believe the potential negative bias in survival estimates caused by emigration of non-juvenile owls may be underestimated.

Of 101 territorial owls that were banded on our study area in 1989–1992, 4.0% were confirmed to have relocated to adjacent study areas by 1993. Because these owls were recaptured after they left our study area, their movements were accounted for in the capture-recapture analysis, and did not cause a negative bias in survival estimates. However, it is highly unlikely that we detected all such movements, and this should be cause for concern, as any bias in survival estimates of adult Spotted Owls is likely to have a nearly equal bias on estimates of λ (Noon and Biles 1990, Bart 1995).

Future demographic studies of Spotted Owls should attempt to evaluate potential bias due to permanent emigration of both juvenile and non-juvenile owls (Bart 1995). One approach might be to examine movements of banded birds between or among adjacent study areas that are thoroughly searched for Spotted Owls each year. Another approach would be to use radiotelemetry techniques to monitor the movements of large samples of owls.

Fecundity

The high annual variation in the proportion of territorial females that nested on our study area could be due to fluctuations in food supply, weather, habitat alteration, or other factors influencing the reproductive physiology or behavior of the birds. For example, annual variation in breeding by Great Gray Owls (*Strix nebulosa*) and Tawny Owls (*Strix aluco*) fluctuates in response to rodent abundance (Duncan 1992, Southern 1970).

Rate of Population Change

A major finding from this study was the computed average annual population decline of 8.7%, or 30.5% over the course of the study (1989–1993). We do not disagree that the population of Spotted Owls on our study area is declining, but we do question the magnitude of the decline.

Given the potential biases in juvenile and adult survival rates, estimation of the rate of population change from capture-recapture data will always involve some degree of uncertainty.

Computed vital rates should only be considered in the context of this study area and the period of study. Spotted Owls are long-lived, and vital rates may vary. If the objective is to evaluate long-term trends in Spotted Owl populations in response to management activities, then studies will need to be continued as management plans are implemented, and habitat conditions gradually change. Consideration should also be given to conducting surveys for Spotted Owls in habitat outside of demographic study areas and among different land use allocations to provide an independent sample for comparison with the demographic area results.

CHANGES IN HABITAT AND OWL ABUNDANCE

Approximately 45% of the Density Study Area was comprised of owl habitat in 1984. From 1985–1989, approximately 18% of that habitat was clear-cut. Subsequent to court imposed harvest restrictions on federally owned lands in 1990, an additional 2% of owl habitat was harvested on the study area between 1990–1992. Most of the owl habitat on privately owned land within the study area was harvested prior to 1990.

The 17% decline in numbers of owls detected on the Wolf Creek Density Study Area during 1990–1993 could be a density dependent response, as the population adjusted to the lower carrying capacity subsequent to harvest of suitable habitat. Van Horne (1983) suggested that species densities may reflect conditions in the recent past or temporary present, rather than long-term habitat quality. However, Van Horne (1983) also cautioned against using density alone as an indicator of habitat quality. The combination of declining survival rates and declining abundance lends support to the hypothesis of a non-stationary, declining owl population on our study area. We suggest the population decline is due to the extensive harvest of Spotted Owl habitat in the central Coast Ranges.

SUMMARY

Demographic characteristics of the Northern Spotted Owl were studied on the Eugene District of the Bureau of Land Management in the central Coast Ranges of Oregon from 1989–1993. This region has been identified as an "Area of Special Concern" because past timber harvesting has greatly reduced the amount of Spotted Owl habitat. Survival rates were estimated from capture histories of banded owls, using Cormack-Jolly-Seber open population models. We banded 176 owls, including 101 that were ≥3 yrs old, 16 that were 1 or 2 yrs old, and 59 juveniles. The proportion of pairs nesting and fecundity of females varied among years ($P < 0.001$). Estimates of apparent annual survival from the selected capture-recapture model were 0.232 (SE = 0.078) for juveniles and 0.853 (SE = 0.026) for ≥3-yr-old owls. The estimated annual rate of population change (0.9134, SE = 0.031) was < 1.0 ($P = 0.003$) over the four years of study, suggesting a population declining at 8.7% per year. We believe the estimated rate of population decline may be somewhat exaggerated because of negative bias in survival estimates resulting from undetected emigration. On a portion of the study area that was thoroughly searched each year, counts of territorial owls decreased by 17% from 1990–1993. We suggest the owl population decline was due to the reduction of Spotted Owl habitat.

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Key words: Abundance, capture-recapture, demography, fecundity, Eugene Bureau of Land Management, Northern Spotted Owl, Oregon, *Strix occidentalis caurina,* survival.