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ARE BARRED OWLS DISPLACING SPOTTED OWLS?

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Abstract. Barred Owls (*Strix varia*) have expanded their range into the Pacific Northwest, and anecdotal evidence suggests that they may be displacing the federally threatened Northern Spotted Owl (*Strix occidentalis caurina*). Our objectives were to describe the current status of Barred Owls in Oregon and compare occupancy of Spotted Owls in historic Spotted Owl territories before and after Barred Owls were first detected in those territories. Between 1974 and 1998, we estimated that 706 different Barred Owl territories were located in Oregon. From 1989–1998 an average of 60 new Barred Owl territories were located in Oregon each year. In Spotted Owl demographic study areas in Oregon and Washington, Barred Owl detections increased at Spotted Owl territories from 1987–1999. Occupancy of Spotted Owl territories declined after Barred Owls were detected within 0.80 km of the territory center. When Barred Owls were detected 0.81–2.40 km from Spotted Owl territory centers, occupancy of Spotted Owls was only marginally less than at territories without Barred Owls. This suggests that the frequency and intensity of interactions between the two species is negatively associated with distance between them. Our results suggest that land managers and regulatory agencies should regard Barred Owls as a threat to Spotted Owls, particularly if Barred Owls continue to increase in number as they have during the past 25 years.

Key words: Barred Owl, competition, distribution, Northern Spotted Owl, occupancy, Strix occidentalis caurina, Strix varia.

¿Está *Strix varia* Desplazando a *Strix occidentalis caurina*?

Resumen. Desde su expansión hacia el Pacífico Noroeste, existe evidencia anecdótica de que *Strix varia* podría estar desplazando a *S. occidentalis caurina*. Nuestros objetivos fueron describir el estatus actual de *S. varia* en Oregon y comparar la ocurrencia de *S. occidentalis caurina* en sus territorios históricos antes y después de que *S. varia* se detectó por primera vez en dichos territorios. Entre 1974 y 1998, estimamos que se confirmaron 706 territorios diferentes de *S. varia* en Oregon. Entre 1989 y 1998, se localizaron en promedio 60 nuevos territorios de *S. varia* anualmente. En áreas con estudios demográficos de *S. occidentalis caurina* en Oregon y Washington, las detecciones de *S. varia* en territorios de *S. occidentalis caurina* se incrementaron entre 1987 y 1999. En comparación con territorios sin *S. varia*, la ocupación de territorios de *S. occidentalis caurina* disminuyó luego de que se detectaron individuos de *S. varia* a menos de 0.80 km del centro del territorio. Cuando se detectaron individuos de *S. varia* entre 0.81 y 2.40 km del centro de los territorios, la ocupación de éstos fue sólo marginalmente menor que en territorios sin *S. varia*. Esto sugiere que la frecuencia e intensidad de la interacción entre las dos especies está asociada con la distancia entre ellas. Nuestros resultados sugieren que las autoridades ambientales y de regulación deben considerar a *S. varia* como una amenaza para *S. occidentalis caurina*, particularmente si los números de *S. varia* se siguen incrementando como en los últimos 25 años.

INTRODUCTION

In the Pacific Northwest, considerable anecdotal evidence suggests that the recent range expansion of the Barred Owl (*Strix varia*) represents a threat to the Northern Spotted Owl (*Strix occidentalis caurina*, Dunbar et al. 1991, Hamer et al. 1994, 2001, Dark et al. 1998, Leskiw and Gutiérrez 1998). Barred Owls and Spotted Owls are congeneric, and Mayr and Short (1970) considered them a superspecies (recently diverged from a common ancestor). Northern Spotted Owls are currently listed as threatened under the Endangered Species Act (USDI 1990).

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Historically, the range of the Barred Owl was limited to eastern North America (Bent 1938). In the early 1900s the range of the Barred Owl gradually expanded westward across wooded regions of central Canada to British Columbia, then north into southeast Alaska and south into western Montana, Idaho, and Washington (Grant 1966, Shea 1974, Boxall and Stepney 1982, Sharp 1989, AOU 1998, Wright and Hayward 1998). Barred Owls were first detected in Washington in 1965 (Reichard 1974), in Oregon in 1974 (Taylor and Forsman 1976), and in California in 1981 (Dark et al. 1998).

Hypotheses that could explain the range expansion of the Barred Owl across Canada include (1) an increased adaptation to coniferous forests (Boxall and Stepney 1982), (2) climate change, such as an increase in summer rainfall and mean temperature, in regions outside of the Barred Owl's historical range (Johnson 1994), or (3) the creation of shelterbelts and riparian woodlands in the Great Plains (Dobkin 1994, Dark et al. 1998). Some have suggested that the range expansion of the Barred Owl was facilitated by forest management practices, specifically clearcut logging (Hamer 1988, Root and Weckstein 1994, Dark et al. 1998, König et al. 1999); however, there are no data to support or refute this hypothesis. In fact, the range expansion may have occurred regardless of forest management activities (Johnson 1994). Barred Owls occupy a broad range of forest conditions, from highly fragmented forests in managed landscapes to pristine forests in wilderness areas (Hamer 1988, Dunbar et al. 1991, Wright and Hayward 1998, Herter and Hicks 2000).

As a result of the recent range expansion, the range of the Barred Owl now overlaps most of the range of the Northern Spotted Owl. Barred Owls have become common in southwestern British Columbia, western Washington, western Oregon, and in other areas west of the northern Rocky Mountains (Dark et al. 1998, Herter and Hicks 2000, Mazur and James 2000). Despite the increasing sympatry between Barred Owls and Spotted Owls, changes in occupancy of historic Spotted Owl territories in the presence of Barred Owls have not been examined. Of primary concern is the impact of Barred Owls on demography and persistence of Spotted Owls. In this paper we describe the current status of Barred Owls in Oregon and compare Spotted Owl occupancy in historic Spotted Owl territories before and after Barred Owls were first detected in those territories.

METHODS

STUDY AREA

We compiled all historic detections of Barred Owls in the state of Oregon (Fig. 1). To evaluate trends in the number of Barred Owls and to examine occupancy of Spotted Owl territories with and without Barred Owls, we summarized data from five long-term demographic study areas in Oregon and Washington (Fig. 2). The demographic study areas were large areas where several different research groups used mark-recapture methods to estimate trends in Spotted Owl populations between 1987 and 1999. These areas were surveyed every year to locate banded owls, band any new owls that were detected, and document nesting status and productivity of owls (Franklin et al. 1996). Although they differed somewhat in terms of precipitation, elevation, and tree species composition, all of the demographic study areas were in mountainous regions dominated by a mosaic of young, mature, and old coniferous forest (Forsman et al. 1996). Two of the demographic study areas (Olympic Peninsula, H. J. Andrews) were located primarily on federal lands, and three (Cle Elum, Oregon Coast Range, Roseburg) were in areas that included a mixture of federal and private lands.

STUDY AREA

To characterize the distribution and population trends of Barred Owls in Oregon, we solicited sightings of Barred Owls from more than 300 individuals from public agencies and private companies. We also compiled data from published accounts, the Oregon Natural Heritage Program, Breeding Bird Surveys, and Audubon Christmas Bird Counts. Most Barred Owl records included the date and location plus information on the type of detection (auditory or visual), and number and sex of owl(s). We converted all locations to Universal Transverse Mercator (UTM) coordinates for analysis.

To calculate a conservative estimate of the number of different territories represented by multiple observations of Barred Owls, we assumed that all locations within a 1.43-km radius represented a single territory, unless there was evidence indicating otherwise (e.g., two same-sex owls or two pairs of owls observed $\leq$1.43

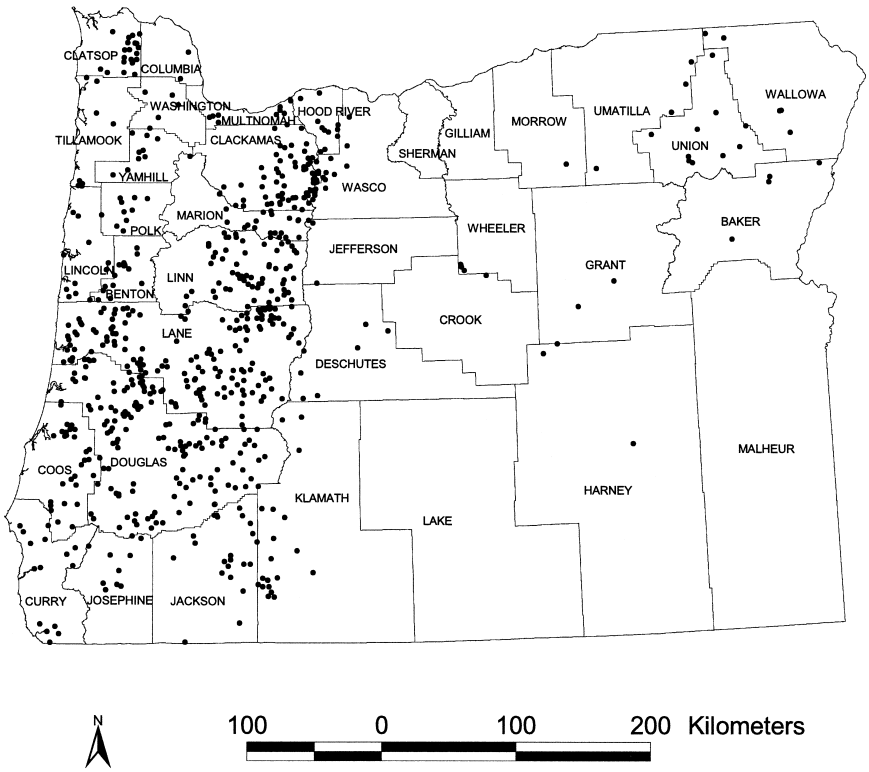

FIGURE 1. Location of 706 Barred Owl territories located in Oregon, 1974–1998.

km apart on the same night). A 1.43-km-radius circle corresponds to the average annual home-range size (644 ha) of individual Barred Owls in northern Washington (Hamer 1988), which reports the only data we could find on Barred Owl home ranges in western North America.

Most information on Spotted and Barred Owl locations came from surveys on demographic study areas, where field biologists followed strict protocols for locating Spotted Owls and estimating their productivity each year (Franklin et al. 1996). Surveys were conducted during the breeding season (1 March–1 September). The primary method of survey was to use a vocal lure (vocal imitation or playback of Spotted Owl calls) to stimulate owls to defend their territories. Most Spotted Owl territories were surveyed at least three times each year to locate and confirm banded owls, band any new owls that were detected, and determine the nesting status and number of young produced by each pair (Franklin et al. 1996). In rare cases, occupancy and nesting status were determined in two surveys.

Although Barred Owls were not the target of vocal lure surveys on demographic study areas, they responded to Spotted Owl calls and were often detected during surveys of Spotted Owls (Hamer 1988, Dunbar et al. 1991). When Barred Owls were seen or heard during Spotted Owl surveys, observers recorded the location, date, time of observation, type of detection (i.e., auditory or visual), number and sex of the individual(s), and reproductive status (if known).

Locations of Spotted and Barred Owls within each territory were reduced to a single set of UTM coordinates representing the center of the activity for each survey year. Centers of activity were based on a nest or location of fledged young. When no nest or young were found, the center of activity was based on one of the following in order of rank: diurnal locations of a pair or single owl, or nocturnal locations of a pair or single owl. When there were multiple sightings of a pair or single owl in the same year, visual locations were ranked higher than auditory locations, and early detections (i.e., during

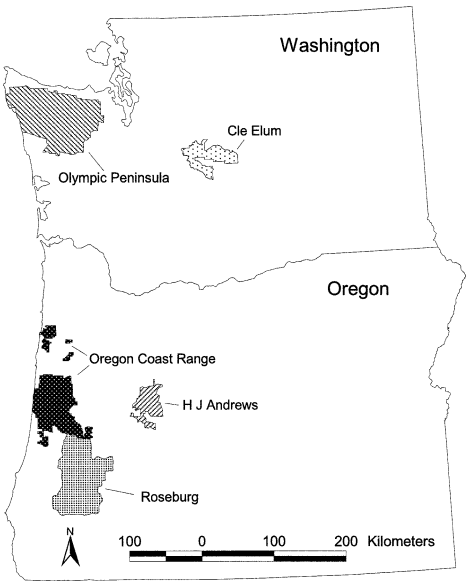

FIGURE 2. Location of five Spotted Owl demographic study areas in Oregon and Washington. Study area sizes: Cle Elum (1784 km^2), Olympic Peninsula (8145 km^2), Oregon Coast Range (3918 km^2), H. J. Andrews (1526 km^2), and Roseburg (6044 km^2).

courtship or breeding) were ranked higher than detections that occurred later in the breeding season. When no Spotted Owls were heard or observed, the territory was considered unoccupied.

STATISTICAL ANALYSIS

BARRED OWL DISTRIBUTION AND POPULATION INCREASE IN OREGON

In addition to estimating the total number of Barred Owl territories located in Oregon, we estimated the annual and cumulative change in the number of known Barred Owl territories in Oregon, and the annual increase in the percentage of Spotted Owl territories in which Barred Owls were detected on demographic study areas. For the latter analysis we used linear regression to test the hypothesis that the percentage of Spotted Owl territories in which Barred Owls were detected was constant among years. We conducted this analysis on Spotted Owl territories that were surveyed for at least six consecutive years and in which a Spotted Owl pair was present during at least one year. The analysis was conducted at two spatial scales around each Spotted Owl territory (0.80-km and 2.40-km-radius circles) to see if results were similar regardless of the spatial context. The 2.40-km-radius circle (1809 ha) is a conservative estimate of the average annual home-range area of pairs of Spotted Owls in western Oregon (Forsman et al. 1984). We used the 0.80-km-radius circle (201 ha) to represent the area of concentrated use or ''core area'' (Bingham and Noon 1997, 1998). All proportions were arcsine-transformed for analysis, but the results were essentially the same for the transformed and untransformed data, so we present the results of the analysis on the untransformed data.

OCCUPANCY OF SPOTTED OWLS IN HISTORIC TERRITORIES

We used paired *t*-tests to compare mean annual occupancy scores of Spotted Owl territories in years before Barred Owls were detected (pre-Barred Owl) with mean annual occupancy scores in years after Barred Owls were detected at the same territories (post-Barred Owl). We used a 5-class scoring system to rank the annual occupancy of each Spotted Owl territory, as follows: 0 = no owls detected; 1 = single male or female owl detected, resident status unknown; 2 = resident female or male detected (multiple detections of an unbanded owl or at least one observation of a previously banded resident); 3 = resident female or male confirmed, with response (auditory or visual) from owl of the opposite sex, pair status unknown; 4 = resident pair confirmed.

Spotted Owl territories used in this analysis met the following criteria: (1) Barred Owls were detected in one or more years, (2) surveys were conducted in at least six consecutive years, including at least two years before the first year of Barred Owl detection and three years after, and (3) a pair of Spotted Owls was present in at least one of the two years prior to or in the year of the first detection of Barred Owls. When no Spotted Owls were found in the year that Barred Owls were first detected in a territory, distance from the Barred Owl location to the territory center of the Spotted Owls was computed based on the most recent Spotted Owl location in previous years at the territory. This analysis was conducted at two spatial scales to determine if the influence of Barred Owls differed depending on whether they occurred close to the center of the Spotted Owl territory (0–0.80 km radius) or in more peripheral areas of the territory (0.81–2.40 km concentric ring).

TABLE 1. Three case history examples of Spotted Owl occupancy scores from paired samples of Spotted Owl territories in which Barred Owls were detected or not detected. Years in which Barred Owls were detected are indicated by asterisks. The mean difference in occupancy at Barred Owl-present territories was estimated by subtracting the mean annual occupancy score from years after the first Barred Owl was detected from the mean annual occupancy score from years before Barred Owls were detected. The mean difference in occupancy at Barred Owl-absent territories was estimated by calculating mean annual occupancy scores corresponding to the same years as the pre- and post-Barred Owl periods in the paired Barred Owl-present territory.

Pairs of Spotted Owl territories	Survey year									Mean difference
	1	2	3	4	5	6	7	8	9	
Case 1										
Barred Owl present	4	4	4	0	4	4	4*	4*	4	–0.67
Barred Owl absent	4	4	4	4	4	2	4	4	4	–0.33
Case 2										
Barred Owl present	4	4	4	4*	4*	3*	0	0	4	1.50
Barred Owl absent	4	4	4	4	4	4	4	4	4	0
Case 3										
Barred Owl present	4	4	4	2	0*	0	0*	0*	—	3.50
Barred Owl absent	4	4	4	4	4	4	4	4	—	0

Because we were concerned that year effects might confound our comparisons of Spotted Owl occupancy at individual territories, we conducted a second analysis in which we paired each of the territories used in the first analysis (Barred Owl-present territories) with a randomly selected Spotted Owl territory that was sampled during the same years on the same demographic study area, but with no detections of Barred Owls (Barred Owl-absent territories). This analysis was conducted on all demographic study areas except Cle Elum, which did not have enough Barred Owl-absent territories for a paired comparison. At each territory in each paired sample, the data were divided into two samples corresponding to the pre-Barred Owl and post-Barred Owl periods at the Barred Owl-present territory. Then we calculated the mean Spotted Owl occupancy score during each period and subtracted the post-Barred Owl score from the pre-Barred Owl score to obtain the mean difference between the two scores at each territory (Table 1). We then used a paired *t*-test to determine if the difference in means was different between Barred Owl-present and Barred Owl-absent territories (F. L. Ramsey, pers. comm.). This analysis was conducted using the same spatial scales and sample restrictions as the previous analysis, with the exception that Barred Owl-absent territories were used. Values reported are means ± SE. All *t*-tests were two-tailed, and we used $P < 0.05$ as the criterion for determination of statistical significance (SAS Institute Inc. 1998).

RESULTS

BARRED OWL DISTRIBUTION AND POPULATION INCREASE IN OREGON

The first record of a Barred Owl in Oregon was a pair observed in the Wenaha River drainage of the Blue Mountains in the northeast corner of the state in June 1974 (Taylor and Forsman 1976). Barred Owls were reported in the same area through 1978. Subsequently, there were sightings of Barred Owls in the Oregon Cascades Range near Mt. Hood in Clackamas and Wasco Counties in 1979 (Harrington-Tweit et al. 1979). In 1981, single adults were detected in the southern Cascades in the Mountain Lakes Wilderness, Klamath County, and on the west side of the Cascades in Lane County (Nehls 1998).

After these early records, sightings of Barred Owls rapidly accumulated, and by 1998, we estimated there were 706 territories where Barred Owls had been observed in one or more years in Oregon (Fig. 1). The 706 territories were derived from 2468 Barred Owl detections from 1974–1998. Although the southward progression of Barred Owl records in the Washington Cascades (Harrington-Tweit et al. 1979, Hamer 1988) suggests that Barred Owls moved south in the Cascades Range into western Oregon, it is also possible that they moved southwest from northeastern Oregon into the Oregon Cascades (Fig. 1).

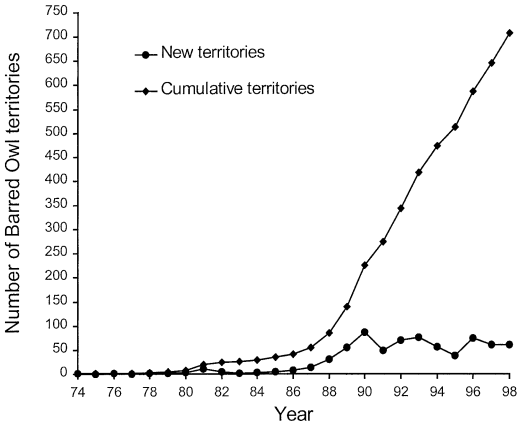

FIGURE 3. Estimated number of new and cumulative Barred Owl territories reported each year in Oregon, 1974–1998.

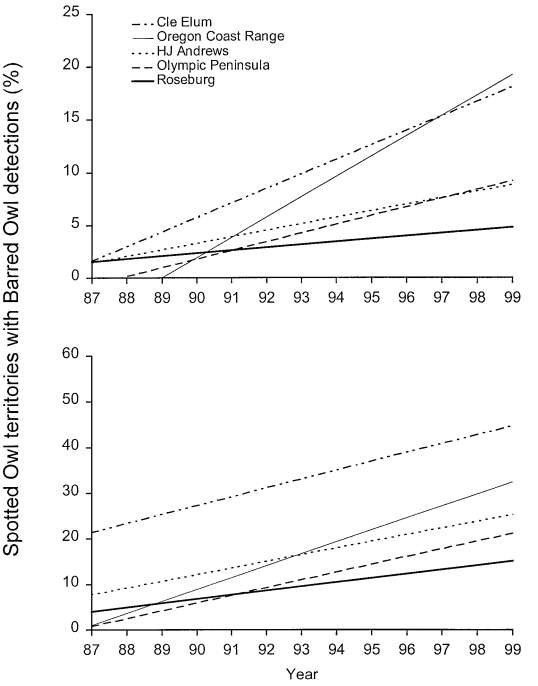

FIGURE 4. Linear regression of percentage of Spotted Owl territories with Barred Owl detections on year within five Spotted Owl demographic study areas in Oregon and Washington. Top and bottom graphs depict results from 0.80- and 2.40-km-radius circles, respectively.

The distribution of Barred Owl territories identified in 1974–1998 is heavily skewed toward western Oregon (Fig. 1). Although this may reflect differences in relative abundance of Barred Owls in eastern and western Oregon, it is at least partly due to survey effort. Western Oregon was intensively and extensively surveyed for Spotted Owls from 1972–1998, whereas comparable surveys were not conducted in eastern Oregon. However, much of southeast Oregon is not forested, so the paucity of Barred Owl records in that region is probably due to the absence of suitable habitat.

The cumulative number of new Barred Owl territories discovered between 1974 and 1998 suggests a steady linear increase in Oregon (Fig. 3). From 1989–1998, approximately 60 new Barred Owl territories were reported each year (Fig. 3). There was a positive linear association between percentage of Spotted Owl territories with Barred Owl detections and year on nearly all demographic study areas, regardless of whether the spatial context was a 0.80-km or 2.40-km circle (Fig. 4). The only exception was the Cle Elum study area, where the number of Spotted Owl territories with Barred Owl detections was positively correlated with year at the 0.80-km circle size but not at the 2.40-km circle size (Table 2).

TABLE 2. Results of linear regression analyses of percentage of Spotted Owl territories with Barred Owl detections on survey year.

Study area	Survey years	Number of territories	n	0.80-km-radius circle r^2	2.40-km-radius circle r^2
Washington					
Cle Elum	1989–1999	66	11	0.50*	0.18
Olympic Peninsula	1987–1999	91	13	0.66**	0.65**
Oregon					
Oregon Coast Range	1990–1999	174	10	0.86**	0.85**
H.J. Andrews	1987–1999	110	13	0.53**	0.49**
Roseburg	1987–1999	251	13	0.50**	0.70**

* $P < 0.05$; ** $P < 0.01$.

TABLE 3. Mean ± SE annual occupancy scores at Spotted Owl territories in years before and after Barred Owls were detected in the territory. Data summarized from five Spotted Owl demographic study areas in Oregon and Washington, 1987–1999.

	Center of Spotted Owl territory	
	≤0.80 km from Barred Owl detection	0.81–2.40 km from Barred Owl detection
Spotted Owl mean annual occupancy score prior to Barred Owl detection	3.42 ± 0.08	3.25 ± 0.09
Spotted Owl mean annual occupancy score after Barred Owl detection	2.16 ± 0.16	2.98 ± 0.13
Mean difference	1.26 ± 0.18	0.27 ± 0.l4

OCCUPANCY OF SPOTTED OWLS IN HISTORIC TERRITORIES

Within territories. At Barred Owl-present territories, mean annual occupancy scores declined after Barred Owls were detected within 0.80 km of territory centers ($t_{83} = 7.1$, $P < 0.001$, Table 3). When Barred Owls occurred 0.81–2.40 km from the territory center, mean annual occupancy scores of Spotted Owls were only marginally lower after Barred Owls were first detected ($t_{84} = 1.9$, $P = 0.06$, Table 3).

Between territories. The paired comparison of occupancy scores indicated that, after Barred Owls were detected within 0.80 km of the territory center, Spotted Owl occupancy declined at Barred Owl-present territories relative to Barred Owl-absent territories (mean difference = 1.08 ± 0.24, $t_{72} = 4.6$, $P < 0.001$). When Barred Owls were detected 0.81–2.40 km from the territory center, there was no difference in occupancy of Spotted Owls between Barred Owl-present and Barred Owl-absent territories (mean difference = −0.18 ± 0.19, $t_{75} = -0.9$, $P = 0.35$).

DISCUSSION

We identified 706 Barred Owl territories in Oregon between 1974 and 1998, with an average of 60 new territories found each year between 1989 and 1998. Barred Owl detections at Spotted Owl territories increased steadily at all five demographic study areas in Oregon and Washington between 1987 and 1999. Our study suggests that when Barred Owls invade Spotted Owl territories, mean annual occupancy of Spotted Owls declines relative to territories without Barred Owls.

Our estimate of 706 Barred Owl territories in Oregon is a cumulative count, and cannot be used to directly estimate total population size for several reasons. First, Barred Owl territories may not have been consistently occupied in all years after they were first detected. Second, our collection of Barred Owl records was extensive, but we were only able to obtain data from a small percentage of the private landowners in Oregon. Third, most Spotted Owl survey efforts on federal lands in 1987–1998 were limited to demographic study areas, and survey data from intervening areas of federal land were not always available. Fourth, we used a 644-ha circle (1.43-km radius) to estimate the number of territories represented by the total sample of Barred Owl locations in Oregon. This estimate of the average annual home-range area of individual Barred Owls was based on a single study in northern Washington, and it is possible that home ranges are smaller in Oregon. Studies of Barred Owls in the eastern United States indicate that Barred Owls have smaller home ranges in that region than were reported in the northern Washington study (Laidig and Dobkin 1995). These various biases may cancel each other to some extent, but the net effect is that our data undoubtedly underestimate the total Barred Owl population in Oregon. The annual increase in the Barred Owl population indicated by our analysis could be slightly inflated if some Barred Owls moved between territories in different years. We could not evaluate the magnitude of this bias, but believe that it was small. Regardless, it is obvious that the Barred Owl population is increasing rapidly in Oregon.

The fact that mean annual occupancy of Spotted Owls declined after Barred Owls were detected within 0.80 km of the territory center, but did not change when Barred Owls were detected at greater distances, suggests that the frequency and intensity of interactions between the two species is negatively associated with distance between them. However, Barred Owl presence

within 0.80 km of the Spotted Owl territory center does not necessarily lead to displacement, as some pairs of Spotted Owls persisted (or new ones arrived) at territories even after Barred Owls were detected near the territory center.

Some complicating factors that we ignored in our analyses of Spotted Owl occupancy at historic territories were the status (single, paired, breeding) of Barred Owls that were observed, the number of years that Barred Owls were detected at a site, the number of times that Barred Owls were detected during a particular year, and differences among territories in habitat condition or quality. Ideally, these factors should have been included in a multivariate model of effects, but this was beyond the scope of our analysis. Had these factors been included, we suspect they might have explained additional variation in the data.

Implicit in our analysis of Spotted Owl occupancy was the assumption that Barred Owls could be detected during surveys for Spotted Owls and that Spotted Owls could be detected if they occurred in areas where Barred Owls were present. Both of these assumptions were undoubtedly violated to some extent, because we know that surveys of owls do not detect all individuals that are present (Reid et al. 1999), and because Spotted Owls may be less likely to respond to vocal imitations or recordings if Barred Owls are present. It is also possible that the nesting status of Spotted Owls caused a sampling bias in detection of Barred Owls, because observers in demographic study areas often had to make more visits and survey larger areas to locate non-nesting Spotted Owls. This would mean that Barred Owls near non-nesting Spotted Owls would be more likely to be detected than those near nesting Spotted Owls. We are unsure how much these factors influenced our results, although we do know that detection probabilities of Spotted Owls in demographic study areas are in the mid-90th percentile after three surveys (Reid et al. 1999).

If Barred Owls continue to increase their range, it will be important to include the presence or absence of Barred Owls as a covariate in analyses of survival and fecundity of Spotted Owls. This presents a scientific dilemma, because anecdotal evidence suggests that surveys targeting Barred Owls (i.e., using Barred Owl instead of Spotted Owl calls) may reduce Spotted Owl responses during the survey period (T. E. Hamer, pers. comm.). In addition, Spotted Owls responding to vocal lure surveys may be vulnerable to harassment or predation by Barred Owls (Leskiw and Gutiérrez 1998). Additional study is needed to determine if these are serious issues or can be dealt with using modified survey techniques.

Inferences from our study can probably be extended to most federal lands in Oregon and Washington within the range of the Spotted Owl. Our results suggest that land managers and regulatory agencies should regard Barred Owls as a threat to Spotted Owls, particularly if Barred Owls continue to increase in number as they have during the past 25 years. Should current trends continue, studies of other avian species indicate that two scenarios seem possible: Barred Owls could eventually displace Spotted Owls, or Barred Owls and Spotted Owls could reach some state of equilibrium, with both species present throughout the area or with Spotted Owls present only in some parts of their historic range (Gill 1980, Confer and Knapp 1981). Further study of the competitive interactions between these two species is needed to predict which of these scenarios is most plausible.

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