HOME RANGE SIZE OF THE NORTHERN BARRED OWL AND NORTHERN SPOTTED OWL IN WESTERN WASHINGTON

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The Department Of Biology

Western Washington University

In Partial Fulfillment

Of the Requirements for the Degree

Master of Science

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by

Thomas Edward Hamer

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MASTER'S THESIS

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ABSTRACT - The morphology, density, home range size and home range utilization of a population of northern barred owls (Strix varia) and northern spotted owls (Strix occidentalis caurina) were studied in northwest Washington.

Spotted owls are 17.9% lighter in weight, have a slightly smaller body size, similar wing loading, and a much larger foot spread than barred owls. Mean nearest neighbor distance for barred owls was 3.17 km (range=1.8-5.4,N=16) while spotted owls were 2.3 times more distant at 7.3 km (range=3.6-11.2, N=6). The difference in these distances is reflected in the population densities of the two species with barred owls being 2.1 times more numerous than spotted owls in the study area.

Using the minimum convex polygon method, mean barred owl summer home ranges were 321.5 ha (range=145-506, S.D.=139.3, N=8) while mean spotted owl summer home ranges were not significantly different at 321.2 ha (range=73-862, S.D.=371.3, N=4). Breeding barred owls had significantly smaller home ranges than non-breeding birds. The average annual spotted owl home range (mean=2,816 ha, range=1,200-7070, S.D.=2,841, N=4) was 4.4 times larger than the mean annual barred owl home range (mean=644 ha, range=205-1,326, S.D.=293.5, N=10). Mean annual pair home ranges of barred owls were 905 ha (range=587-1,477, N=4 pair) while spotted owl pairs averaged 4,750 ha (range=2,430-7070, N=2pair). Barred owl pairs showed higher home range overlaps (mean=39%, range=16-62%) than spotted owl pairs (mean=18%, range=17.1-19.1%). Home ranges of barred and spotted owls in this study are much larger than those reported by other researchers.

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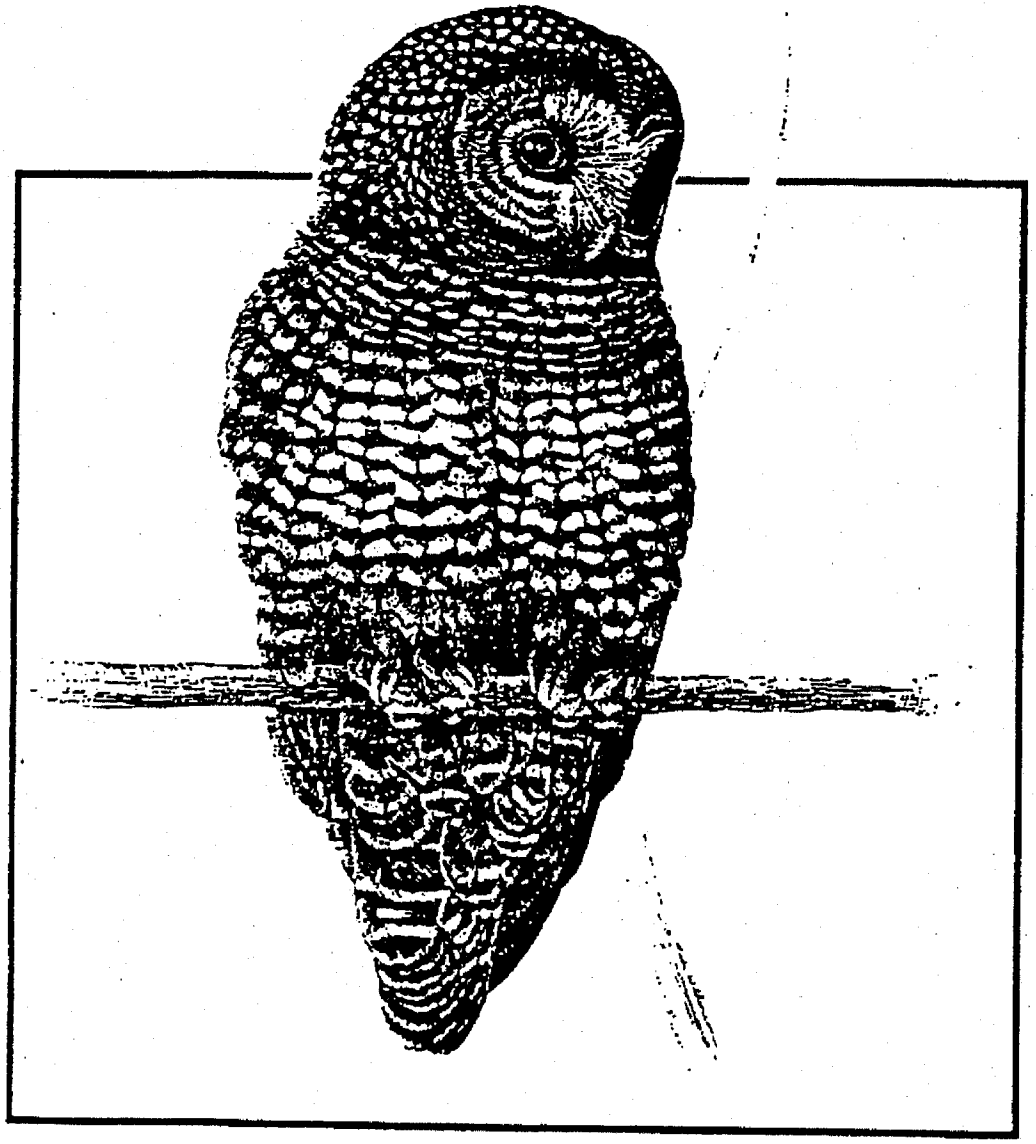


INTRODUCTION

The northern spotted owl (Strix occidentalis caurina) inhabits low elevation old-growth forests in the Pacific Northwest from southern British Columbia through the Cascade Range in Washington and Oregon, Olympic Peninsula and coastal mountains of Oregon and California (Fig. 1). There has been a significant reduction of low elevation old-growth forest habitat throughout the northern spotted owl range within the last 80 years. Recent studies indicate that northern spotted owl populations in Washington, Oregon and California are declining, concurrent with the gradual elimination of old-growth coniferous forest (Forsman et al., 1977; Forsman, 1976; Marcot and Gardetto, 1980).

The spotted owl is State listed as a threatened species in Oregon and was recently added to the State of Washington endangered species list. The major reason for listing is concern for the decline in old growth forests. Only 10% of the original old-growth forest is estimated to remain in Washington. As a result, management of the spotted owl has become a concern to conservation and environmental groups as well as to wildlife biologists and forest managers.

The Northern Barred owl (Strix varia varia) is an inhabitant of mixed hardwood and coniferous woodlands east of the Rocky Mountains ranging from the east coast of the United States to the

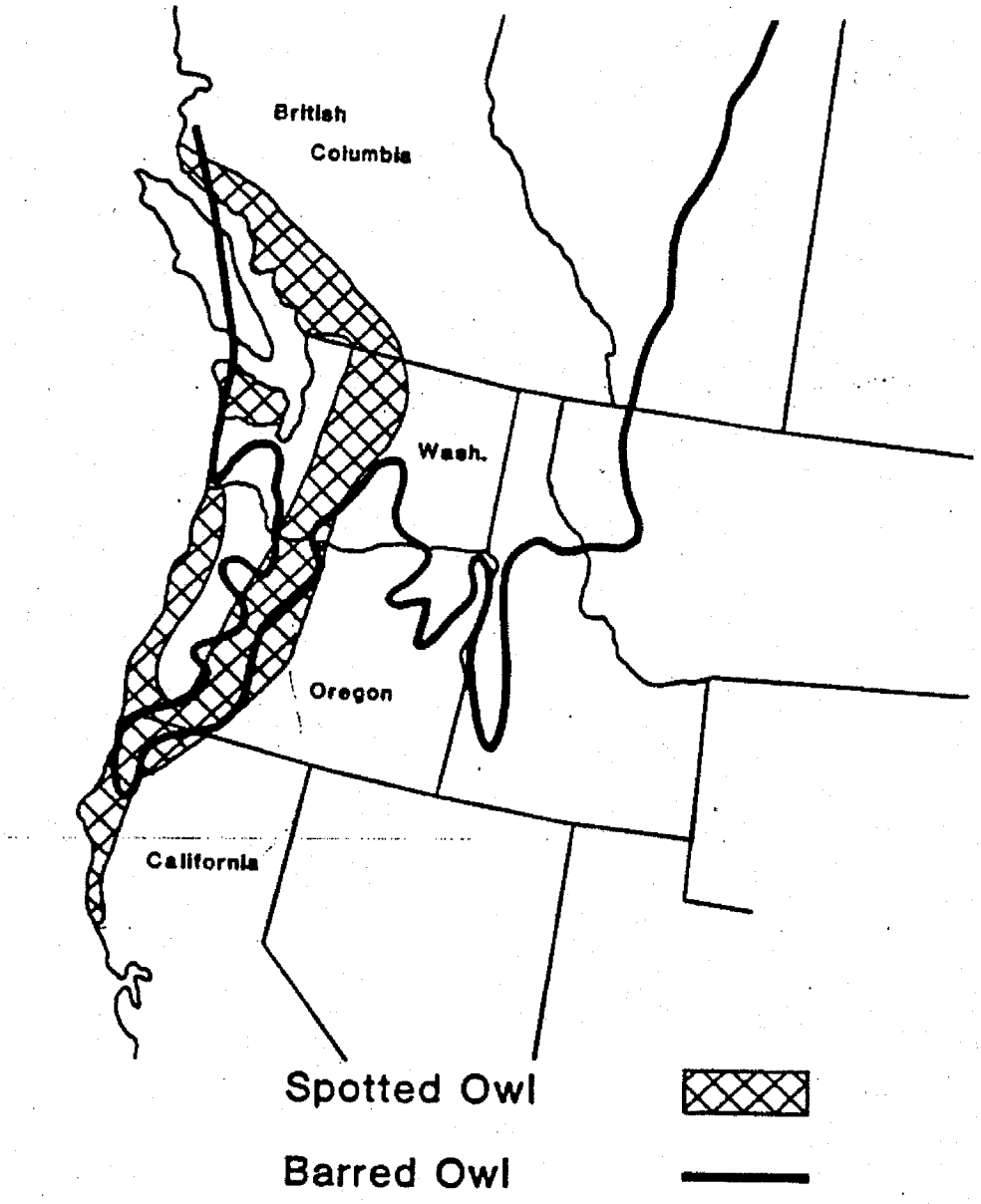
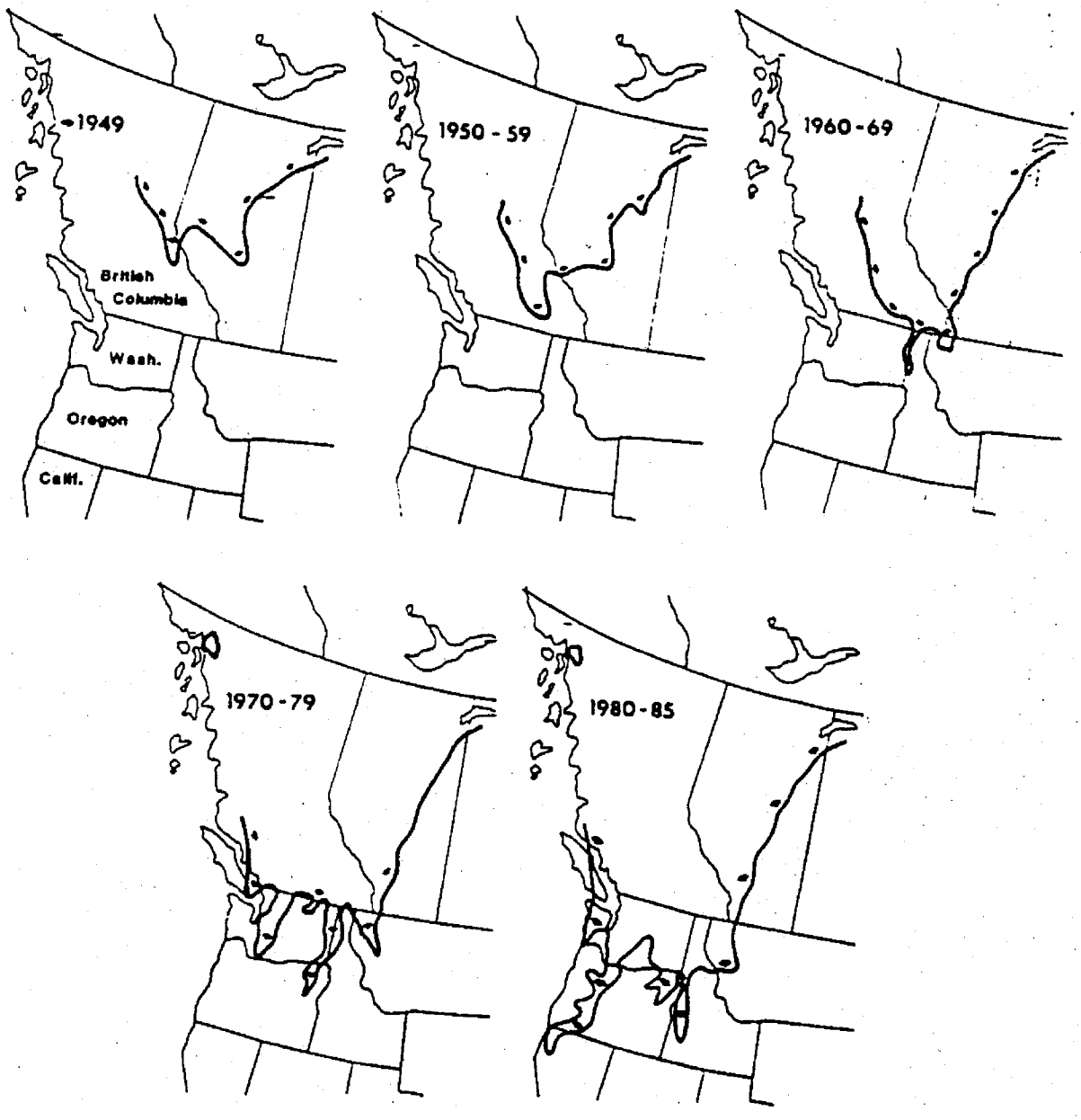


Figure 1 . Geographic range overlap of the barred owl and spotted owl in the Northwest in 1985. The two species are now sympatric in British Columbia, Washington, Oregon and Northern California.

western Canadian provincesbut more abundant in eastern North America (Burton, 1973). Recent records from western North America indicate the barred owl has rapidly expanded its range into the Pacific Northwest during the last three decades (Grant, 1966; Hamer and Allen, 1985). The series of maps depicted in Figure 2 show the progress of the range expansion in ten year periods beginning with a few records collected prior to 1949 (Hamer and Allen, 1985). The figure illustrates the remarkable ability of the barred owl to expand its geographic range over long distances in a relatively short period of time.

The barred owl appears to have taken advantage of extensive habitat alterations in the northwest and expanded its geographic range into these disturbed areas. The problem of range expansions by non-native species has been clearly stated by Knopf (1986) in a paper on changing landscapes. Knopf (1986:137) writes that "changes in landscapes are causing subtle but potentially dramatic changes in the distribution of native species". The dispersal corridor depicted in Figure 2 presumably has acted as a filter bridge which has allowed the barred owl to come in contact with the once geographically isolated but closely related species, the Northern spotted owl (Strix occidentalis caurina). Many other examples exist where habitat alterations created filter bridges allowing one species to come in contact with other, once isolated species. Such examples include the hybridization of the blue jay (Cyanocitta cristata) and Stellar's

Figure 2. Range expansion of the northern barred owl in ten year periods from 1949 to 1985.


1949
British Columbia
Wash.
Oregon
Calif.
1950 - 59
1960 - 69
1970 - 79
1980 - 85

jay (Cyanocitta stelleri) and the merging of the red-shafted flicker and yellow shafted flicker into one species (Colaptes auratus) (Knopf, 1986).

By 1985, the geographic range of the barred owl almost overlapped the entire range of the northern spotted owl, except in a small portion of northwest California and western Oregon (Figure 1) (Allen and Hamer, 1985). These two congeneric species are now sympatric throughout the Cascade Ranges and Coast Ranges from Garibaldi Provincial Park, British Columbia, south to northern California. Whether these two species can coexist sympatrically for any length of time is unknown. A large overlap in the resource requirements may make coexistence of the two species unlikely.

No information exists on the home range size, habitat requirements, food habits, activity patterns or behavior of the barred owl west of the Rocky Mountains. Three radio-telemetry studies conducted in the midwest have attempted to estimate the home range size of barred owls. Nicholls and Warner (1972), and Fuller (1979), found the average home range size for barred owls in Minnesota was 273 ha (N=13, range=86.1 to 770 ha). The average home range size for barred owls in Michigan's upper peninsula was 282 ha (Elody and Sloan, 1985). One other study estimated the density of breeding pairs of barred owls in northern New Jersey using surveying techniques. They found .142 barred owl pairs per square kilometer (Bosakowski et al., 1987).

Two studies in Washington and Oregon have used radio-telemetry techniques to estimate the home range size of spotted owls. Forsman et al. (1984) found that an average pair home range size in Oregon varied from 172 ha to 1154 ha (mean=1177 ha, N=3 pair). Brewer and Allen (1985) reported an average annual home range of 3703 ha per pair in Washington (N=6 pair). Finally, Allen (1987) later reports that a mean individual spotted owl home range in Washington is 1963 ha (N=18 range=406-7134). All the estimates above are based on the minimum convex polygon method for calculation of home range size.

The long term goals of the study are to answer some basic questions about the biology of the northern barred owl and northern spotted owl in an area of sympatry and begin to evaluate the possible impact of the barred owl on spotted owl populations. The objectives for the first year of research were to:

1) Document the relative density of barred and spotted owls in the study area.
2) Estimate breeding season (March through August) and annual home range (March through February) sizes for five pairs of northernbarred owls and two pairs of northern spotted owls, and for each individual owl.
3) Compare four different techniques to estimate home range size. These are the minimum convex polygon, harmonic mean transformation, Fourier transformation and 95% ellipse.

Information was also collected on the habitat use by both species, activity patterns, territorial behavior and interspecific interactions which will be reported elsewhere.

STUDY AREA

The study area is located in Northwest Washington in the Baker Lake Basin on the west slope of the North Cascade Mountains and comprises an area of 357 square kilometers (138 sq. miles) (Figure 3). Baker Lake lies just south of Mt. Baker, a dormant volcano, with much of the study area comprising the lower forested slopes of the mountain itself. This area was selected because previous surveys for spotted owls had been conducted throughout the drainage and thus many locations of both barred and spotted owls were known. All the land is managed by the U.S.F.S. and is part of the Mt. Baker Ranger District.

The study area is part of the North Cascades Physiographic Province described by Franklin and Dyrness (1973). The topography of the area consists of very deep and steep sided valleys of maximum relief. Elevations range from 244 m on the valley floor to 3,283 m on the peak of Mt. Baker. Areas above 1,980 m are heavily glaciated and commonly consist of permanent snow fields. The region is characterized by a wet, mild maritime climate and precipitation is highly variable. The mean annual precipitation is 254 cm with most of the moisture falling during the winter in the form of rain. Snow can accumulate in the valley floor during some winters but snowpack is highly variable between years. Summer drought is common with only 6-9 % of the annual precipitation falling during this period. The mean annual temperature is 10.1 C. Mean July temperature is 17.4 C and the

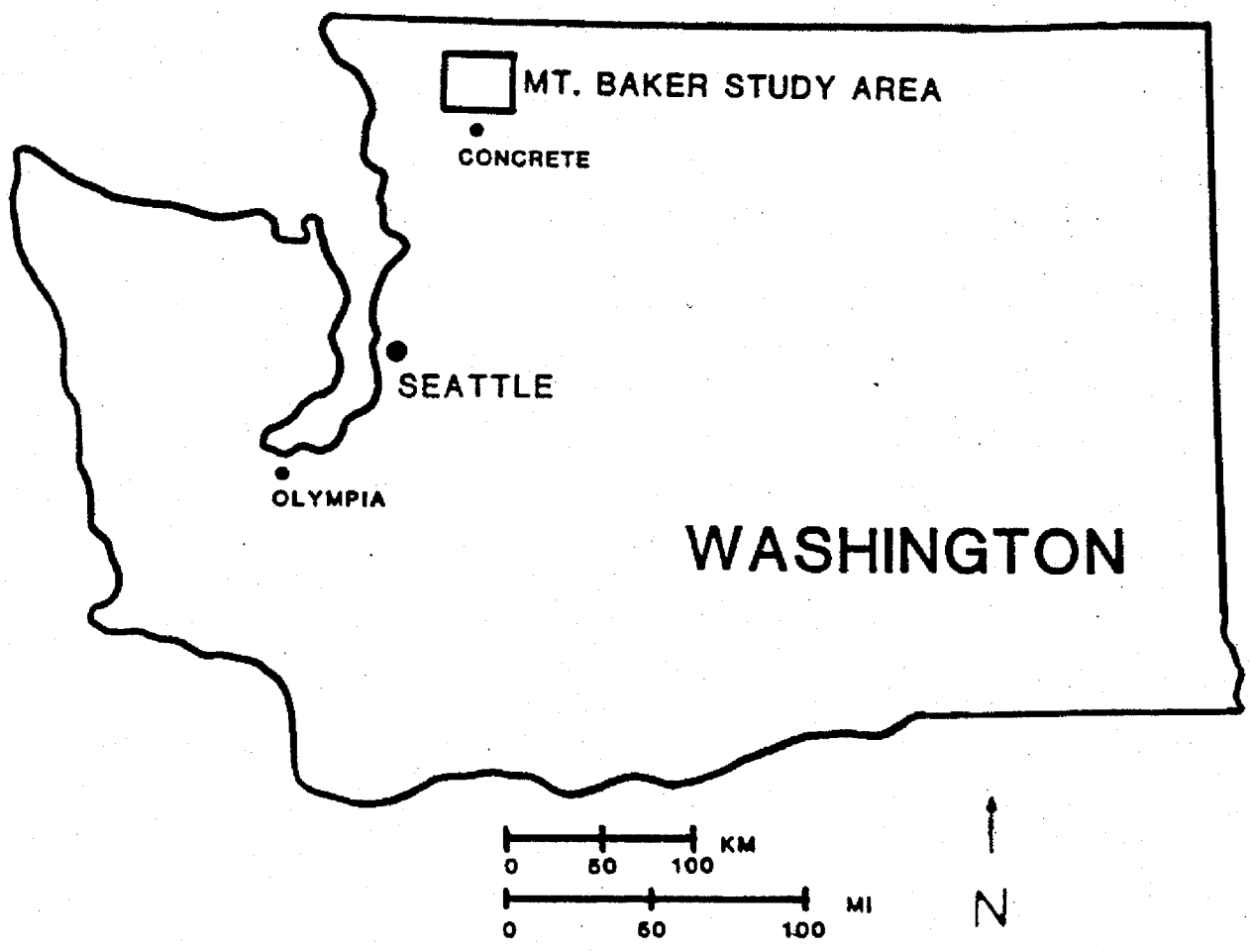


Figure 3 . Location of the Mt. Baker study area for barred and spotted owls during 1986 and 1987 in Northwestern Washington.

mean January temperature is 1.0 C.

The study area is entirely forested except areas that have been recently clear-cut and those portions over 1,800 m in elevation which are above treeline. Three forest vegetation zones occur here. The Western Hemlock zone occurs primarily along the lower reaches of major drainages while the Mountain Hemlock zone occurs above 1000 m in wetter areas. The Silver fir zone occurs on cooler, mid-elevation slopes from 400 m to 900 m in elevation. Forest stands are of various ages and conditions from pristine old-growth associations to heavily disturbed younger aged stands that have been high-graded or clear-cut within the last 60 years. Portions of the study area are highly fragmented due to current forest management practices while other areas contain large contiguous forest stands.

METHODS

Location of owls

The U.S. Forest Service, Washington Department of Wildlife, Biosystems Analysis Incorporated and Puget Power and Light Company have all conducted nothern spotted owl surveys in portions of the study area between 1981 and 1984. The Mt. Baker Ranger District continued its surveys in 1986 and 1987 as part of the U.S.F.S. spotted owl monitoring effort being conducted forest wide. From this information many of the locations of barred owl and spotted owl pairs were known. During the spring of 1986 and 1987 I re-surveyed much of the study area to confirm the locations of these pairs, document the locations of new pairs, and establish trapping sites.

Surveys to locate barred and spotted owls were conducted after dusk from March 1st through June 30th. They were discontinued after June 30th because the responsiveness of the owls declined. Survey methods generally follow that described by Forsman et al. (1984) with owls located using pre-recorded vocalizations, portable cassette recorders and megaphone speakers. Both spotted owl and barred owl vocalizations were played back at each station although I found barred owls to be responsive regardless of the type of call used.

Calling inventories were conducted by driving along forest roads and stopping at .4 km (1/4 mile) intervals to call and listen for owls. Observers waited for responses for 15-20 minutes at each

station. Surveys were also conducted along forest trails and overgrown roads by calling every few minutes as the area was traversed on foot.

To document the spacing of barred and spotted owls in the study area, mean nearest neighbor distances were calculated by measuring the distance between repeated survey locations of owl pairs and individuals, or by measuring the distance between nest sites or core areas (for radio-tagged pairs). Core areas were delineated by the harmonic mean transformation method of home range estimation using the 25% isopleth. Nest sites were found by following radio-tagged females back to their nesting cavities.

Radiotelemetry data collection

Several methods were used to capture barred owls and spotted owls. The most successful method I used to capture barred owls was a technique described by Elody (1983). Three 121 mm stretch nylon mist nets were arranged in a large triangle and supported by 3 meter long aluminum poles. A live decoy barred owl was placed on a perch within the nets along with a large megaphone speaker which was connected to a cassette recorder in a blind constructed approximately 15 meters from the nets. Observers kept hidden in the blind and could then play-back various vocalizations to attract resident owls. Resident owl pairs would defend their territory by calling and diving at the decoy, thus getting caught in the nets. I found the effectiveness of this

technique was increased by using my own recorded vocalizations of adjacent territorial neighbors or vocalizations of the individuals I was trying to trap. Barred owls were also trapped using mist nets with live tethered gerbils placed between the nets. Once owls were attracted to the area using recorded vocalizations their attention was focused on the bait using a hand held mouse squeaker. Barred owls were originally trapped in the evening when it was thought birds would respond best. I eventually found that birds would respond and could be trapped at any time of the day or night.

It sometimes happens that barred owls are not in the area after setting up the trapping equipment. I have developed a technique to draw the birds to the trap site that are beyond the normal calling distance. I first start a survey effort to locate the birds in the area. When an owl is located, an attempt is made to attract a bird to the trap site by calling the bird to successive stations toward the trapping area. Owls were drawn more than 1/2 mile by using this technique. The method saved considerable time since it can take 1 1/2 hours to establish a trap site.

Spotted owls were captured using mist nets with gerbils as bait and with the noose pole technique described by Forsman (1976). I found the noose pole technique inefficient because of the difficulty in placing a small thin noose around an owls head at distances of 4-6 meters. It was easier to use tree climbing

spikes and safety belt, ascend a tree adjacent to the roosting owl, and then use an extendable aluminum pole with a dip net made of mist net material to capture the owl. I have been able to capture owls perched as high as 18 meters with this method.

I recorded information on the capture location, date, time, observer, bird weight (gm), sex, body length (cm), wing chord length (cm), wing span (cm), wing area (sq. cm), body length (cm), tail length (cm), beak length (cm), middle and hind talon length (cm), foot spread (cm), brood patch size, and number of tail bars on the center, left center and outer left rectrices for each owl trapped. Wing chord was measured from the alula to the end of the primaries. Total wing area was measured by tracing around the outstreched wings, body and tail of captured owls. A digital planimeter was then used to calculate total wing area. Body length was measured starting at top of the head and extending down to the end of the rectrices. Tail length was measured from the uropygial gland to the end of the center rectrices. Beak length measurements included the cere. Foot spread was measured from the the end of the hind toe to the end of the middle front toe. The number of tail bars on each tail feather was determined by only counting those tail bars that extend completely from the vane margin to the rachis at least on one side of the tail feather (Barrows and Bloom, 1982). The sex of the owls was determined by the pitch of their vocalizations (females are higher), comparing the weight and size, and by

checking for the presence of a brood patch. By using this combination of methods I felt male and female owls could be identified without error. Wing loading was calculated for each owl by dividing the weight of the bird by wing area.

Radio transmitters (AVM Instrument Co., Ltd.) were attached with a backpack harness of tubular teflon ribbon described by Dunstan (1972). Transmitters weighed 18-22 grams (2.7% of mean body weight for barred owls and 3.2% for spotted owls) with a battery life expectancy of 12 months. Transmitter frequencies were in the 164-166 Mhz range.

Radio receiving equipment included a Telonics TR-2 portable receiver, Telonics H-style hand held Yagi antennae and low impedence (4-6 ohm) headphone set. To determine the location of an owl by triangulation, an observer would get as close to the owl as possible to minimize radio-location error. Once an initial bearing was recorded, the person would move down the road or trail and obtain two or more additional bearings to allow plotting of the owls location. The Bearing stations that were used were known locations that were easily identifiable on aerial photographs. Each location from which a bearing was taken was marked on the aerial photograph (1:24,000 scale) and the radio frequency recorded. The information for each radio location includes the observer's name, date, time of day, each degree bearing, percent cloud cover, precipitation, wind speed, temperature, method of location (visual, triangulation or

aircraft location), and any appropriate notes or comments. Accuracy codes were recorded depending on whether the owl was located visually or by radio signal (Forsman, 1976). Accuracy codes for radio locations were those locations accurate to within 1 ha, 2ha, 8ha, or 20 ha. Accuracy was determined by examining the area covered by the error polygon of the triangulation. I then transferred all relocation points to 4"=1 mile Orthophotos and transformed the data into Universal Transvers Mercator (UTM) coordinates using a digitizer.

Monitoring procedures

A sampling problem encountered with owls as compared to purely diurnal raptors is that owls may be active during both diurnal and nocturnal periods and they may have different biological requirements and behavior in these two time periods. Therefore, in order to obtain a more accurate picture of total owl activity, home range size and habitat use, it is necessary to sample at different times during a 24 hour period. The routine schedule was to locate radio-tagged owls four times per week. Two approaches were used to obtain an equal number of roost (diurnal) and forage (nocturnal) relocations. If only one person was sampling, one week of monitoring was conducted from 9 am to 5pm and the next week of monitoring ran from 6 pm to 2 am. The schedule was then repeated. When two people were working, one

would be on the night shift and the other on the day shift. Birds were relocated throughout the year until the tranmitters stopped functioning. I greatly reduced or eliminated biases in data collection by randomizing the sequence in which observers located the owls during each monitoring period. By randomizing the location sequence of owls, individual birds were rarely relocated less than eight hours apart, even when two people were working different shifts. Relocations that are spaced close together can lead to autocorrelation. The result of this procedure was the random relocation of individuals during both nocturnal and diurnal periods, collection of data sets equal in size for each owl and avoidance of autocorrelated relocations. Autocorrelation in radio relocation data sets can lead to biased estimates of home range size and habitat use (Swihart and Slade, 1985).

The use of a Cessna 182 aircraft was neccessary to relocate owls that dispersed into roadless areas or areas with limited access due to snow conditions. At least one flight per week was scheduled.

Home range determinations

Summer home range sizes (March 1-August 30) and annual home range sizes were calculated for each individual and pair of owls. Four methods were used to calculate summer and annual home ranges for each owl. The computer program MCPAAL (Stuwe and Blohowiak,

1985) was used to calculate minimum convex polygons (MCP) (Mohr and Stumph, 1966),95% ellipses (Jennrich and Turner, 1969), 95% harmonic mean contours of utilization distributions (Dixon and Chapman, 1980) and the Fourier transformation 95% index (Anderson, 1982). The various estimates produced by these methods were then compared. Most of the home range estimates reported here are those using MCP because of its wide use by other researchers.

I calculated owl pair home ranges using the minimum convex polygon method only, since it is the easiest method to use and most commonly reported. The area was calculated by creating a composite of the two home ranges on 4"=1 mile orthophoto, and measuring the total area using a digital planimeter. Percent overlap was calculated by dividing this total area by the area of overlap. The percent overlap of adjacent territorial barred owls was calculated in the same manner.

I calculated the mean dates that barred owls and spotted owls left their core use areas in the fall to start foraging over larger areas, the mean date they returned to these core areas in the spring, and the mean date where the annual home range stopped growing. Cumulative home range graphs showing how home range size grows through time were created for each owl and the mean date where home range stopped growing derived from these graphs. The mean dates that owls left and returned to their core use areas was more subjective. For spotted owls these dates were

fairly clear since the birds wandered over large areas and often had seperate summer and winter home ranges. This calculation was more difficult for barred owls since these raptors can be found on their territories all year. I used the harmonic mean 50% isopleth to delineate core use areas and then examined the relocations through time to determine the mean dates that owls left and returned to these cores. The cumulative home range for each individual owl was calculated by repeatedly estimating the home range every 5 relocations, throughout the year, using the minimum convex polygon method. Therefore, I would start by analyzing the first 5 relocations, then 10, then 15, and so on, until the whole sample had been analyzed on a cumulative basis. All the individuals of each species were then averaged to obtain a comparative cumulative home range graph .

Statistical analysis

Statistical tests were done using the software program NCSS (Hintz, 1987) to generate the descriptive statistics on home range size and to run unpaired T-tests to compare various means. Means with unequal variances were compared using the nonparametric Mann-Whitney test. Home range estimates were compared using a paired T-test. All tests were conducted at a significance level of $p < 0.05$.

RESULTS AND DISCUSSION

Morphology

Table 1 shows the mean weights and body measurements of 15 barred owls and 9 spotted owls trapped during the study. Barred owls on average are 17.9% heavier than spotted owls. Male and female spotted owls are 5-6 centimeters shorter in body length than male and female barred owls. The wing spans of these two species are similar with spotted owls 1-2 cm shorter. Tail lengths of spotted owls are 2-3 cm shorter than barred owls. The sexual dimorphism of both species is apparent when comparing the body weights of the sexes. Barred owl females are 21.8% heavier than barred owl males and spotted owl females are 22.6% heavier than spotted owl males. Such reverse sexual dimorphism is common in raptors.

Based on my small sample size, male spotted owls have 2-3 tail bars on the center rectrices while female spotted owls have 4-6 bars. This concurs with the findings of Barrows and Bloom (1982). There appears to be no overlap in the tail barring pattern of spotted owls which may be used to indicate the sex of the bird. This sexing technique is not applicable in barred owls since the males have 3-4 bars and females have 3-5 bars. In the spring, I observed the males and females of both species to have a variable sized patch of bare skin on the lower abdomen. This bare patch could be used to promote heat loss during periods of high temperatures in the summer. In females, this bare skin also

Table 1. Mean weights and body measurements of barred and spotted owls from the Baker Lake Basin.

MEASUREMENT	BARRED MALE N = 8	SPOTTED MALE N = 4	BARRED FEMALE N = 7	SPOTTED FEMALE N = 5
Weight (g)	663	560	805	687
Body Length (cm)	44.7	39.4	47.4	40.8
Tail Length (cm)	23.6	20.8	25.0	21.5
Wing Chord (cm)	32.7	33.2	35.5	34.0
Wing Span (cm)	44.0	43.3	47.0	44.7
No. of Tail Bars	3-4	2-3	3-5	4-6
Beak Length (cm)	4.0	3.9	4.4	4.0
Foot Spread (cm)	5.1	5.8	5.9	6.4

serves as a brood patch. Brood patches on nesting females of both species were very different from that of non-nesting females. Nesting females had rough, dry, scaley looking skin that was bright red in appearance, apparently from incubating eggs and young. Non-nesting females brood patch areas were smooth, unchaffed and were light pink in color, normal skin color for the owls. One can therefore determine whether or not a female was nesting by an examination of the brood patch.

Considering size, spotted owls have a much larger foot spread (measured from the end of the hind talon to the end of the center talon) than barred owls. The mean foot spread for a male spotted owl is 13% larger than a male barred owl, even though barred owls are larger and weigh 17.9% more. Mean foot spread for a female spotted owl is 8% larger than a female barred owl. The large foot spread of the spotted owl may be an adaptation for preying on medium sized arboreal mammals rather than smaller terrestrial forms.

There is no difference in the wing loading between male spotted owls and male barred owls or between the females of each species (Table 2). Therefore, the wing loading remains constant, even though there are differences in the body sizes between the males of each species and the females of each species. The intraspecific differences in the wing loading between the sexes is dramatic. The females of each species have a wing loading that is .06 grams/sq. cm heavier than the males. Since wing

Table 2. Mean wing loading of male and female barred and spotted owls in grams/square centimeter, including the means for each species.

BARRED MALE N = 4	BARRED FEMALE N = 5	SPOTTED MALE N = 4	SPOTTED FEMALE N = 4
.29	.35	.30	.35
Barred owl mean: .32		Spotted owl mean: .32	

loading is a ratio of body weight to wing area we must examine each of these factors to determine which contributes most to the observed difference. The actual wing area differences between the sexes are small, falling in the 4-6% range. The weight differences between the sexes are dramatic and range from 21-23%. Therefore, differences in the wing loading between the sexes are primarily due to body weight differences.

It is surprising that the spotted owl, a specialist on arboreal mammals (Forsman, 1980), does not have a lighter wing loading than the barred owl, which has been reported to prey primarily on small terrestrial mammals (Blakemore, 1940; Cahn and Kemp, 1930; Korschgen, 1972; Wilson, 1938). A lighter wing loading in the spotted owl would allow this specialist to 1) be more maneuverable in dense forest canopies, 2) produce less noise in flight and 3) transport heavier prey (Norberg, 1987). Therefore, a lighter wing loading in the spotted owl would potentially allow this bird to better maneuver through a dense forest canopy after arboreal prey items.

After capture, barred owls appeared to be more aggressive than spotted owls when handled. Barred owls would try and inflict damage with their talons and often tried to bite the handler. Females with young sometimes let out a high pitched, piercing scream during capture. Spotted owls appeared to "relax" immediately upon capture, rarely tried to bite, and did not struggle to any great degree. The larger size of the barred owl

This may be one reason why spotted owls have a much lower breeding success than barred owls (see section on reproduction), since prey densities must recover in the summer range before another nesting attempt can be successful. We have also seen that spotted owl pairs have much less home range overlap than barred owl pairs, which could be the result of male and female owls avoiding foraging in each others use areas due to a scarcity of prey. Forsman (1980) found that spotted owl pairs in Oregon partitioned foraging areas on a spatial and temporal basis.

MacAurther and Pianka (1966) have shown that specialized predators should have longer search times when locating suitable prey items than a generalist predator, although the pursuit times would be similar. Since the barred owl can be expected to prey on a variety of acceptable food items, this owl should have shorter search times/item caught, but pursuit times would increase, as a large variety of new hard-to-catch items are sought. They also state that predators with specialized habitat preferences (few habitat patch types) would be expected to have longer traveling times/prey item caught, since specialists muct travel longer distances between habitat patches to reach a suitable patch type. The spotted owl appears to be a habitat specialist requiring old-growth coniferous forest to survive (Forsman, 1980). Therefore, one could expect the spotted owl to have larger home range sizes since it may spend more time searching for suitable prey over a larger area and spend more time traveling longer distances,

between suitable patch types. Schoener (1968) has shown that a predator whose diet consists of prey categories different in frequency from that available in the area should be feeding on relatively less dense food than a predator who is opportunistic and preying on whatever is available. He found that the home ranges of most raptors reviewed were larger if the number of prey per unit area is smaller. The fact that home range size varies with food density has been demonstrated in several studies on birds (Schoener, 1968). Therefore, barred owls may be able to sustain themselves on much smaller home ranges and have larger home range overlaps between paired individuals than spotted owls because of differences in diet.

In a discussion of spotted owl home range size, one can not overlook the fact that large areas of suitable habitat have been removed and remaining stands of old growth fragmented due to clear-cut logging practices. These negative effects will act to reduce prey densities and require owls to travel longer distances between suitable patch types. I theorize that spotted owl home ranges today are probably larger than they were historically, but feel home ranges were most likely very large even under natural conditions. I have monitored owls in relatively undisturbed areas and still find large home range sizes for these birds. Present day logging practices are probably increasing the food stress on spotted owls, and eventually, may act to tip the energy balance against this

species.

Effect of sampling procedures on home range size

Figure 10 shows the number of days it took to estimate various percentages of the total home range of an average barred owl. A total of 320 days (10.6 months) were required to estimate 100% of a barred owl's home range and 285 days (9.5 months) were needed to estimate 90% of this area. This is the main reason why I feel the estimates of barred owl home ranges from three studies in the midwest cannot be used with confidence. The average monitoring time for 13 owls studied by Nicholls and Warner (1972), and Fuller (1979), was only 114 days (3.8 months), with most of the monitoring conducted in the spring and summer when owl home ranges are small. Only two owls were monitored during the winter and only for short periods of time. The two largest home ranges reported are for birds monitored for the longest periods of time. Figure 10 shows my home range estimate at 114 days would be 200 ha (only 30% of total) while they report an average home range of 273 ha. These estimates are very similar and demonstrate the danger in estimating home range size with data sets of short duration. Since barred owl cumulative home ranges often plateau at different times of the year (Fig.9) before increasing again, researchers can be deceived into thinking that they have estimated the total home range in periods of less than 10.6 months. Elody (1983) reports an average home

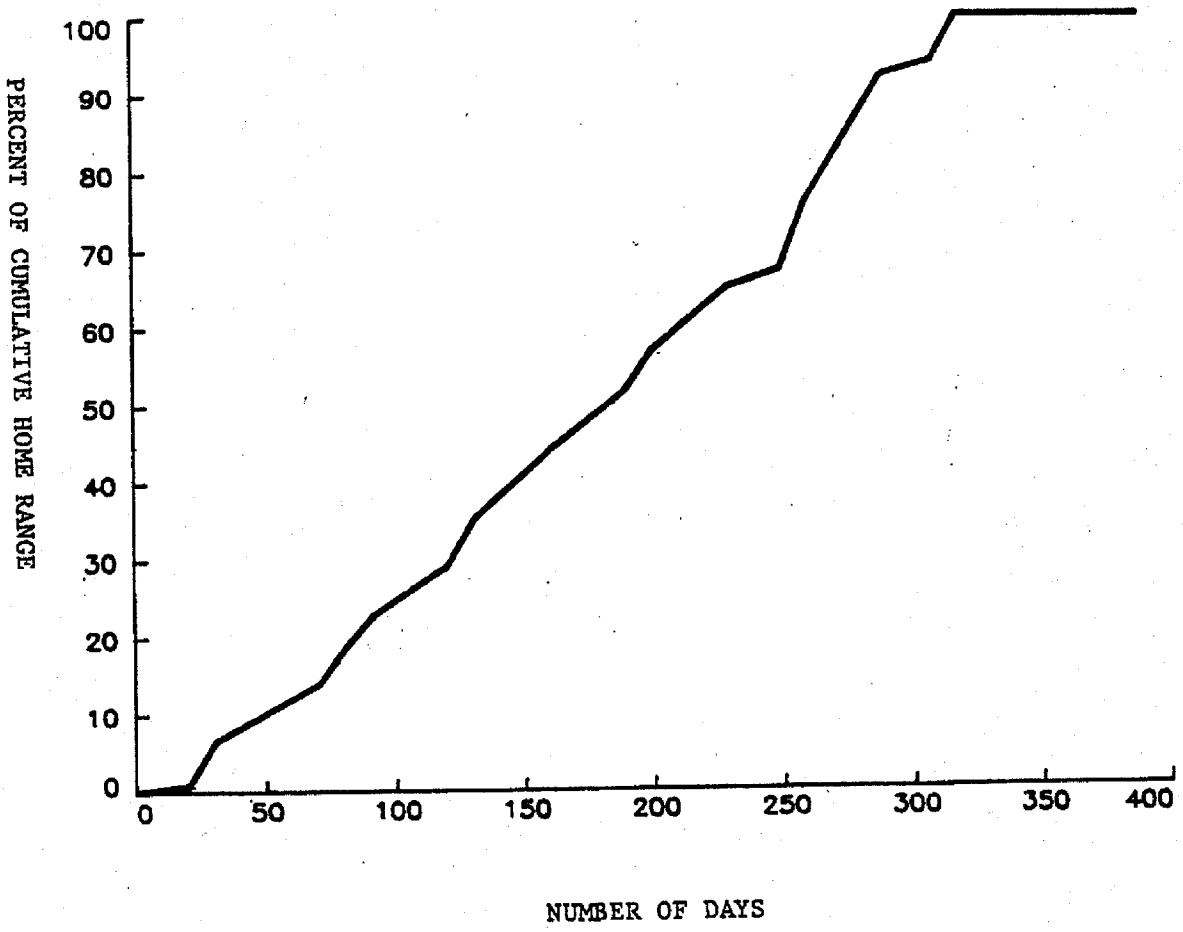


Figure 10. Percent of mean cumulative home range for 8 barred owls over a 12 month period. The figure illustrates the number of days required to estimate total home range size. Home range size was calculated using the minimum convex polygon method.

range size of 282 ha for seven radio-tagged barred owls but states that he only collected 270 total usable locations from May to August, a period of only 4 months. This is a similar to the home range estimate found by Nicholls and Fuller and is once again probably due to the effect of a short study duration combined with sampling only during summer periods.

The relocation sample size, length of the sampling period, sampling method, and variation between individual owls will all affect the estimate of total home range size for barred and spotted owls (Fig. 8 and 9). Collecting relocations for periods of less than 10.6 months will underestimate barred owl home range size and periods of less than 12 months will underestimate spotted owl home range size. Less intensive sampling strategies will also tend to skew cumulative home range graphs into a concave shape so that home range size is underestimated throughout the year, possibly never reaching a 100% estimation (Fig. 11 and 12). This problem is true for both barred and spotted owls and can be seen in Figure 11 for the Diobsud male barred owl where a less intensive sampling strategy (one relocation/week) yielded only 50 relocations throughout a 12 month period. The same relationship can be seen in Figure 12 for the Diobsud male spotted owl which had a similar sampling regime. Larger sampling intervals (smaller sample sizes) will most likely miss locating owls in certain portions of their home ranges throughout the year, thus underestimating home range size. I

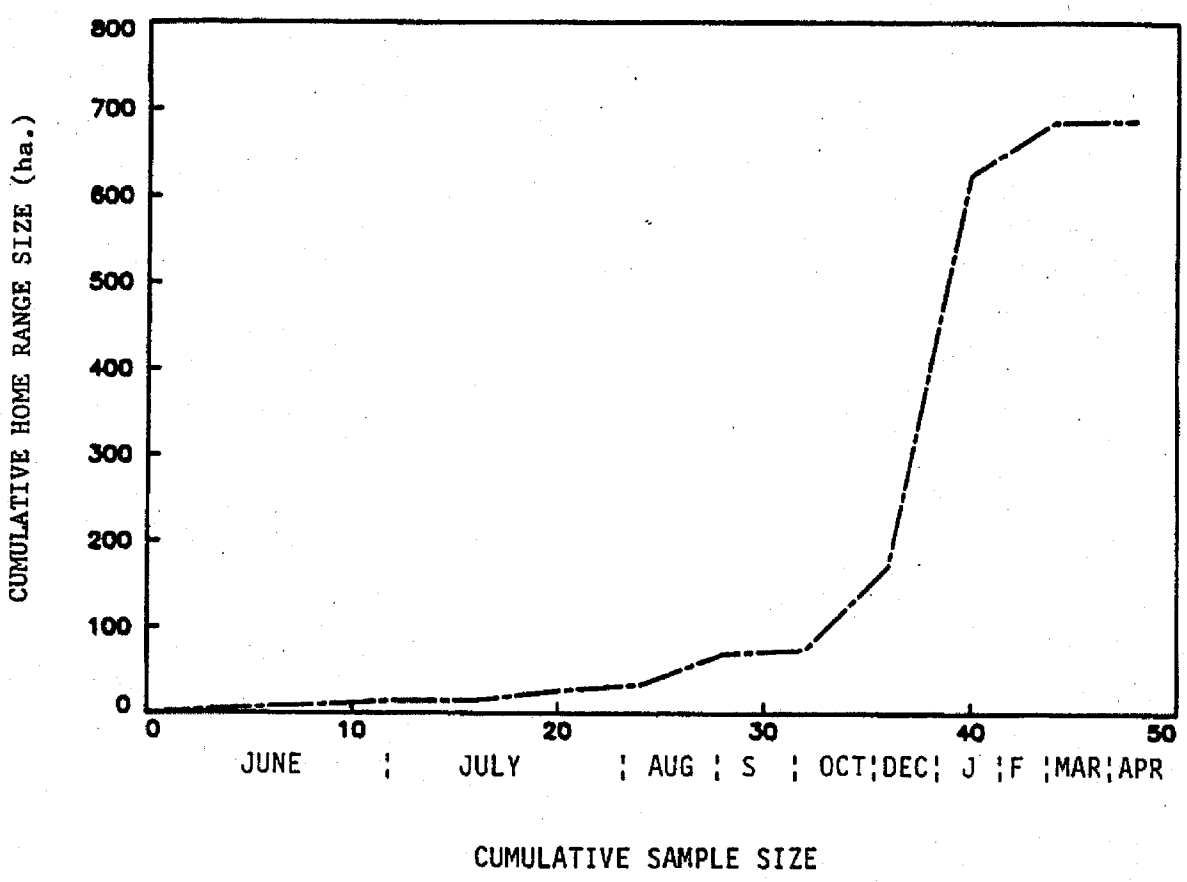


Figure 11. Cumulative home range analysis for the Diobsud male barred owl showing how convex polygon size varies with sample size and season. The monitoring period ran 11 months from 5 June 86 - 27 Apr 87.

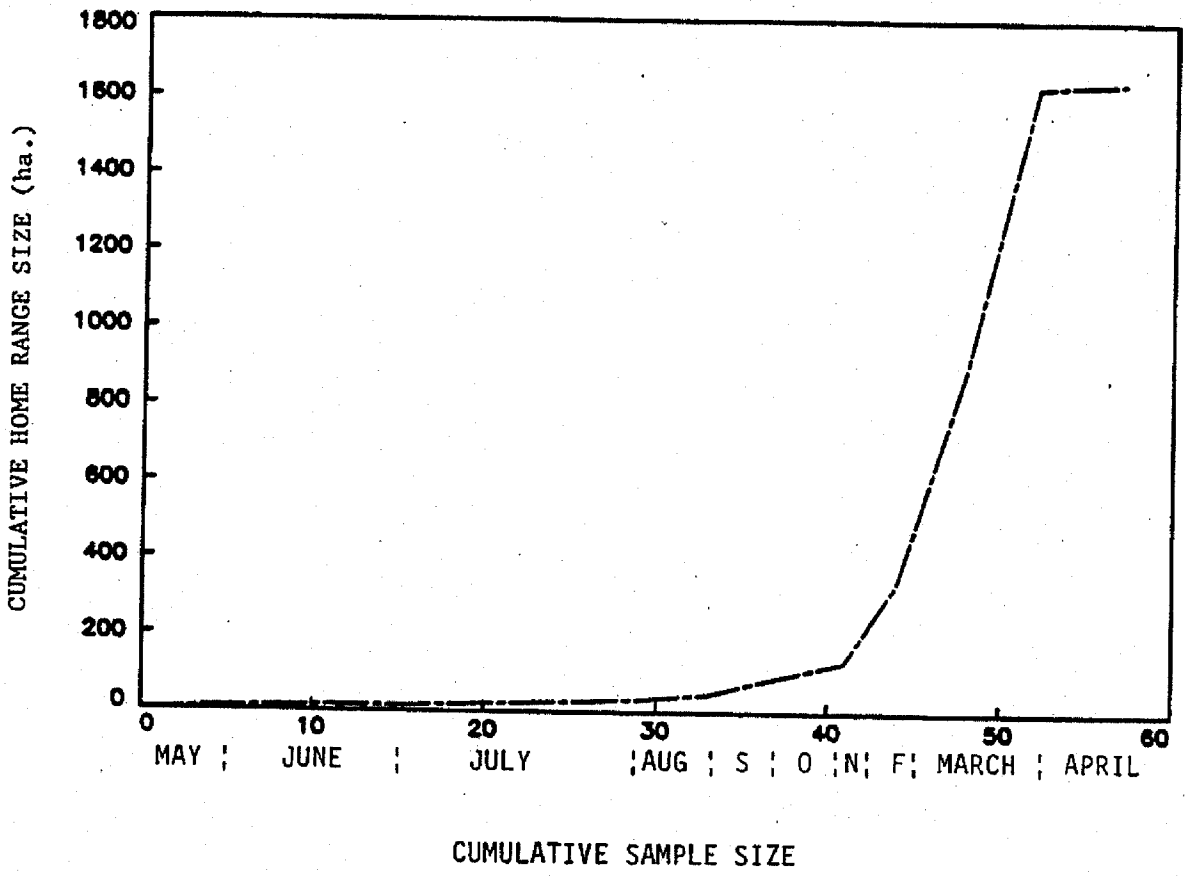


Figure 12. Cumulative home range analysis for the Diobsud male spotted owl showing how convex polygon size varies with sample size and season. The monitoring period ran 11 months from 22 May 86 - 13 Apr 87.

suspect that studies examining habitat use would also obtain biased results if small, less intensive sampling methods are employed. Since both barred and spotted owls expand their ranges significantly during the winter, missing any portion of this time period in a sampling routine will bias results. The cumulative home range graphs for individual owls can be found in the Appendix.

Home range overlap of adjacent barred owls

Figure 13 illustrates the amount of home range overlap of neighboring barred owl individuals in the study area. Mean barred owl home range overlap is 0.7% (range=0-1.7%, N=6). Barred owls appeared to rigorously defend their home ranges throughout the year with little variation in this behavior between individuals. I have found that even non-breeding resident owls aggressively defended their home ranges. During the winter, owls made occasional short excursions into an adjacent individual's home range, but these were of short duration and seldom occurred. The small home range size of the barred owl and sedentary nature of this bird in the winter, enables this owl to actively defend its territory throughout the year. Nicholls and Fuller (1987) also report that barred owls maintain nearly exclusive home ranges, expel intruders and neighbors from their ranges and vocalize to advertize the occupancy of their space. They felt that these behaviors were consistent with the criteria for territoriality.

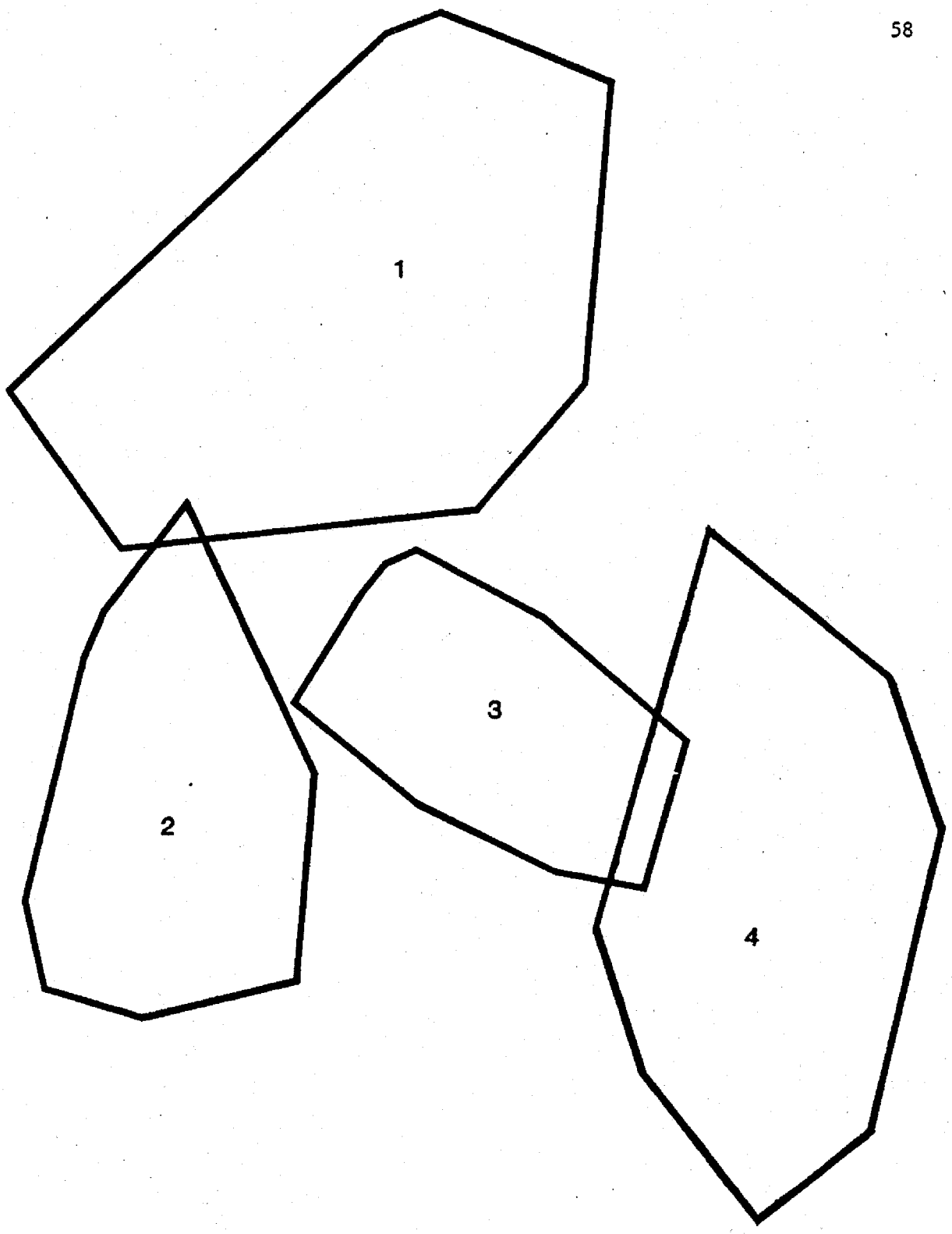


Figure 13. Home range boundary overlap of four neighboring barred owl individuals. Very little overlap exists between adjacent territories. Mean home range overlap is .7% (range=0 - 1.7%, N=6).

I agree with these observations and feel that barred owl territories correspond with their home ranges. The extremely large home ranges of the spotted owl may make an active and regular defense of home range impossible. It would be energetically very costly to defend an average spotted owl home range (over 10 sq. miles). Thus, A spotted owl territory is probably an area surrounding the nest tree and much smaller than the home range area traversed by these birds.

Comparison of home range estimators

Table 7 lists the mean summer home range estimates of barred and spotted owls using the minimum convex polygon, 95% ellipse, harmonic mean transformation and Fourier transformation methods. Very little difference exists between the estimators for this time period. The Fourier analysis gave the smallest estimate for both species. Otherwise, there is no consistent relationship in the home range size estimates between the other three methods.

Mean annual home range estimates for the four estimators can be found in Table 8. Once again the Fourier analysis gave the smallest estimate of home range size for both species. A paired T-test reveals that the Fourier analysis result is significantly different than the other three estimators for both species. No significant differences could be found between the other three methods. For barred owls, the estimates from these three

Table 7. Mean summer (March 1st-August 30th) home range estimates in hectares for 8 barred owls and 4 spotted owls using the minimum convex polygon, 95% ellipse, harmonic mean transformation and Fourier transformation methods.

	HOME RANGE ESTIMATOR			
	CONVEX POLYGON	ELLIPSE	HARMONIC MEAN	FOURIER
Barred owl	281	336	293	270
S.D.	139.3	146.7	133.9	124.3
Spotted owl	321	283	209	207
S.D.	371.3	265.5	145.5	63.6

Table 8. Mean annual home range estimates in hectares for 10 barred owls and 4 spotted owls using the minimum convex polygon, 95% ellipse, harmonic mean transformation and Fourier transformation methods.

	HOME RANGE ESTIMATOR			
	CONVEX POLYGON	ELLIPSE	HARMONIC MEAN	FOURIER
Barred owl	644	534	564	393
S.D.	293.5	174.8	234.7	219.0
Spotted owl	2,816	4,348	3,642	774
S.D.	2,841	3,730	3,346	339.1

techniques correspond closely while the estimate spotted owls are more variable. The standard deviations for spotted owls are extremely large and often approach the home range estimate itself. This may be because spotted owls traverse large areas and have many distant outlying points which can greatly affect home range estimation.

Figure 14 shows the home range boundaries of the Sandy Creek male spotted owl depicted by the harmonic mean transformation, 95% ellipse and minimum convex polygon. No graphic output was available for the Fourier transformation. The main difference between the estimators lies in their definition of home range boundaries and how these boundaries encompass outlying points. The minimum convex polygon often includes large areas that are apparently unutilized by the owls, since this method simply connects the outer relocation points. Therefore, MCP is very sensitive to outlying locations. The probability ellipse (95% ellipse) is the intensity of use of an area as described by a bivariate normal distribution. The 95% ellipse can also include large unused areas but to a lesser degree. Therefore, these two estimators will be more useful for animals that show a preference for a wide variety of habitat types and use their home range homogenously, or for areas that have an even distribution of habitat types throughout the home range.

The harmonic mean transformation provides contours or isopleths of use for a sample of relocations by calculating the

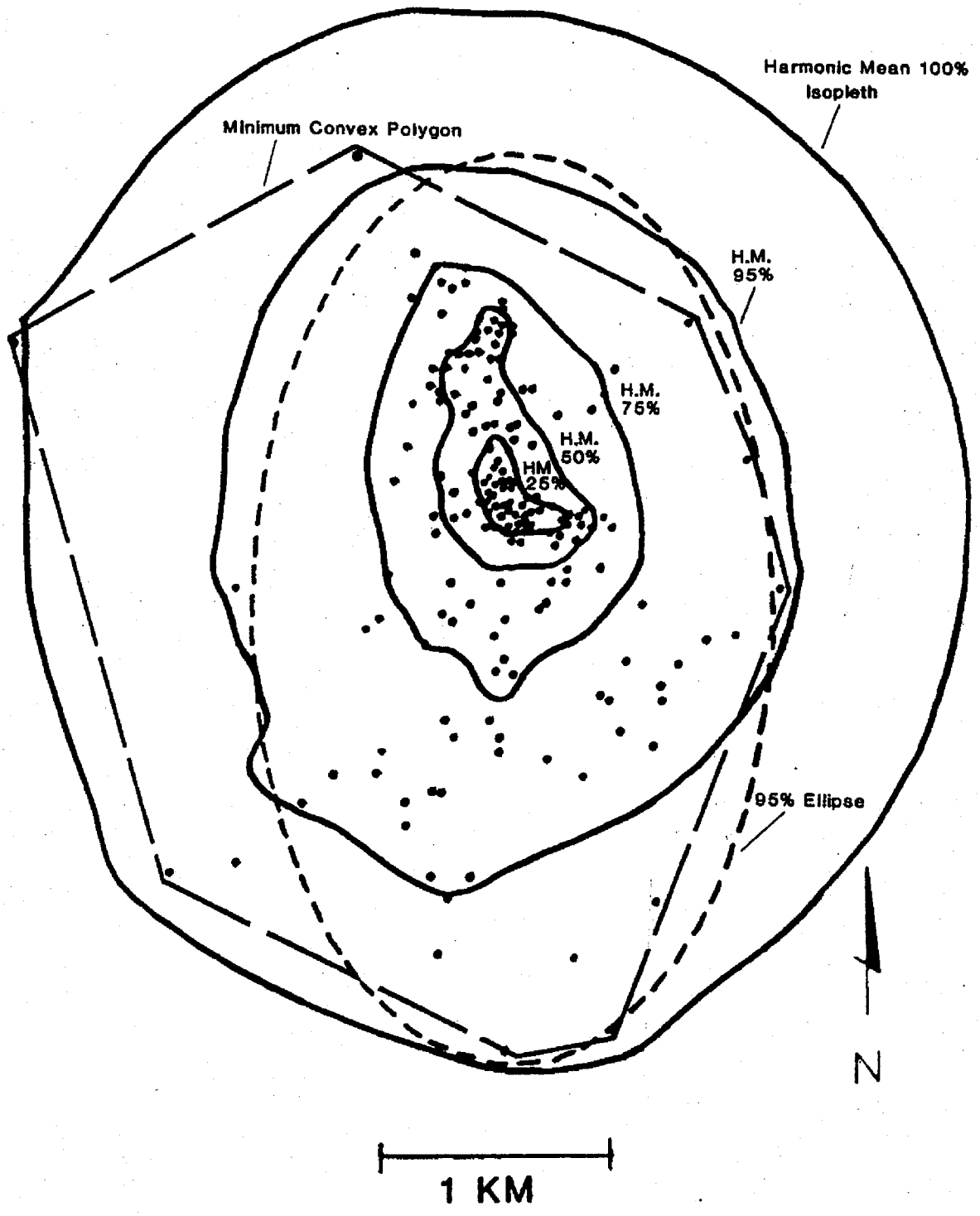


Figure 14. Home range area of the Sandy Creek male spotted owl depicted by the 95% ellipse, minimum convex polygon and the 25%, 50%, 75%, 95%, and 100% harmonic mean isopleths. The sample size is for 202 relocations.

average distance between a point on a grid and the animal locations. Figure 14 shows the 25%, 50%, 75%, 95% and 100% contours. For the purposes of this study the 95% contour was used to calculate home range size. The method automatically de-emphasizes outlying locations. This method also assumes no specific home range shape and multiple activity centers can be depicted. It provides an excellent representation of the use of space and therefore may be the most appropriate technique for habitat preference studies.

The Fourier analysis (.95 index) calculates a utilization distribution for a set of data points and also assumes no specific home range shape, provides a representation of space use and can depict multiple areas of concentrated use. It is not clear why this method consistently provided smaller estimates of a home range since no graphic output was available to me. Jaremovic and Croft (1987) state that the Fourier analysis .95 contour index excluded the greatest number of locations when compared to other estimators, resulting in more outliers for reasons that were not always clear. This method is the least understood of the four methods used.

As we have seen, the definition of home range is dependent upon the number of location points used in the calculation and on the assumptions used by the models themselves. The minimum convex polygon uses all data points in a set, lends equal weight to each point, and assumes home range can be defined by a convex

polygon. The harmonic mean approach assumes no home range shape, and can utilize any number of data points desired by the researcher. Since area estimation techniques reveal little about the ecology of an animal, new techniques are needed to examine the internal anatomy and dynamics of home ranges (Jaremovic and Croft, 1987).

Reproduction

All barred owl and spotted owl nest sites located during the study have been found in similar types of tree cavities. A larger sample of nest sites is needed to determine whether the dimensions of the cavities required by the birds are the same or significantly different. The similar body, tail and wing lengths of the two species (Table 1) suggest that cavity size requirements are probably similar.

Spotted owl reproduction in the study area can best be described as sporadic. Over a two year period I recorded a possible nine nesting opportunities for spotted owl pairs. Only one pair bred successfully out of these nine chances and this pair raised two young. Spotted owls in western Washington may breed only once every three years (Harriet Allen, pers. com.) I recorded 12 possible nesting opportunities for barred owl pairs and six (50%) of these pairs of birds successfully fledged young producing an average of 1.85 young per nest. Some barred owl pairs have successfully raised young for three consecutive years

while others have yet to produce young. The higher reproduction of the barred owl helps explain the rapid range expansion of this owl into the Pacific Northwest. The low reproductive rate of the spotted owl may be another symptom of a population stressed by low food supplies.

I have recorded a limited amount of information on the nesting chronology of barred owls. Barred owls appear to lay eggs by the end of March with young fledging by the first week in June. More information is needed to confirm this. These dates are similar to that reported by Devereaux and Mosher (1984). They report a mean egg date of March 20th (N=6 nests) and a mean fledging date of May 24th (N=2). They also report that 2.0 young were fledged from 5 active nests.

Before barred owl females lay eggs, I have noticed that females will begin to utilize very small home range areas. I have defined these as pre-breeding home ranges and calculated the size of these areas using the minimum convex polygon method. The mean pre-breeding home range size of 3 female barred owls was 15.7 ha (range=2-40 ha). The function of this behavior is unknown. I offer two hypothesis. The first is that female barred owls that are carrying eggs should not expose themselves to the risk of damaging developing eggs by hunting. Therefore it is possible that the male is feeding her at this stage of the nesting cycle. This feeding would speed up energy accumulation by the female for egg production and also enable her to conserve

energy by not hunting (Norberg, 1987). The added weight to the female from egg production already reduces her flight performance in hunts, on top of an already higher wing loading when compared to the male. Also, the female obviously has to visit the nest site in order to lay eggs. I have found pre-breeding home ranges to be centered around the nest tree. The second hypothesis concerns pair bonding and mating between the male and female. Pair bonding could occur in a shorter period of time, and copulations and feeding could occur more frequently, if the male has a precise idea of where the female can be found at any time of the day or night. This might be especially true for an owl that is nocturnal and lives in a dense forest canopy with limited visibility. Although loud vocalizations might accomplish this same routine, they would also reveal the location of the nesting area to any predators or competitors.

The mean date that females restricted themselves to pre-breeding home ranges was March 10th (range=Mar.3-Mar.17, N=3). The mean date that pre-breeding home ranges ended was March 28th (range=Mar.23-April 8, N=3). This corresponds closely with the egg laying dates for females. This home range behavior thus lasted an average of 18 days.

I am experimenting with a method to attract young barred owls to an area to count fledged young to determine productivity and possibly determine fledgling mortality over time. I have

found young fledged barred owls to be attracted to the pre-recorded calls of female adult barred owls and the hissing food begging calls of young birds. The technique needs additional evaluation but could be used to repeatedly locate young birds in an area until they disperse in the fall. To my knowledge the method has not been tried on spotted owls.

Conclusion

Spotted owl population densities are much lower than barred owl densities due to the larger home range size of this species. Since the spotted owl is an old-growth dependent species, the removal and fragmentation of old-growth forests may also have the effect of increasing the home range size of this owl. The extremely large home ranges of spotted owls, smaller home range overlap, wide winter wanderings, rapid home range growth throughout the year, early departure and late return to core nesting areas, and low reproductive rate, may be related to the food habits specialization in this species. These factors could reflect the behavior of a population stressed by a low food supply.

Researchers that are estimating the home range size of an animal need to be aware that the total relocation sample size, sampling interval, length of the sampling period, sampling method, and variation between the home range estimators used, will all effect the final home range estimate. The total sample

size, sampling interval, length of the sampling period, sampling method, and type of home range estimator used should be clearly stated. Small sample sizes with long sampling intervals and short monitoring periods will all underestimate home range size. Large differences in results can be obtained from the same data set analyzed by different home range estimators. More work is needed in the field of home range estimation to determine what constitutes an adequate sample size for each estimator, and to develop techniques to calculate the standard error and confidence intervals for the most common home range methods used.

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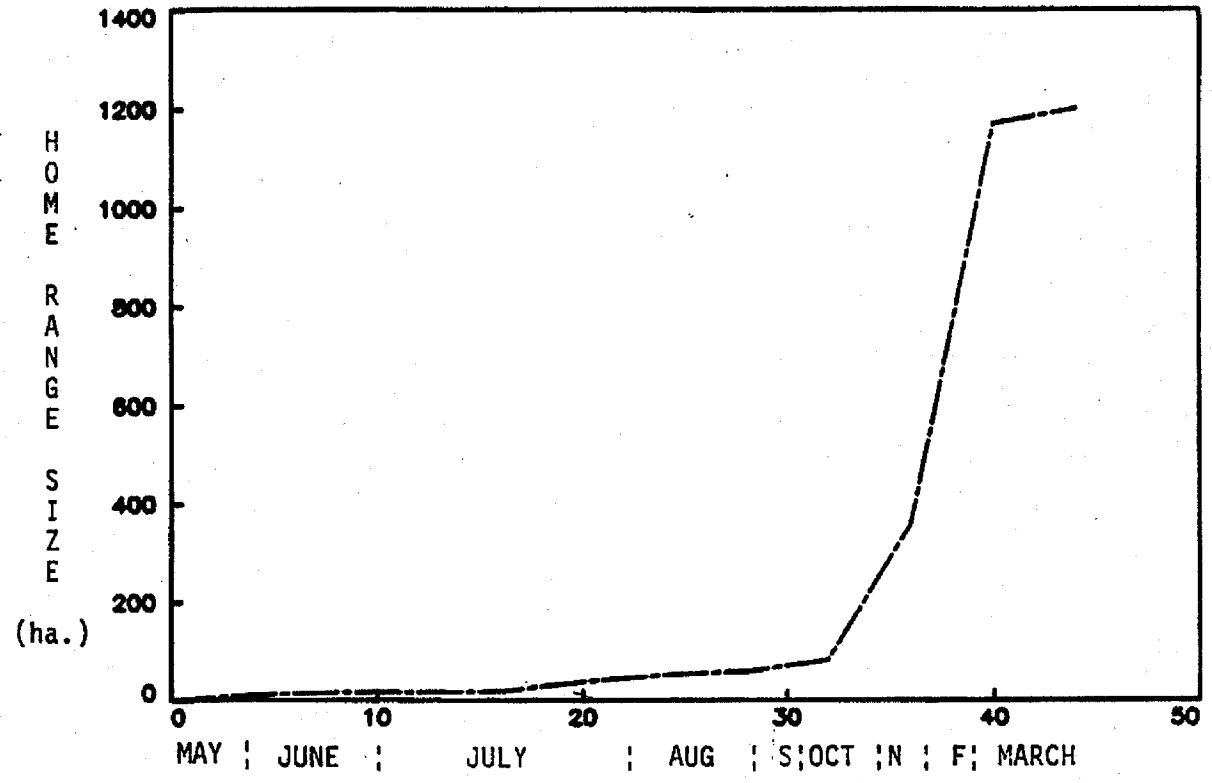
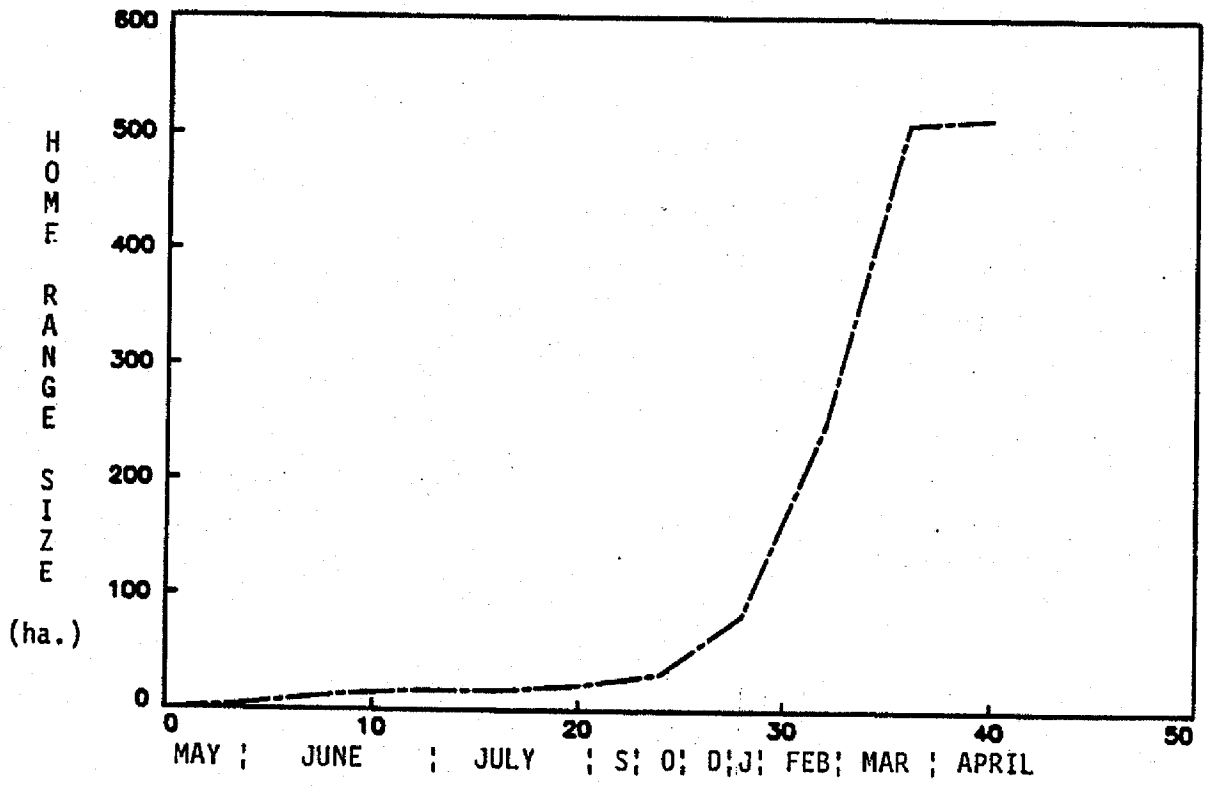
APPENDIX

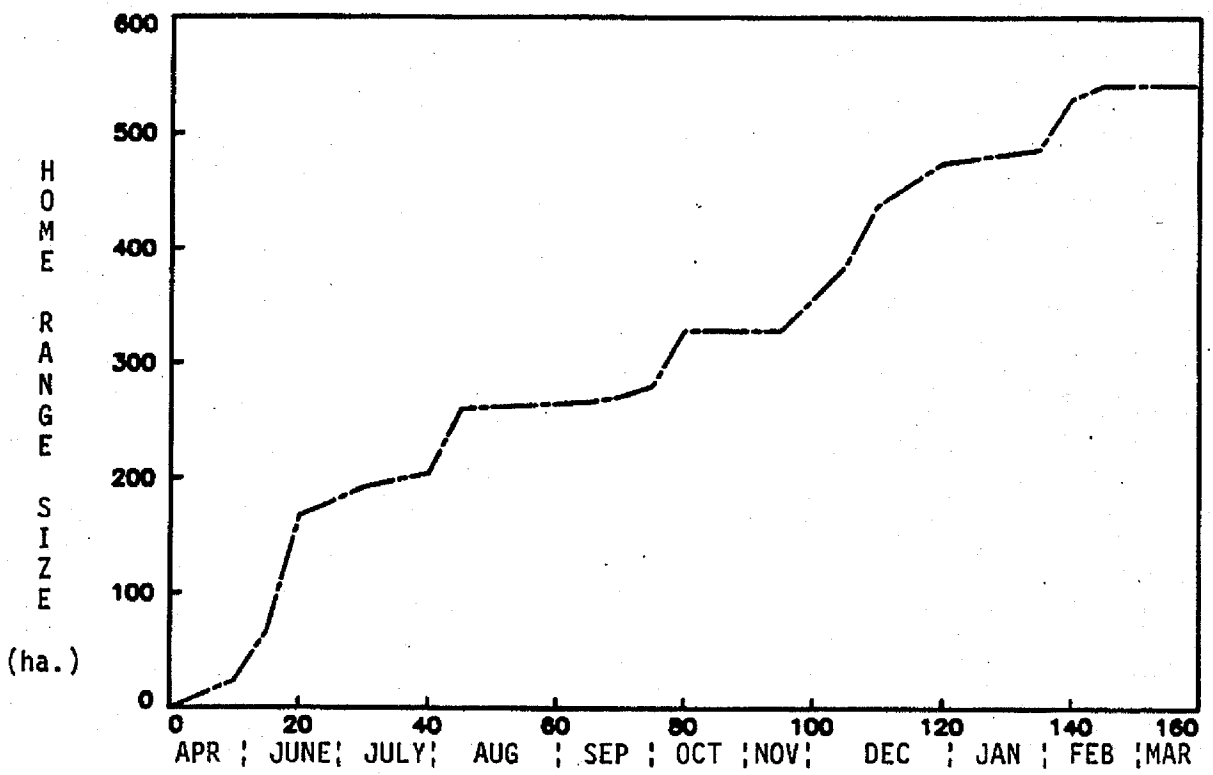
The following figures are the cumulative home range graphs for each individual spotted owl and barred owl radio-tagged, along with the dates indicating the total period that each bird was monitored.



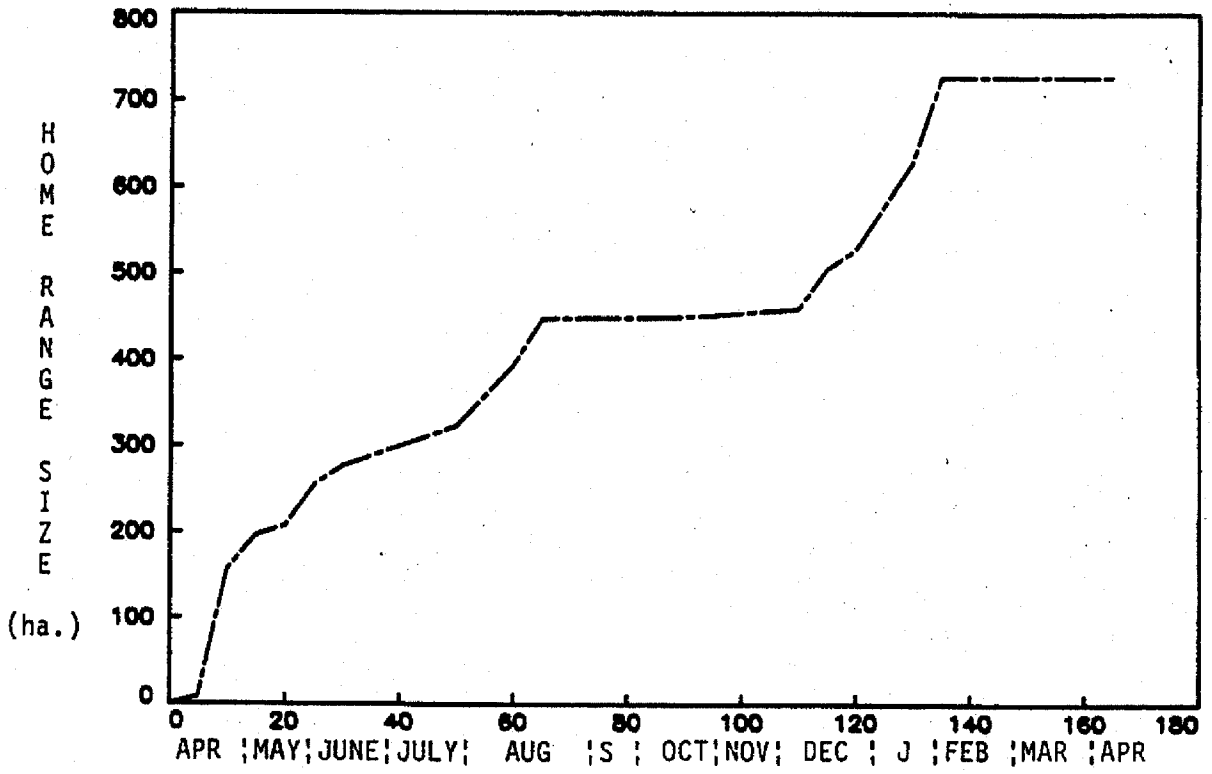
Cumulative home range analysis for the Diobsud female spotted owl showing how convex polygon size varies with sample size and season. The monitoring period ran 10 months from 29 May 86 - 15 Feb 87.



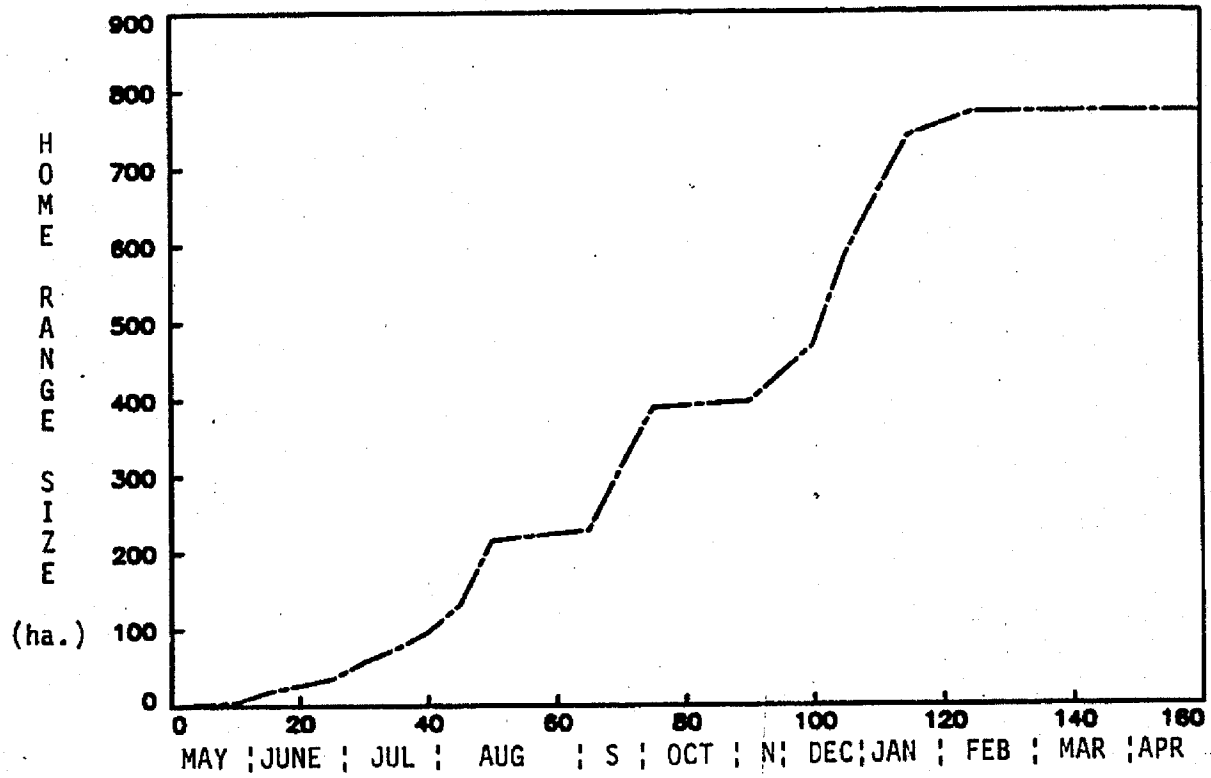
Cumulative home range analysis for the Diobsud female barred owl showing how convex polygon size varies with sample size and season. The monitoring period ran 11 months from 22 May 86 - 27 Apr 87.



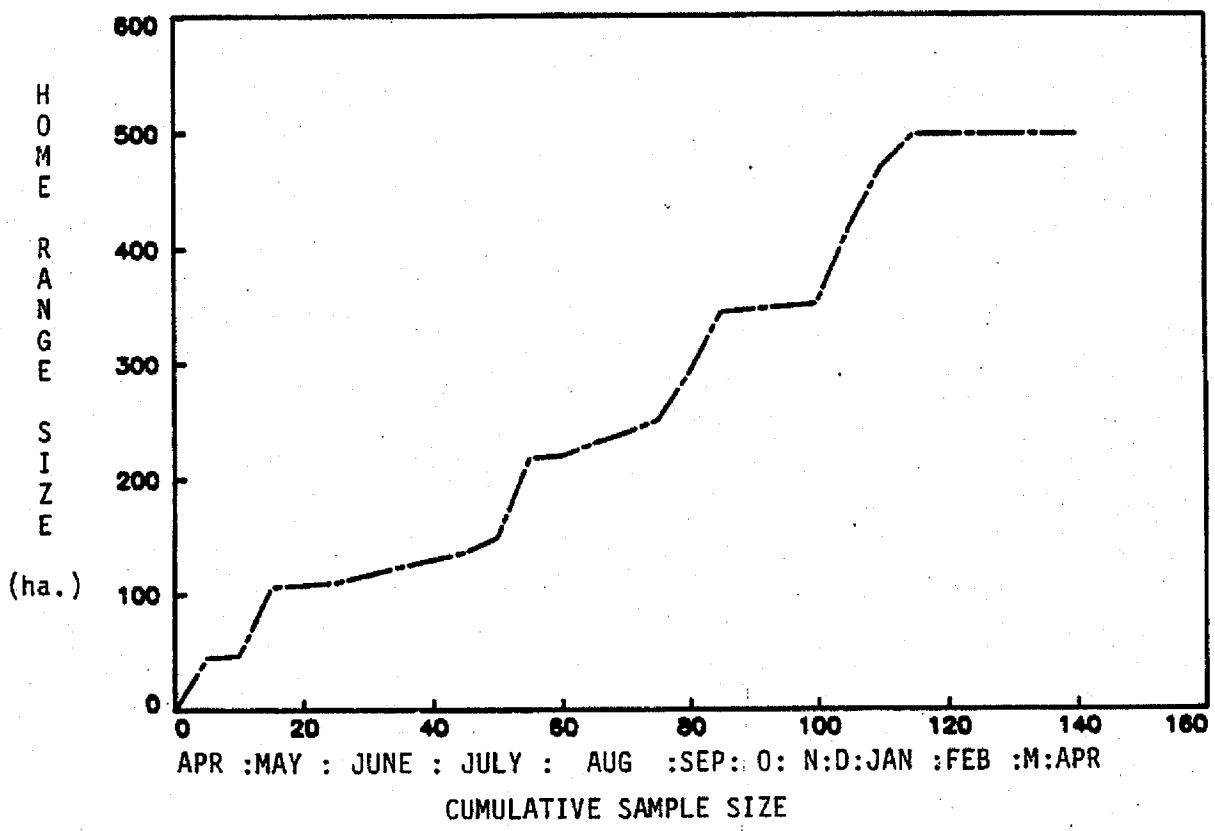
Cumulative home range analysis for the 1799 female barred owl showing how convex polygon size varies with sample size and season. The monitoring period ran 11 months from 11 Apr 86 - 2 Mar 87.



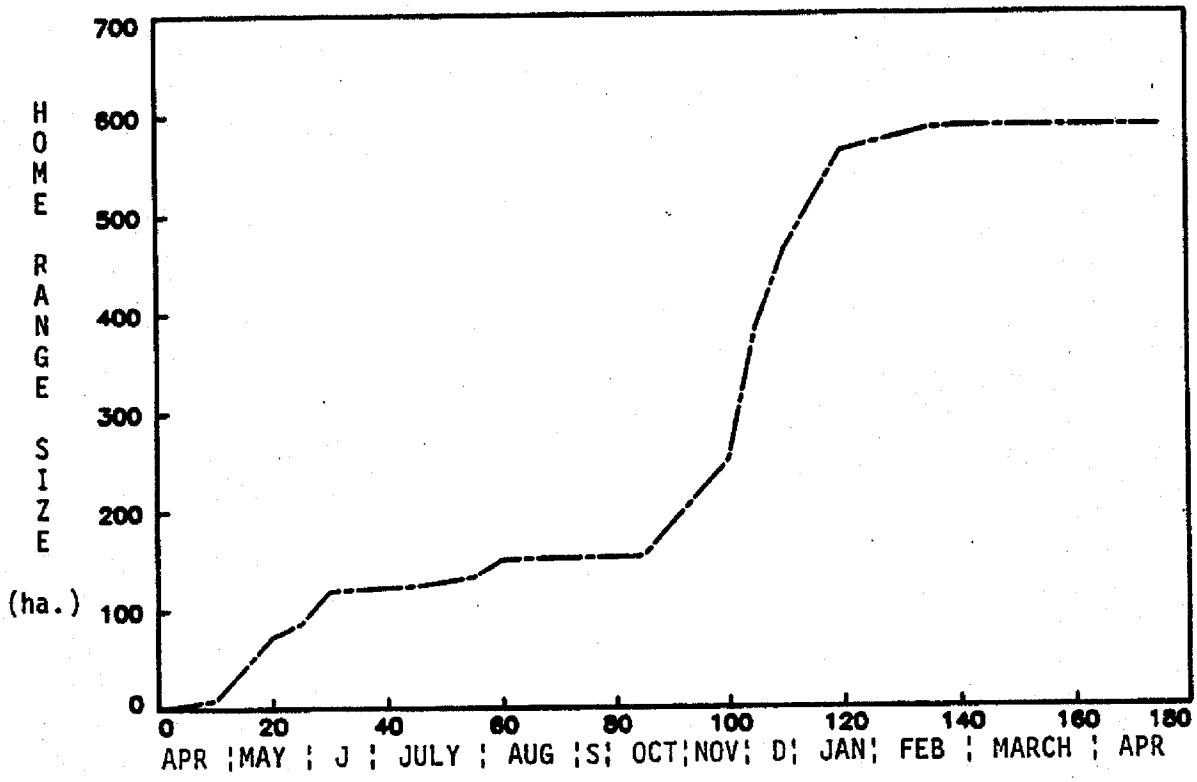
Cumulative home range analysis for the 1799 male barred owl showing how convex polygon size varies with sample size and season. The monitoring period ran 12 months from 3 Apr 86 - 10 Apr 87.



Cumulative home range analysis for the Welker barred owl female showing how convex polygon size varies with sample size and season. The monitoring period ran 11 months from 3 May 86 - 8 Apr 87.

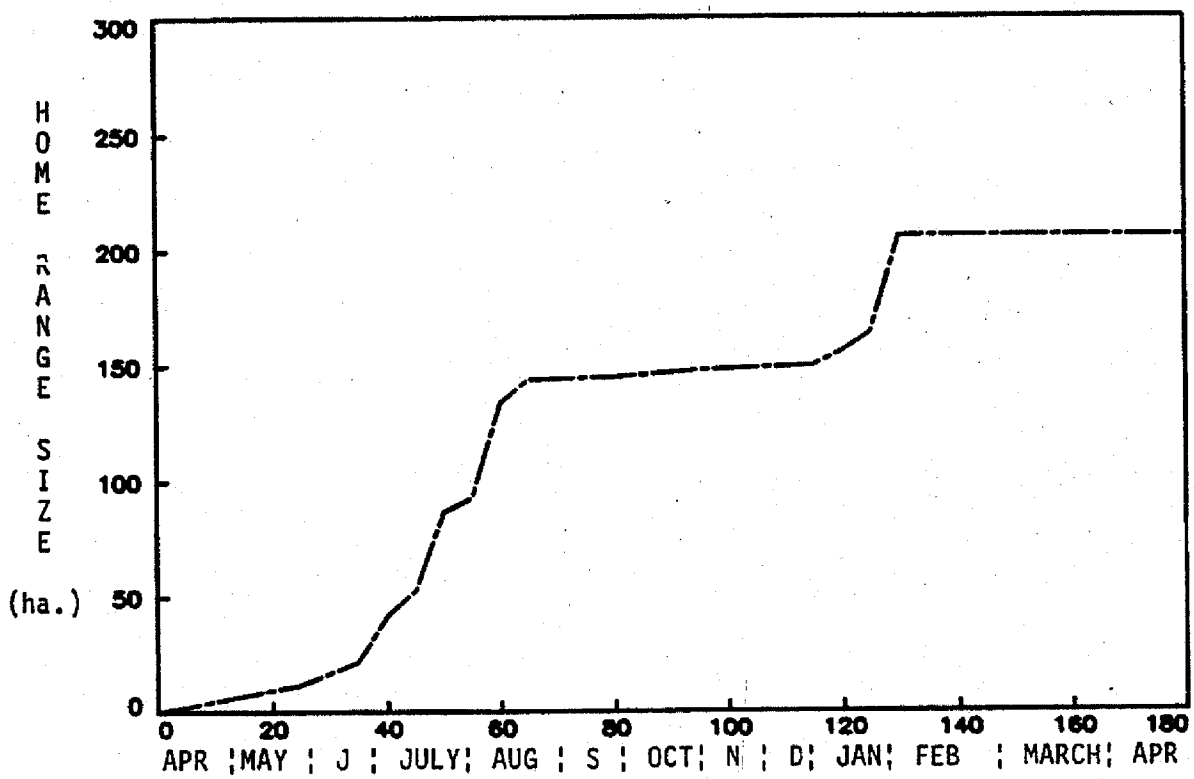


Cumulative home range analysis for the Welker male barred owl showing how convex polygon size varies with sample size and season. The monitoring period ran 12 months from 4 Apr 86 - 8 Apr 87.



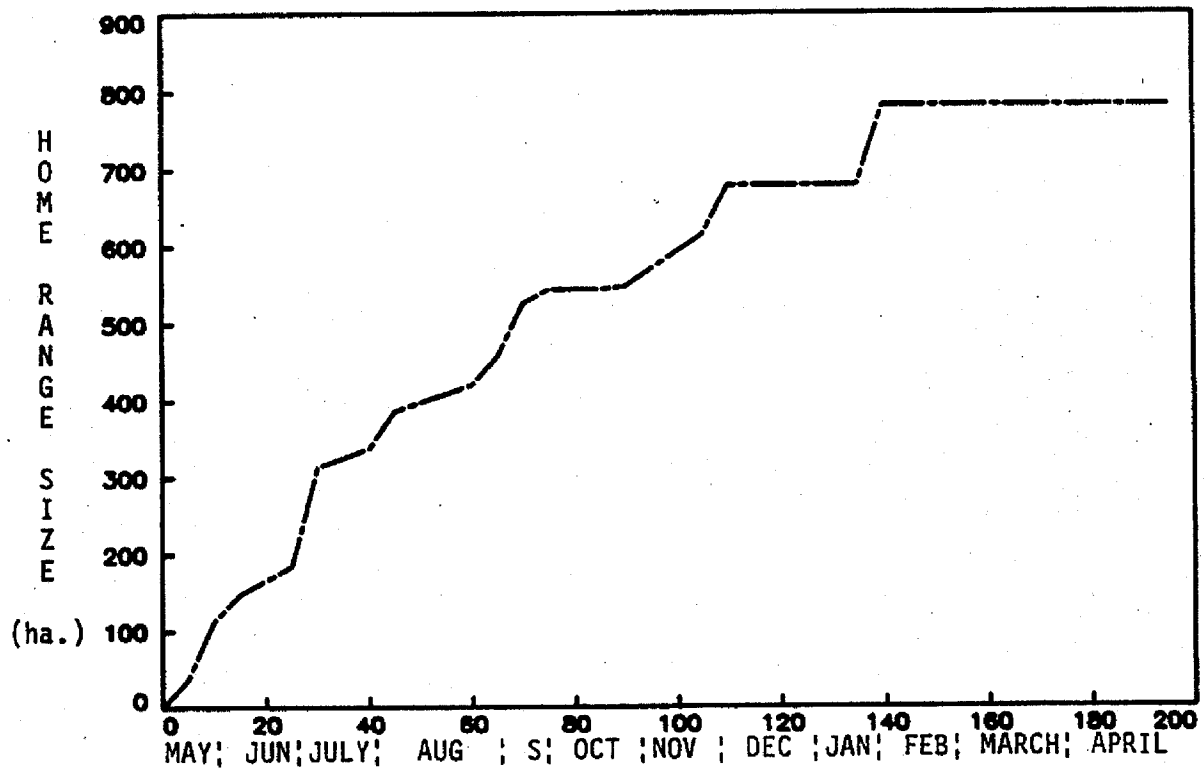
CUMULATIVE SAMPLE SIZE

Cumulative home range analysis for the Rearing Ponds male barred owl showing how convex polygon size varies with sample size and season. The monitoring period ran 12 months from 8 Apr 86 - 8 Apr 87.

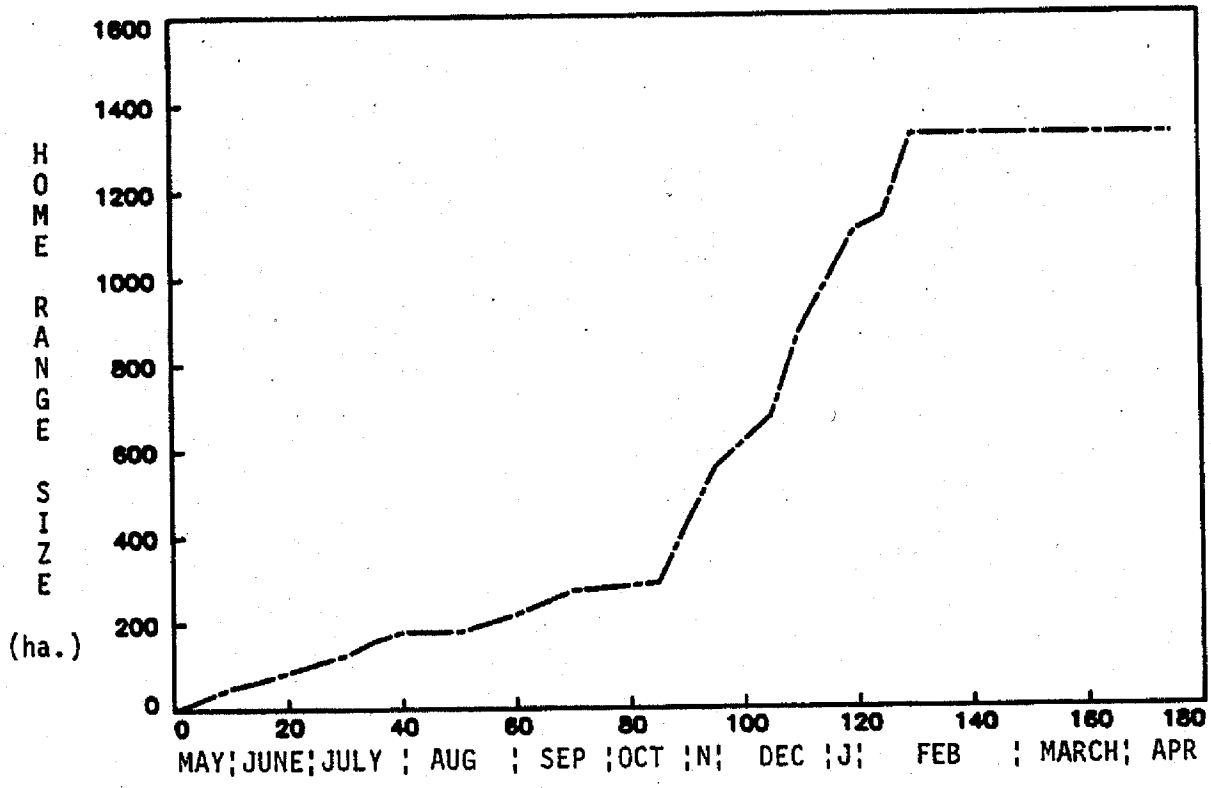


CUMULATIVE SAMPLE SIZE

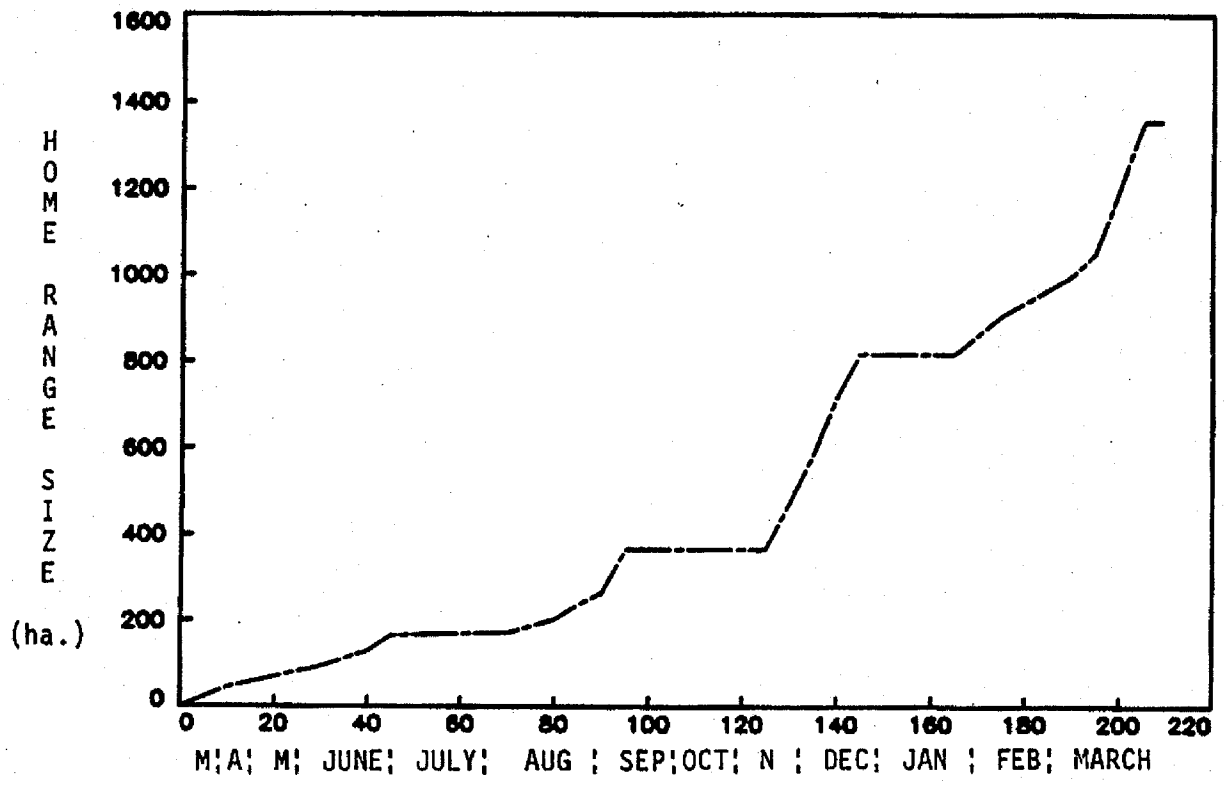
Cumulative home range analysis for the Rearing Ponds female barred owl showing how convex polygon size varies with sample size and season. The monitoring period ran 12 months from 8 Apr 86 - 8 Apr 87.



Cumulative home range analysis for the Sandy female barred owl showing how convex polygon size varies with sample size and season. The monitoring period ran 11½ months from 6 May 86 - 17 Apr 87.



Cumulative home range analysis for the Sandy male barred owl showing how convex polygon size varies with sample size and season. The monitoring period ran 11 months from 16 May 86 - 17 Apr 87.



Cumulative home range analysis for the Sandy male spotted owl showing how convex polygon size varies with sample size and season. The monitoring period ran 12 months from 11 Mar 86-31 Mar 87.

HOME RANGE SIZE OF THE NORTHERN BARRED OWL AND NORTHERN SPOTTED OWL IN WESTERN WASHINGTON

by

Thomas Edward Hamer

accepted in Partial Completion
of the Requirements for the Degree
Master of Science

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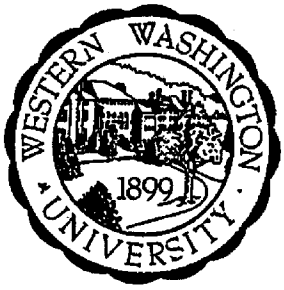

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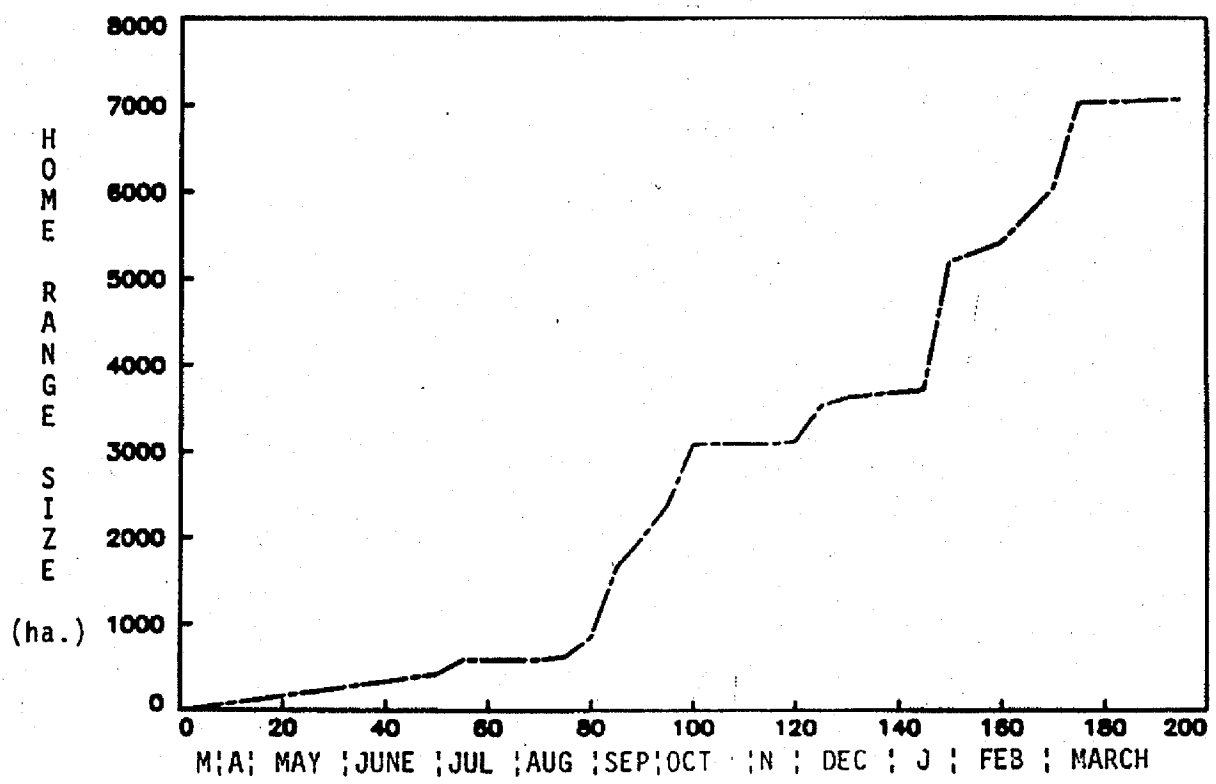

Cumulative home range analysis for the Sandy female spotted owl showing how convex polygon size varies with sample size and season. The monitoring period ran 12 months from 11 Mar 86 - 31 Mar 87.

HOME RANGE SIZE OF THE NORTHERN BARRED OWL AND NORTHERN SPOTTED OWL IN WESTERN WASHINGTON

by
Thomas E. Hamer

ABSTRACT - The morphology, density, home range size and home range utilization of a population of northern barred owls (Strix varia) and northern spotted owls (Strix occidentalis caurina) were studied in northwest Washington.

Spotted owls are 17.9% lighter in weight, have a slightly smaller body size, similar wing loading, and a much larger foot spread than barred owls. Mean nearest neighbor distance for barred owls was 3.17 km (range=1.8-5.4,N=16) while spotted owls were 2.3 times more distant at 7.3 km (range=3.6-11.2, N=6). The difference in these distances is reflected in the population densities of the two species with barred owls being 2.1 times more numerous than spotted owls in the study area.

Using the minimum convex polygon method, mean barred owl summer home ranges were 321.5 ha (range=145-506, S.D.=139.3, N=8) while mean spotted owl summer home ranges were not significantly different at 321.2 ha (range=73-862, S.D.=371.3, N=4). Breeding barred owls had significantly smaller home ranges than non-breeding birds. The average annual spotted owl home range (mean=2,816 ha, range=1,200-7070, S.D.=2,841, N=4) was 4.4 times larger than the mean annual barred owl home range (mean=644 ha, range=205-1,326, S.D.=293.5, N=10). Mean annual pair home ranges of barred owls were 905 ha (range=587-1,477, N=4 pair) while spotted owl pairs averaged 4,750 ha (range=2,430-7070, N=2pair). Barred owl pairs showed higher home range overlaps (mean=39%, range=16-62%) than spotted owl pairs (mean=18%, range=17.1-19.1%). Home ranges of barred and spotted owls in this study are much larger than those reported by other researchers.

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I would like to dedicate this thesis to my parents, Paul and June Hamer, who taught me to begin whatever I can do or dream. And to my wife Christine, who tolerated many of my long nights in the field.

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Two studies in Washington and Oregon have used radio-telemetry techniques to estimate the home range size of spotted owls. Forsman et al. (1984) found that an average pair home range size in Oregon varied from 172 ha to 1154 ha (mean=1177 ha, N=3 pair). Brewer and Allen (1985) reported an average annual home range of 3703 ha per pair in Washington (N=6 pair). Finally, Allen (1987) later reports that a mean individual spotted owl home range in Washington is 1963 ha (N=18 range=406-7134). All the estimates above are based on the minimum convex polygon method for calculation of home range size.

The long term goals of the study are to answer some basic questions about the biology of the northern barred owl and northern spotted owl in an area of sympatry and begin to evaluate the possible impact of the barred owl on spotted owl populations. The objectives for the first year of research were to:

1) Document the relative density of barred and spotted owls in the study area.
2) Estimate breeding season (March through August) and annual home range (March through February) sizes for five pairs of northernbarred owls and two pairs of northern spotted owls, and for each individual owl.
3) Compare four different techniques to estimate home range size. These are the minimum convex polygon, harmonic mean transformation, Fourier transformation and 95% ellipse.

jay (Cyanocitta stelleri) and the merging of the red-shafted flicker and yellow shafted flicker into one species (Colaptes auratus) (Knopf, 1986).

By 1985, the geographic range of the barred owl almost overlapped the entire range of the northern spotted owl, except in a small portion of northwest California and western Oregon (Figure 1) (Allen and Hamer, 1985). These two congeneric species are now sympatric throughout the Cascade Ranges and Coast Ranges from Garibaldi Provincial Park, British Columbia, south to northern California. Whether these two species can coexist sympatrically for any length of time is unknown. A large overlap in the resource requirements may make coexistence of the two species unlikely.

No information exists on the home range size, habitat requirements, food habits, activity patterns or behavior of the barred owl west of the Rocky Mountains. Three radio-telemetry studies conducted in the midwest have attempted to estimate the home range size of barred owls. Nicholls and Warner (1972), and Fuller (1979), found the average home range size for barred owls in Minnesota was 273 ha (N=13, range=86.1 to 770 ha). The average home range size for barred owls in Michigan's upper peninsula was 282 ha (Elody and Sloan, 1985). One other study estimated the density of breeding pairs of barred owls in northern New Jersey using surveying techniques. They found .142 barred owl pairs per square kilometer (Bosakowski et al., 1987).

Information was also collected on the habitat use by both species, activity patterns, territorial behavior and interspecific interactions which will be reported elsewhere.

STUDY AREA

The study area is located in Northwest Washington in the Baker Lake Basin on the west slope of the North Cascade Mountains and comprises an area of 357 square kilometers (138 sq. miles) (Figure 3). Baker Lake lies just south of Mt. Baker, a dormant volcano, with much of the study area comprising the lower forested slopes of the mountain itself. This area was selected because previous surveys for spotted owls had been conducted throughout the drainage and thus many locations of both barred and spotted owls were known. All the land is managed by the U.S.F.S. and is part of the Mt. Baker Ranger District.

The study area is part of the North Cascades Physiographic Province described by Franklin and Dyrness (1973). The topography of the area consists of very deep and steep sided valleys of maximum relief. Elevations range from 244 m on the valley floor to 3,283 m on the peak of Mt. Baker. Areas above 1,980 m are heavily glaciated and commonly consist of permanent snow fields. The region is characterized by a wet, mild maritime climate and precipitation is highly variable. The mean annual precipitation is 254 cm with most of the moisture falling during the winter in the form of rain. Snow can accumulate in the valley floor during some winters but snowpack is highly variable between years. Summer drought is common with only 6-9 % of the annual precipitation falling during this period. The mean annual temperature is 10.1 C. Mean July temperature is 17.4 C and the

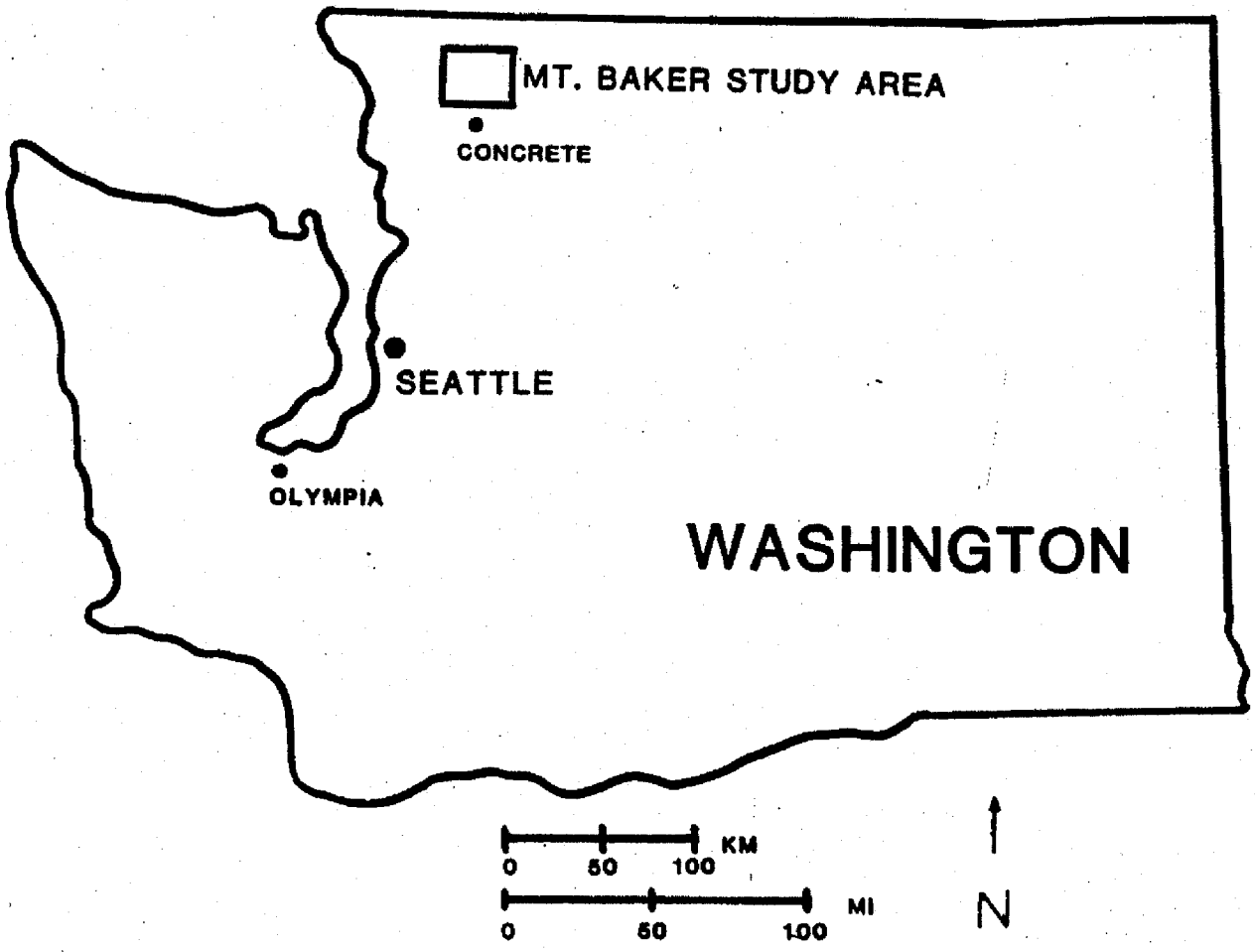

Figure 3 . Location of the Mt. Baker study area for barred and spotted owls during 1986 and 1987 in Northwestern Washington.

mean January temperature is 1.0 C.

The study area is entirely forested except areas that have been recently clear-cut and those portions over 1,800 m in elevation which are above treeline. Three forest vegetation zones occur here. The Western Hemlock zone occurs primarily along the lower reaches of major drainages while the Mountain Hemlock zone occurs above 1000 m in wetter areas. The Silver fir zone occurs on cooler, mid-elevation slopes from 400 m to 900 m in elevation. Forest stands are of various ages and conditions from pristine old-growth associations to heavily disturbed younger aged stands that have been high-graded or clear-cut within the last 60 years. Portions of the study area are highly fragmented due to current forest management practices while other areas contain large contiguous forest stands.

METHODS

Location of owls

The U.S. Forest Service, Washington Department of Wildlife, Biosystems Analysis Incorporated and Puget Power and Light Company have all conducted nothern spotted owl surveys in portions of the study area between 1981 and 1984. The Mt. Baker Ranger District continued its surveys in 1986 and 1987 as part of the U.S.F.S. spotted owl monitoring effort being conducted forest wide. From this information many of the locations of barred owl and spotted owl pairs were known. During the spring of 1986 and 1987 I re-surveyed much of the study area to confirm the locations of these pairs, document the locations of new pairs, and establish trapping sites.

Surveys to locate barred and spotted owls were conducted after dusk from March 1st through June 30th. They were discontinued after June 30th because the responsiveness of the owls declined. Survey methods generally follow that described by Forsman et al. (1984) with owls located using pre-recorded vocalizations, portable cassette recorders and megaphone speakers. Both spotted owl and barred owl vocalizations were played back at each station although I found barred owls to be responsive regardless of the type of call used.

Calling inventories were conducted by driving along forest roads and stopping at .4 km (1/4 mile) intervals to call and listen for owls. Observers waited for responses for 15-20 minutes at each

station. Surveys were also conducted along forest trails and overgrown roads by calling every few minutes as the area was traversed on foot.

To document the spacing of barred and spotted owls in the study area, mean nearest neighbor distances were calculated by measuring the distance between repeated survey locations of owl pairs and individuals, or by measuring the distance between nest sites or core areas (for radio-tagged pairs). Core areas were delineated by the harmonic mean transformation method of home range estimation using the 25% isopleth. Nest sites were found by following radio-tagged females back to their nesting cavities.

Radiotelemetry data collection

Several methods were used to capture barred owls and spotted owls. The most successful method I used to capture barred owls was a technique described by Elody (1983). Three 121 mm stretch nylon mist nets were arranged in a large triangle and supported by 3 meter long aluminum poles. A live decoy barred owl was placed on a perch within the nets along with a large megaphone speaker which was connected to a cassette recorder in a blind constructed approximately 15 meters from the nets. Observers kept hidden in the blind and could then play-back various vocalizations to attract resident owls. Resident owl pairs would defend their territory by calling and diving at the decoy, thus getting caught in the nets. I found the effectiveness of this

able to utilize habitats made available by natural disturbances.

In 1987, surveys were conducted for barred and spotted owls in the North Cascades National Park, Ross Lake Drainage (Bjorklund and Drummond, 1987). Repeated surveys failed to reveal any spotted owls, however, 11 barred owls were located in the survey area. This area lies just 18 miles to the east of our study location. The lack of spotted owls is attributed to the extensive fire history of the area, higher elevation, and therefore, fragmented nature of the remaining stands of old-growth forests.

Barred owls appear to have a higher population density than spotted owls (Fig.4). This can be explained by the differences in home range size and home range utilization to be discussed later.

Home ranges

Sample size and tracking periods

In the spring of 1986, I radio-tagged 10 barred owls, representing 4 breeding pairs and two individuals, and 4 spotted owls, representing 2 breeding pairs. Therefore, the sample included 5 male barred owls, 5 female barred owls, 2 male spotted owls and 2 female spotted owls. Two pairs of barred owls nested in 1986 and one pair of spotted owls nested. From these 14 birds 2,700 relocations were collected during a 12 month period. For ten barred owls, I gathered an average of 151 relocations/bird

over an average time span of 11.4 months (Table 3). I collected an average of 123 relocations/spotted owl over an average time span of 10.7 months (Table 4). The average tracking period for spotted owls is lower because the Diobsud Creek female spotted owl was found dead due to unknown causes after 9 months. The tracking dates for each individual are shown in Tables 3 and 4.

Summer home range

Based on the minimum convex polygon method, barred owls had a mean summer (March 1-Aug. 30) home range size of 321.5 ha (range= 145-506, S.D.=139.3, N=8). Spotted owls had a mean summer home range size of 321.2 ha (range=73-862, S.D.=371.3, N=4). I collected an average of 68 relocations/owl over the summer period. It is surprising how close the summer home range estimates are for these two species. A Mann-Whitney U-test revealed no significant difference ($P>0.05$) in the summer home range size between barred and spotted owls.

An unpaired T-test revealed breeding barred owls (mean=215 ha, S.D.=80.3, N=4) had significantly smaller ($P<.05$) home ranges than non-breeding individuals (mean=427, S.D.=94.2, N=4). Non-breeding barred owl individuals have summer home ranges that are about twice the size of the home range of breeding birds. Since breeding birds are delivering prey items to a nest site, they may be restricted to foraging in smaller areas around the nest tree. I observed a similar trend in spotted owls but the small sample

Table 3. Tracking dates, total tracking period, relocation sample size and home range size in hectares for 10 barred owls in Western Washington. Home range size was calculated using the minimum convex polygon method.

SITE NAME	SEX	TRACKING DATES	NUMBER OF MONTHS	SAMPLE SIZE	HOME RANGE SIZE (hectares)
Sandy Creek	M	16 May 86 - 17 Apr 87	11	179	1,326
Sandy Creek	F	6 May 86 - 17 Apr 87	11	197	782
1799 Hill	M	3 Apr 86 - 10 Apr 87	12	163	727
1799 Hill	F	11 Apr 86 - 2 Mar 87	11	158	542
Welker Creek	M	4 Apr 86 - 8 Apr 87	12	142	509
Welker Creek	F	3 May 86 - 8 Apr 87	11	158	771
Rearing Ponds	M	29 Mar 86 - 8 Apr 87	12	177	587
Rearing Ponds	F	8 Apr 86 - 8 Apr 87	12	177	205
Diobsud Creek	M	5 Jun 86 - 27 Apr 87	11	51	479
Diobsud Creek	F	22 May 86 - 27 Apr 87	11	40	515
Mean			11.4	151	644
S.D.					293.5

Table 4. Tracking dates, total tracking period, relocation sample size and home range size in hectares for 4 spotted owls in Western Washington. Home range size was calculated using the minimum convex polygon method.

SITE NAME	SEX	TRACKING DATES	NUMBER OF MONTHS	SAMPLE SIZE	HOME RANGE SIZE (hectares)
Sandy Creek	M	11 Apr 86 - 31 Mar 87	11	202	1,351
Sandy Creek	F	11 Mar 86 - 31 Mar 87	12	188	7,070
Diobsud Creek	M	22 May 86 - 13 Apr 87	11	57	1,643
Diobsud Creek	F	22 May 86 - 10 Feb 87	9	46	1,200
Mean			10.75	123	2,816
S.D.					2,841

size for this species prohibited the use of a statistical test.

Annual home range

Barred owl individuals had an annual home range size (using MCP) of 644 ha (range= 205-1326, S.D.=293.5, N=10) (Table 3). Spotted owl individual home ranges averaged 2,816 ha (range= 1200-7070, S.D.=2,841, N=4) (Table 4). Mann-Whitney U-test results indicate that spotted owls have significantly larger annual home ranges than barred owls. Spotted owl annual home ranges were 4.4 times larger than barred owl home ranges. Core nesting and activity areas were defined for spotted and barred owls using the harmonic mean 50% isopleth. Barred owl core areas were 56 ha (range=16-98, N=10) in size and spotted owl core areas were 86 ha (range=43-130, N=4) in size.

Allen (1987) reports mean spotted owl individual home range in Washington to be 1,963 ha, much smaller than the average found in this study. My estimates do fall within the range she reported (range=409-7134 ha). A look at the average sample size and monitoring period for the 18 owls Allen studied reveals that, on average, birds were only monitored for a period of 7.5 months with a mean sample size of 96 relocations collected/bird. The shorter monitoring period and smaller relocation sample for some of the owls has probably biased the home range estimate toward smaller values. Forsman (1980) reports even smaller home range values (1,177 ha) for spotted owls in Oregon which may be due to

a geographic variation in the home range size of the spotted owl as one moves north. This trend has been noticed by several researchers.

Although male barred owls (mean=726, S.D.=349, N=5) had home ranges 29% larger than females (mean=563, S.D.=235.6, N=5), an unpaired T-test revealed no significant difference in these means. The two barred owls with the largest home ranges were the Sandy Creek pair, which were living adjacent to a pair of spotted owls. These two birds had an average home range size that was 64% larger than the average barred owl. The larger home range may be the result of the interaction between these two species.

Pair home range

Mean annual home range for barred owl pairs was 905 ha (range= 587-1477ha, N=4 pair) (Table 5), while spotted owl pairs averaged 4,750 ha (range=2430-7070, N=2 pair) (Table 6) estimated by the minimum convex polygon method. Allen (1987) reports pair home ranges of spotted owls in Washington to be 3,703 ha in size (N=6 pair). Again, the smaller estimate is probably due to the shorter monitoring period for these birds. Forsman (1980) reports an average pair home range size in Oregon to be 2,144 ha.

The mean percent home range overlap of paired male and female barred owls was 38.9% (range=16-62, N=4 pair). The average home range overlap between males and females for two pairs of spotted owls was 18.1% (range=17.1-19.1). Forsman

Table 5. Minimum convex polygon home range estimates for four pair of barred owls and the percent of home range overlap for paired male and female owls.

SITE NAME	HOME RANGE SIZE (hectares)	PERCENT OVERLAP
Rearing Pond Pair	587	35.0
Welker Ridge Pair	789	62.2
Sandy Creek Pair	1,477	42.6
Diobsud Creek Pair	767	16.0
Mean	905	38.9

Table 6. Minimum convex polygon home range estimates for two pair of spotted owls and the percent of home range overlap for paired male and female owls.

SITE NAME	HOME RANGE SIZE (hectares)	PERCENT OVERLAP
Sandy Creek Pair	7,070	19.1
Diobsud Creek Pair	2,430	17.1
Mean	4,750	18.1

(1984) reports the mean pair overlap for spotted owls in Oregon to be 68%, a much higher overlap than that observed in this study. Figures 5 and 6 illustrate the size, shape and amount of overlap of the polygon boundaries for barred and spotted owl pairs. The Diobsud Creek and Sandy Creek barred owl pairs show less home range overlap than the Rearing Ponds and Welker Creek pairs. The former two pairs were living adjacent to spotted owls (Fig.5). Competitive interactions with spotted owls could be causing barred owl pairs to forage farther apart during the winter, but a larger sample of pairs is needed to confirm this trend. For the latter two pairs, the Rearing Ponds female residedcompletely within the male's home range while the Welker male was found living almost entirely within thefemale's home range. Nicholls and Fuller (1987) found large home range overlaps of paired barred owls in their study. For spotted owls, the calculation of home range overlap is more complex since the Diobsud male and the Sandy Creek female had winter ranges that were separate from their summer ranges (Fig. 7). Therefore, althoughthe Sandy Creek male's home range lies entirely within the female's, there is actually much less home range overlap than is first apparent, since the female spent 5 weeks in an area 9 air miles to the south. The Diobsud Creek Male spent 12 weeks in an area 6 miles to the south of his summer home range.

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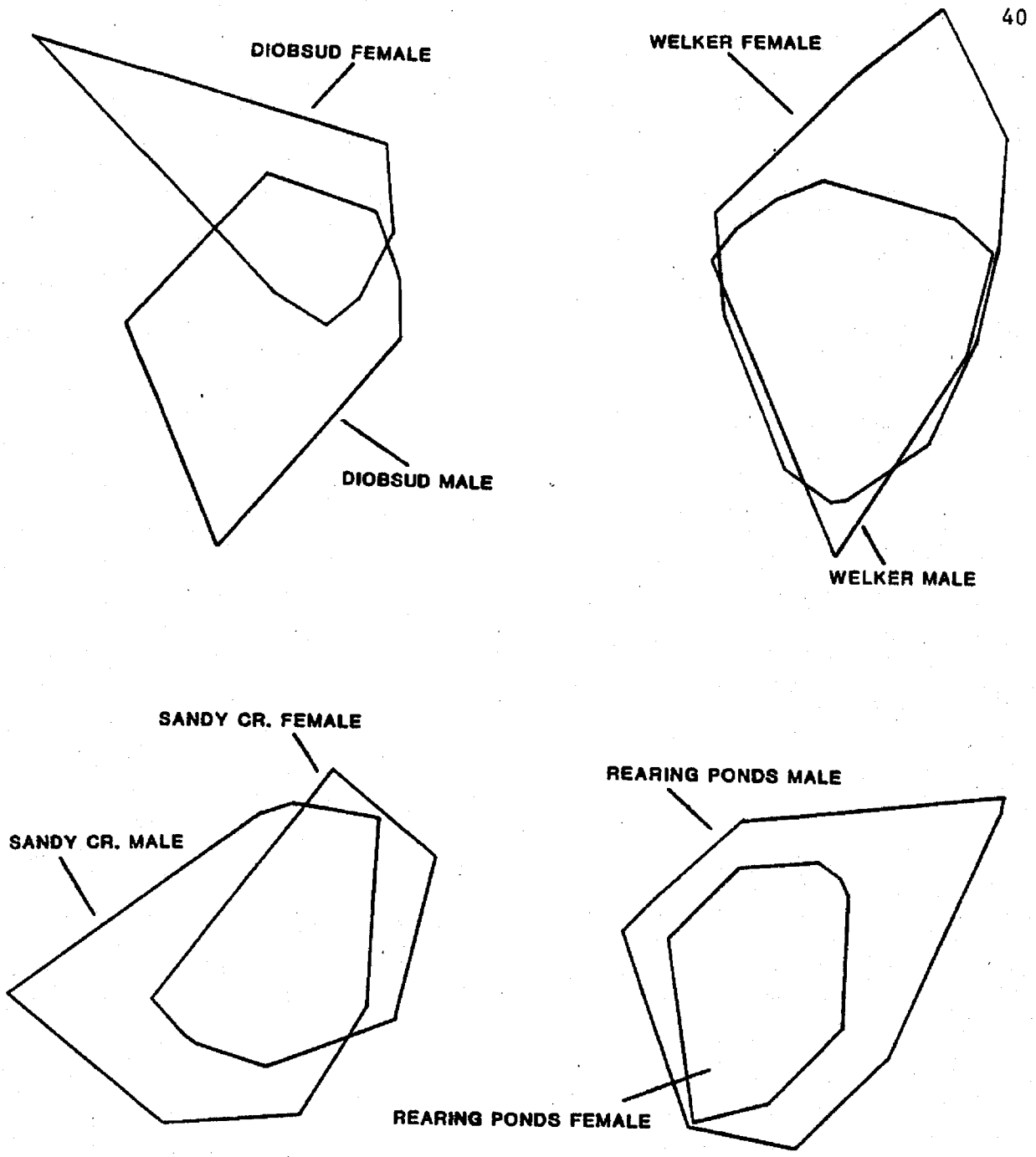

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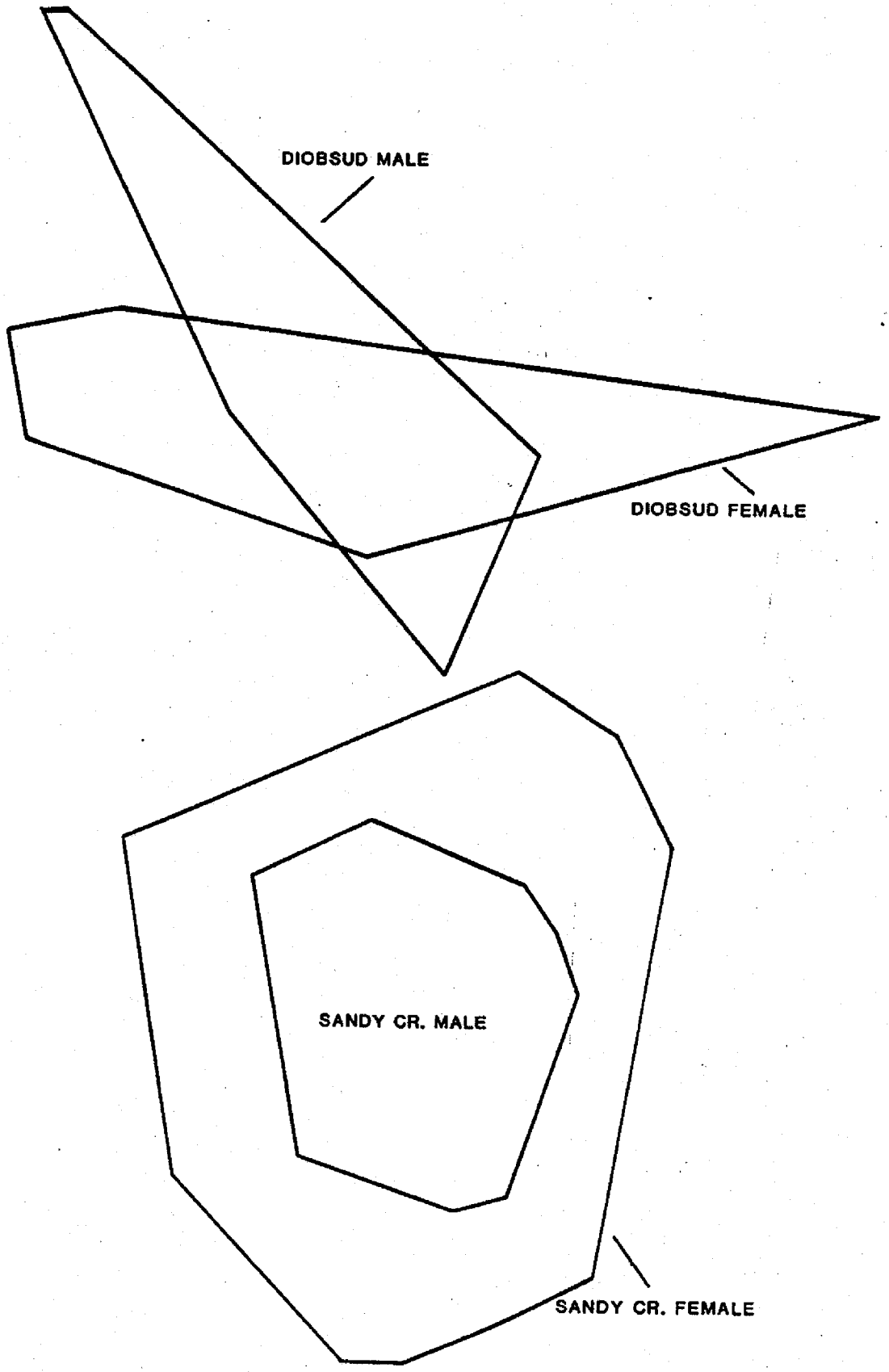

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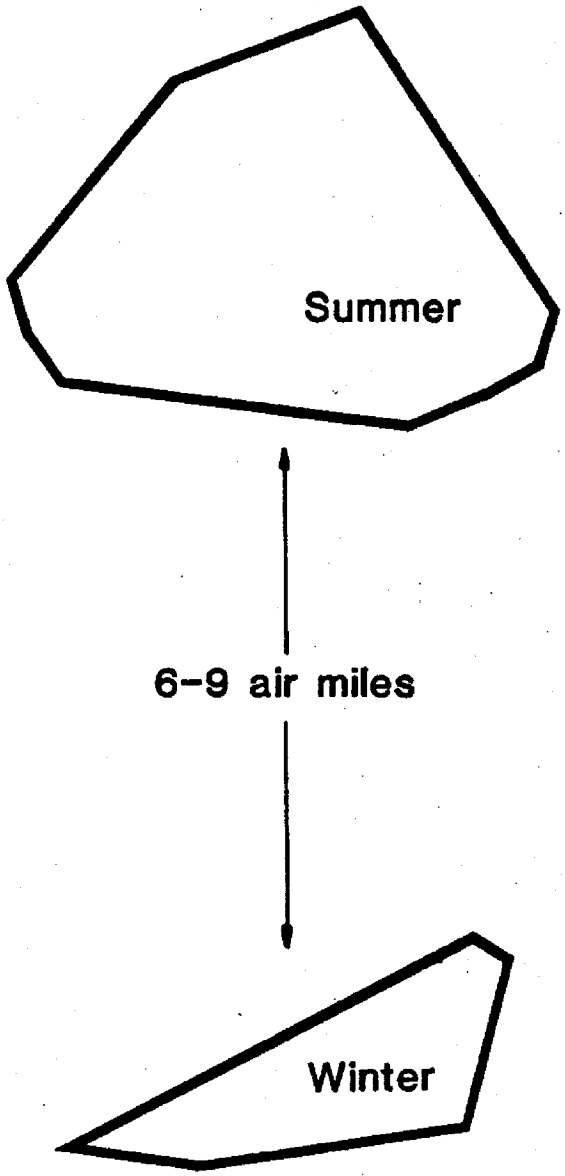

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Cumulative home range

A comparison of the mean cumulative home range for 8 barred owls and two spotted owls is shown in Figure 8. As we have seen, the summer home ranges of these two species is very similar. Large differences in home range utilization begin to appear in late August when the rate of growth of spotted owl home ranges increases rapidly. One reason for this difference is the mean

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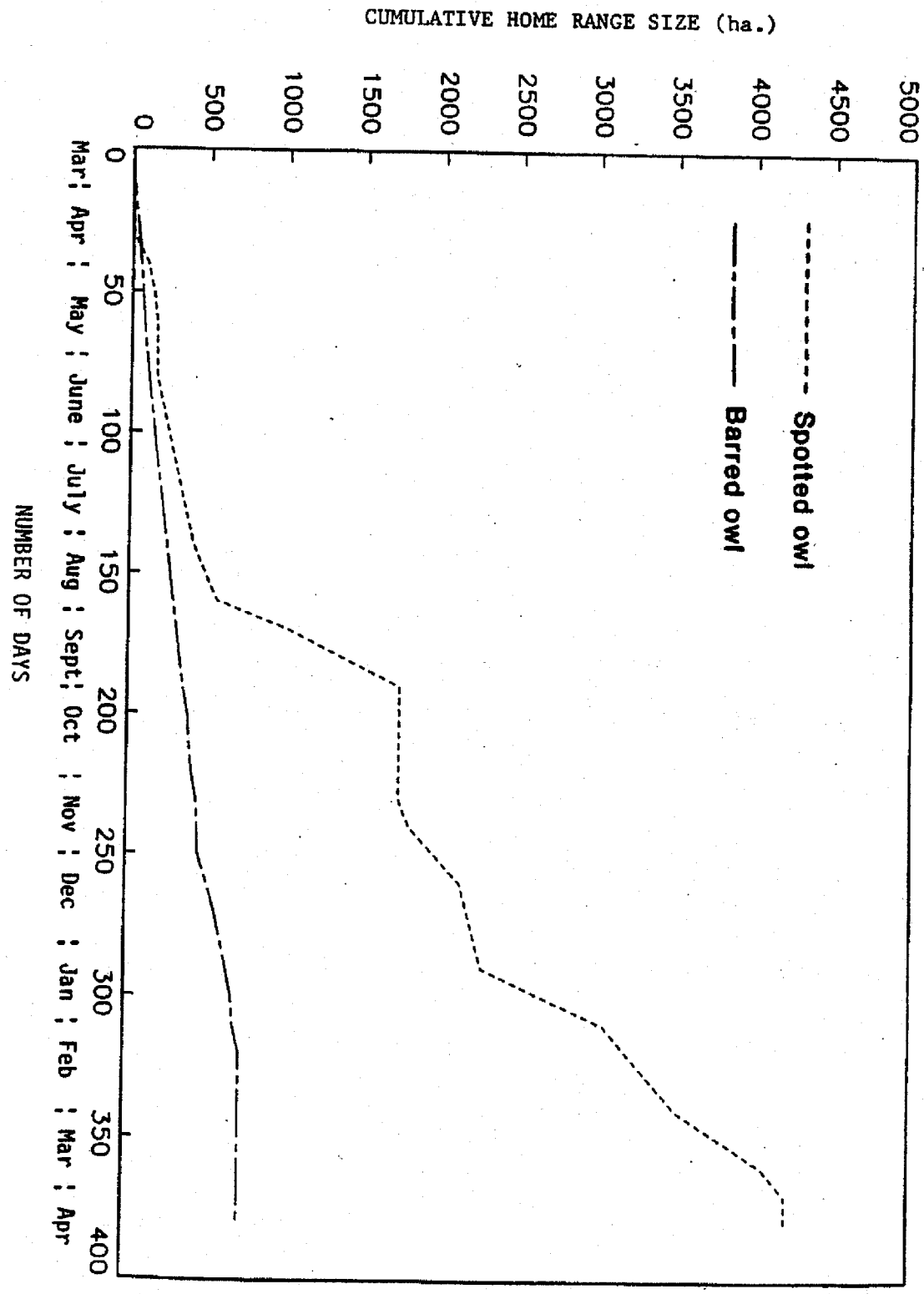
CUMULATIVE HOME RANGE SIZE (ha.)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Spotted owl
Barred owl
0
50
100
150
200
250
300
350
400
Mar ; Apr ; May ; June ; July ; Aug ; Sept ; Oct ; Nov ; Dec ; Jan ; Feb ; Mar ; Apr
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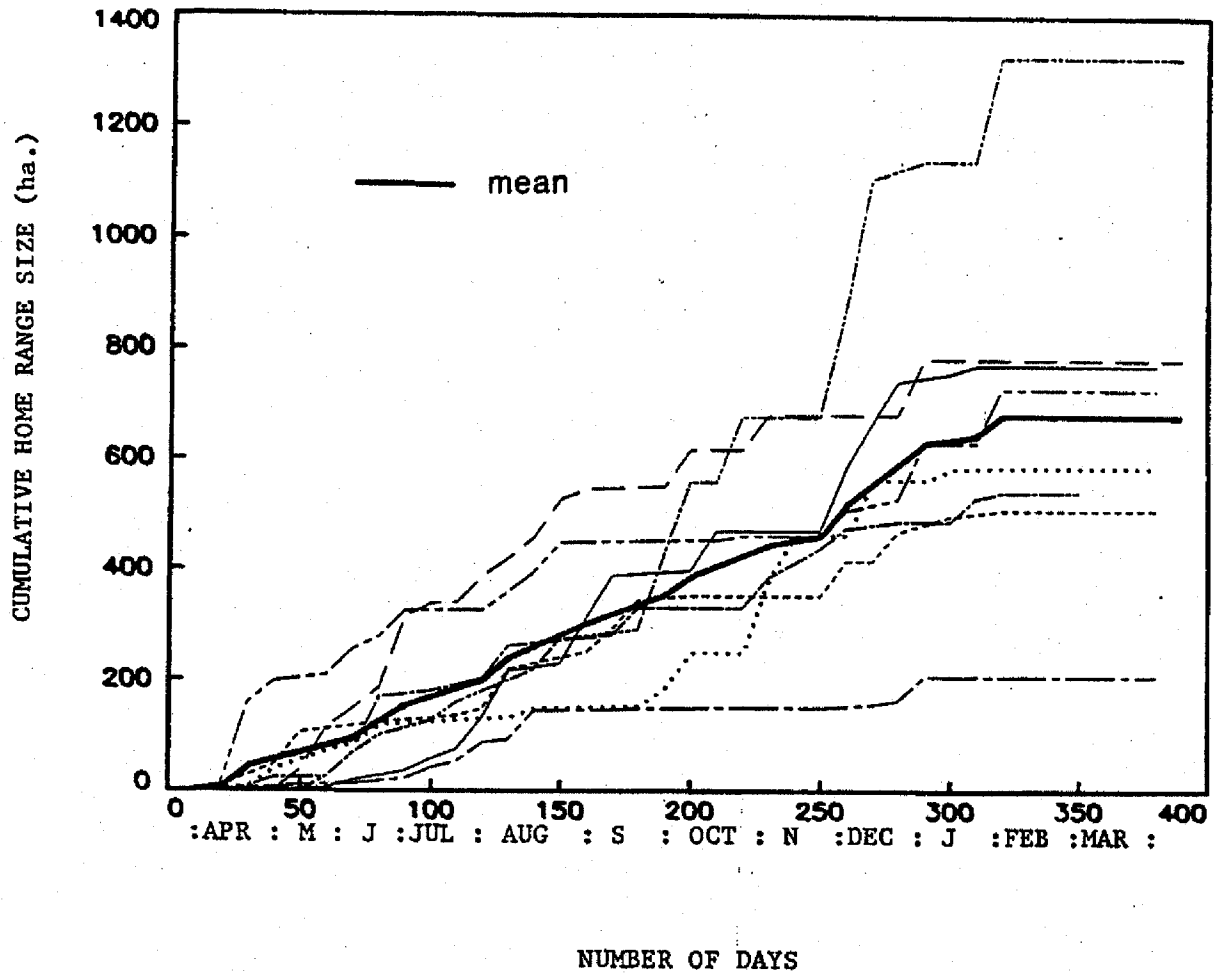

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of this species. The smaller home range size of the barred owl allows these birds to have a higher population density than spotted owls (Fig. 4). Mean nearest neighbor distances reflect this density.

Food habits differences and home range size

The extremely large home range size of the spotted owl, smaller pair home range overlap, wide winter wanderings, rapid home range growth throughout the year, early departure from core areas in the fall and late return to core areas in the spring, could be a result of the food habits specialization in this species. These factors could reflect the behavior of a population stressed by low food supplies. Spotted owls have been shown to specialize on medium sized arboreal and semi-arboreal mammals such as the flying squirrel (Glaucomys sabrinus), red tree vole (Arborimus longicaudus) and two woodrat species (Neotoma) in Oregon (Forsman et al., 1984). In Washington the owl has been shown to primarily feed on flying squirrels (Gutierrez and Carey, 1985). The barred owl appears to be very much a food habits generalist throughout its range in the eastern United States feeding on a large variety of small terrestrial mammals, small passerines, insects, amphibians, reptiles and even fish is commonly reported in the literature (Blakemore, 1940; Devereux and Mosher, 1984; Karalus and Eckert, 1974; Wilson, 1938). Errington and McDonald (1937) report that the diet

composition of the barred owl is governed by availability, ease of capturing prey and by chance. Not only are there differences in the range of prey types taken by these owls, but the spotted owl also appears to prefer prey of larger biomass. Barrows (1985) has found that spotted owls have a high porportion of larger prey items in their diet have greater breeding success than spotted owl pairs that feed on smaller prey items.

The population density of mammals declines with increasing body size with a regression slope of -.75 (Damuth, 1981). Therefore, the spotted owl will have to search for prey over a larger area than the barred owl since it is searching for fewer different prey species of larger body size and lower numerical densities. Since the spotted owl is searching for fewer prey items, individuals may have to forage over larger areas to procure these items. This will not be true during the breeding season where males and females must deliver prey items to a nest site and thus forage in smaller areas. An increase in prey availability during the summer would also allow the spotted owl to have smaller summer home ranges. The breeding (summer) home ranges of barred and spotted owl are therfore similar in size. Spotted owls may also be expected to have a larger negative effect on prey densities since they are feeding on fewer prey items. Preliminary results of several researchers have showed extremely low flying squirrel densities in spotted owl nesting areas compared to other areas (Andy Carey, USFS, pers. com.).

and aggressive behavior may give this species an advantage during territorial disputes with spotted owls. Limited observational data (Harriet Allen, Washington Dept. of Wildlife; Jim Ackinson, Willapa Nat. Wildlife Refuge, pers. com.) suggest that behavioral interactions between the barred owl and spotted owl are occurring with the barred owl dominant in each encounter.

Density

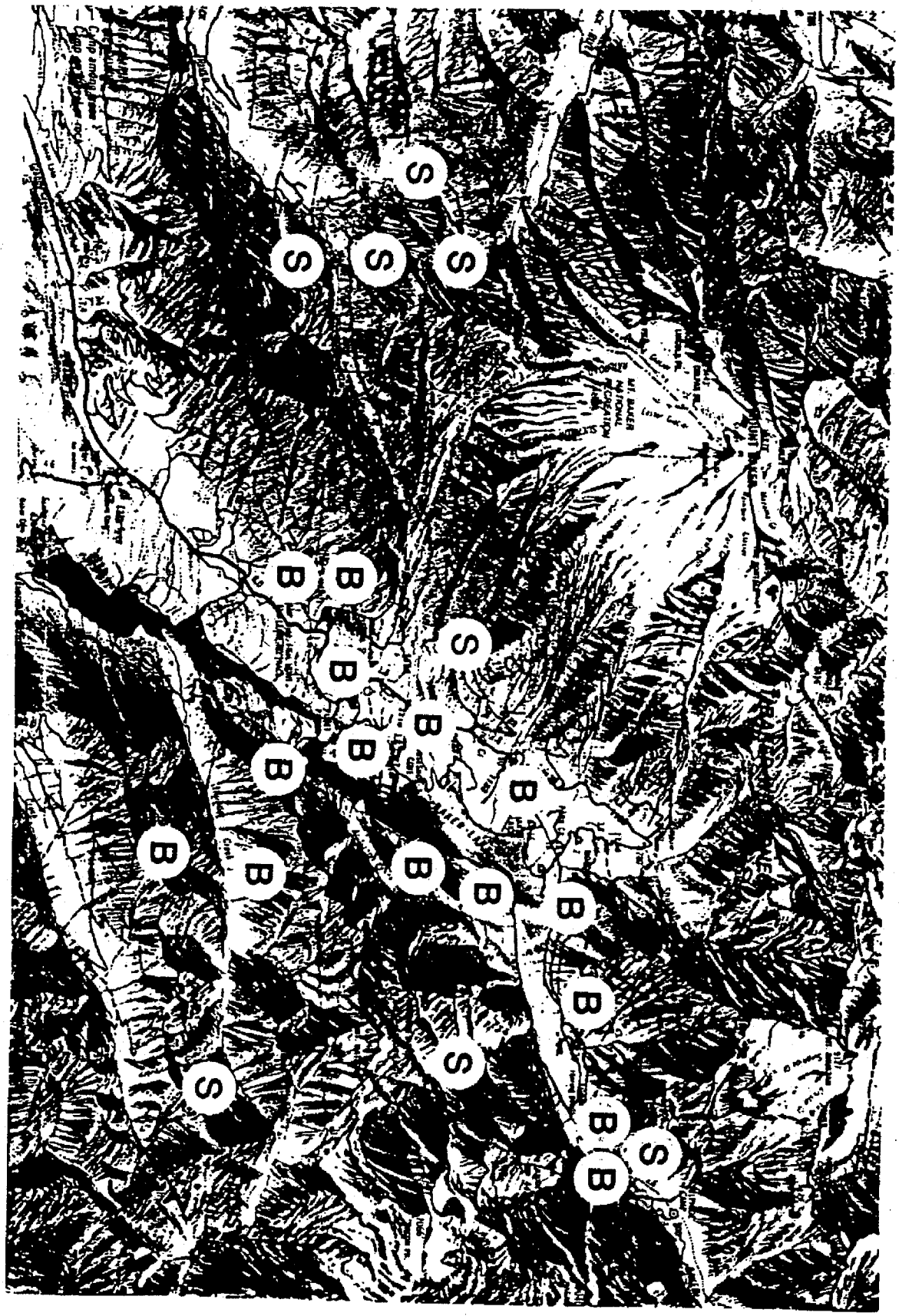
The mean nearest neighbor distance between nest areas or core areas of resident barred owl pairs was 3.17 km (1.98 mi) (N=16, range 1.8-5.4 km). Spotted owl mean nearest neighbor distance was 7.3 km (4.56 mi) (N=6, range 3.6-11.2 km). Forsman (1984) reports mean nearest neighbor distances for spotted owls in Oregon were 2.6 km (N=47). This is a much closer spacing than that observed in my study area. Spotted owls are therefore 2.3 times more distant between resident pairs than barred owls in the study area. I monitored three sites where barred and spotted owls were living in adjacent territories. The mean nearest neighbor distance for these interspecific pairs was 1.6 km (1.0 mi.) (range=.87-1.12 km,N=3). It is interesting to note that adjacent territorial pairs of barred and spotted owls nest closer to each other than either adjacent barred owl pairs or neighboring spotted owl pairs. Therefore, we can expect to see a degree of interspecific home range overlap between these two species. Whether these two raptors require similar habitat

types, food resources or nest sites remains to be documented.

The population density and spatial distribution of barred and spotted owls in the study area is shown in Figure 4. Prior to 1974 there were no barred owl records within the study area (Hamer and Allen, 1985). The population of barred owls on the study area has thus grown from zero individuals prior to 1970 to 32 individuals by 1987. The spotted owl population has remained stable with 15 individuals residing in the area over the last three years. My survey results show that barred owls are now 2.1 times more numerous than spotted owls. The barred owl population is probably still increasing in the study area since the species has had only 13 years to establish itself.

Figure 4 shows barred owls inhabiting those areas lower in elevation around Baker Lake and associated drainages. Spotted owls are found higher in elevation and further distances from the Lake Basin. This may be a result of the long history of high grading and clearcutting of the lower elevations around Baker Lake. These areas were historically pure coniferous forest old-growth, but after being disturbed, have grown back into mixed stands of deciduous-coniferous forest. Habitat studies in the eastern United States have found this habitat type to be preferred barred owl habitat (Bird and Wright, 1977; Dunstan and Sample, 1972; Elody, 1983; Fuller, 1979; Gutmore, 1977; Nicholls and Warner, 1972). The areas away from the basin are less roaded and disturbed, and contain much larger and contiguous tracts of

Figure 4. Spacial distribution and density of barred and spotted owls in the study area. The symbol B represents barred owl individuals or pairs and the symbol S represents spotted owl individuals or pairs. There is an absence of resident barred owls on the west side of the study area.


S
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pure coniferous old-growth forest which is preferred spotted owl habitat (Forsman, 1980). The difference in habitat preference between barred and spotted owls can also be observed by looking at the total distribution of barred owls across the study area. Figure 4 shows an absence of barred owls on the west side of the study area, but a high density of spotted owls. This area was only recently roaded and contains large amounts of contiguous old-growth habitat. Those areas that have been clearcut are in very young stages of developement (<20 years) and provide no suitable habitat for barred owls or spotted owls since a forest canopy has not yet developed. These disturbed areas will eventually grow back into mixed stands of coniferous-deciduous forest and provide suitable barred owl habitat in the near future. One individual barred owl appeared in this area in the fall of 1986, set up residency for 10 months, and then disappeared early in the spring of 1987.

I have also located barred owls in areas where the habitat is undisturbed by human activities. In one instance, a pair of barred owls was using mixed stands of coniferous-deciduous habitat along a river floodplain. This area has been repeatedly disturbed by flood events and therefore developed into a mixed stand of timber along a wide riparian zone producing preferred barred owl habitat. In several other instances, I have found barred owls utilizing younger stands of timber that have been maintained by fire histories. Therefore, barred owls also appear

able to utilize habitats made available by natural disturbances.

In 1987, surveys were conducted for barred and spotted owls in the North Cascades National Park, Ross Lake Drainage (Bjorklund and Drummond, 1987). Repeated surveys failed to reveal any spotted owls, however, 11 barred owls were located in the survey area. This area lies just 18 miles to the east of our study location. The lack of spotted owls is attributed to the extensive fire history of the area, higher elevation, and therefore, fragmented nature of the remaining stands of old-growth forests.

Barred owls appear to have a higher population density than spotted owls (Fig.4). This can be explained by the differences in home range size and home range utilization to be discussed later.

Home ranges

Sample size and tracking periods

In the spring of 1986, I radio-tagged 10 barred owls, representing 4 breeding pairs and two individuals, and 4 spotted owls, representing 2 breeding pairs. Therefore, the sample included 5 male barred owls, 5 female barred owls, 2 male spotted owls and 2 female spotted owls. Two pairs of barred owls nested in 1986 and one pair of spotted owls nested. From these 14 birds 2,700 relocations were collected during a 12 month period. For ten barred owls, I gathered an average of 151 relocations/bird

over an average time span of 11.4 months (Table 3). I collected an average of 123 relocations/spotted owl over an average time span of 10.7 months (Table 4). The average tracking period for spotted owls is lower because the Diobsud Creek female spotted owl was found dead due to unknown causes after 9 months. The tracking dates for each individual are shown in Tables 3 and 4.

Summer home range

Based on the minimum convex polygon method, barred owls had a mean summer (March 1-Aug. 30) home range size of 321.5 ha (range= 145-506, S.D.=139.3, N=8). Spotted owls had a mean summer home range size of 321.2 ha (range=73-862, S.D.=371.3, N=4). I collected an average of 68 relocations/owl over the summer period. It is surprising how close the summer home range estimates are for these two species. A Mann-Whitney U-test revealed no significant difference ($P>0.05$) in the summer home range size between barred and spotted owls.

An unpaired T-test revealed breeding barred owls (mean=215 ha, S.D.=80.3, N=4) had significantly smaller ($P<.05$) home ranges than non-breeding individuals (mean=427, S.D.=94.2, N=4). Non-breeding barred owl individuals have summer home ranges that are about twice the size of the home range of breeding birds. Since breeding birds are delivering prey items to a nest site, they may be restricted to foraging in smaller areas around the nest tree. I observed a similar trend in spotted owls but the small sample

Table 3. Tracking dates, total tracking period, relocation sample size and home range size in hectares for 10 barred owls in Western Washington. Home range size was calculated using the minimum convex polygon method.

SITE NAME	SEX	TRACKING DATES	NUMBER OF MONTHS	SAMPLE SIZE	HOME RANGE SIZE (hectares)
Sandy Creek	M	16 May 86 - 17 Apr 87	11	179	1,326
Sandy Creek	F	6 May 86 - 17 Apr 87	11	197	782
1799 Hill	M	3 Apr 86 - 10 Apr 87	12	163	727
1799 Hill	F	11 Apr 86 - 2 Mar 87	11	158	542
Welker Creek	M	4 Apr 86 - 8 Apr 87	12	142	509
Welker Creek	F	3 May 86 - 8 Apr 87	11	158	771
Rearing Ponds	M	29 Mar 86 - 8 Apr 87	12	177	587
Rearing Ponds	F	8 Apr 86 - 8 Apr 87	12	177	205
Diobsud Creek	M	5 Jun 86 - 27 Apr 87	11	51	479
Diobsud Creek	F	22 May 86 - 27 Apr 87	11	40	515
Mean			11.4	151	644
S.D.					293.5

Table 4. Tracking dates, total tracking period, relocation sample size and home range size in hectares for 4 spotted owls in Western Washington. Home range size was calculated using the minimum convex polygon method.

SITE NAME	SEX	TRACKING DATES	NUMBER OF MONTHS	SAMPLE SIZE	HOME RANGE SIZE (hectares)
Sandy Creek	M	11 Apr 86 - 31 Mar 87	11	202	1,351
Sandy Creek	F	11 Mar 86 - 31 Mar 87	12	188	7,070
Diobsud Creek	M	22 May 86 - 13 Apr 87	11	57	1,643
Diobsud Creek	F	22 May 86 - 10 Feb 87	9	46	1,200
Mean			10.75	123	2,816
S.D.					2,841

size for this species prohibited the use of a statistical test.

Annual home range

Barred owl individuals had an annual home range size (using MCP) of 644 ha (range= 205-1326, S.D.=293.5, N=10) (Table 3). Spotted owl individual home ranges averaged 2,816 ha (range= 1200-7070, S.D.=2,841, N=4) (Table 4). Mann-Whitney U-test results indicate that spotted owls have significantly larger annual home ranges than barred owls. Spotted owl annual home ranges were 4.4 times larger than barred owl home ranges. Core nesting and activity areas were defined for spotted and barred owls using the harmonic mean 50% isopleth. Barred owl core areas were 56 ha (range=16-98, N=10) in size and spotted owl core areas were 86 ha (range=43-130, N=4) in size.

Allen (1987) reports mean spotted owl individual home range in Washington to be 1,963 ha, much smaller than the average found in this study. My estimates do fall within the range she reported (range=409-7134 ha). A look at the average sample size and monitoring period for the 18 owls Allen studied reveals that, on average, birds were only monitored for a period of 7.5 months with a mean sample size of 96 relocations collected/bird. The shorter monitoring period and smaller relocation sample for some of the owls has probably biased the home range estimate toward smaller values. Forsman (1980) reports even smaller home range values (1,177 ha) for spotted owls in Oregon which may be due to

a geographic variation in the home range size of the spotted owl as one moves north. This trend has been noticed by several researchers.

Although male barred owls (mean=726, S.D.=349, N=5) had home ranges 29% larger than females (mean=563, S.D.=235.6, N=5), an unpaired T-test revealed no significant difference in these means. The two barred owls with the largest home ranges were the Sandy Creek pair, which were living adjacent to a pair of spotted owls. These two birds had an average home range size that was 64% larger than the average barred owl. The larger home range may be the result of the interaction between these two species.

Pair home range

Mean annual home range for barred owl pairs was 905 ha (range= 587-1477ha, N=4 pair) (Table 5), while spotted owl pairs averaged 4,750 ha (range=2430-7070, N=2 pair) (Table 6) estimated by the minimum convex polygon method. Allen (1987) reports pair home ranges of spotted owls in Washington to be 3,703 ha in size (N=6 pair). Again, the smaller estimate is probably due to the shorter monitoring period for these birds. Forsman (1980) reports an average pair home range size in Oregon to be 2,144 ha.

The mean percent home range overlap of paired male and female barred owls was 38.9% (range=16-62, N=4 pair). The average home range overlap between males and females for two pairs of spotted owls was 18.1% (range=17.1-19.1). Forsman

Table 5. Minimum convex polygon home range estimates for four pair of barred owls and the percent of home range overlap for paired male and female owls.

SITE NAME	HOME RANGE SIZE (hectares)	PERCENT OVERLAP
Rearing Pond Pair	587	35.0
Welker Ridge Pair	789	62.2
Sandy Creek Pair	1,477	42.6
Diobsud Creek Pair	767	16.0
Mean	905	38.9

Table 6. Minimum convex polygon home range estimates for two pair of spotted owls and the percent of home range overlap for paired male and female owls.

SITE NAME	HOME RANGE SIZE (hectares)	PERCENT OVERLAP
Sandy Creek Pair	7,070	19.1
Diobsud Creek Pair	2,430	17.1
Mean	4,750	18.1

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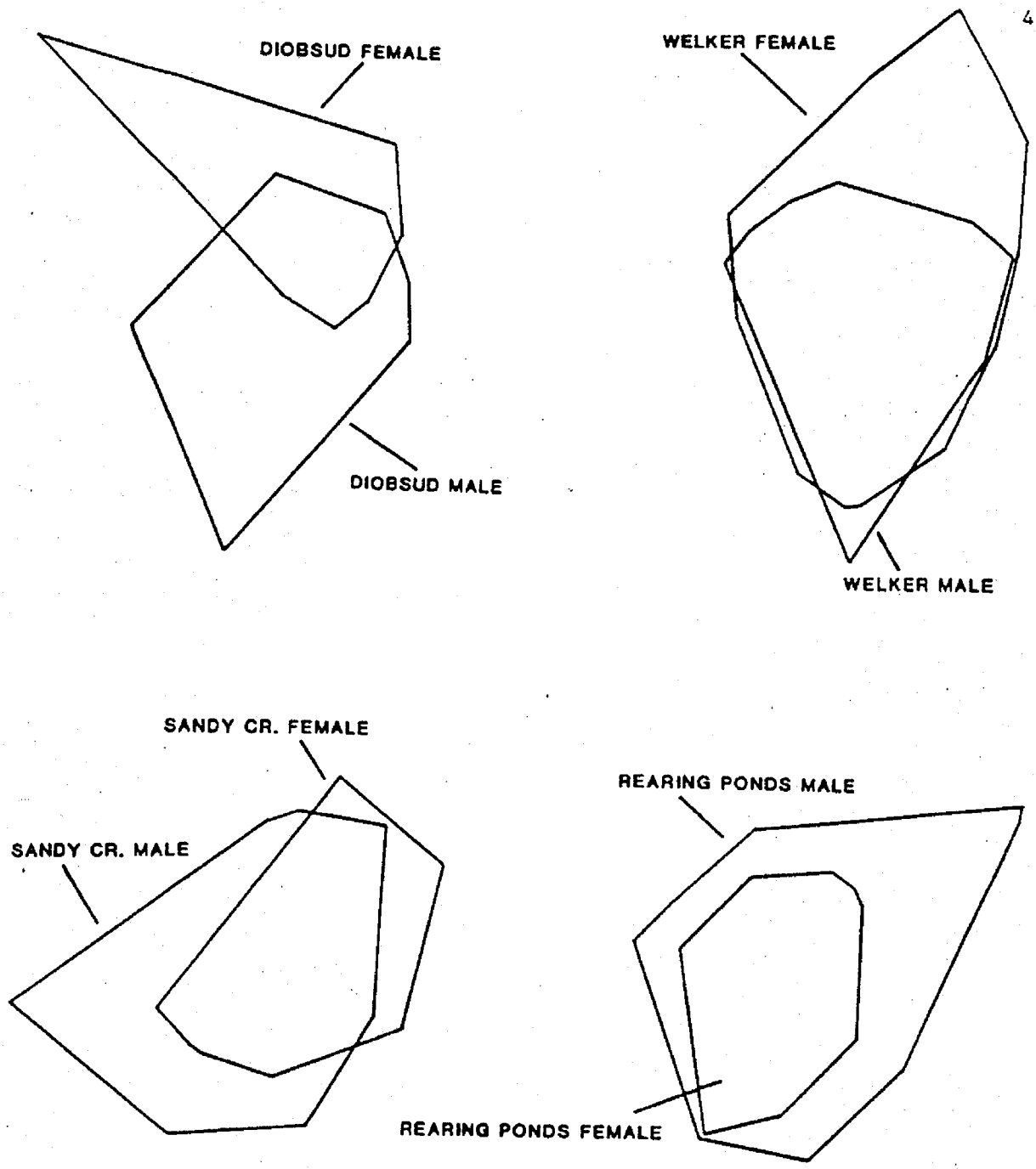

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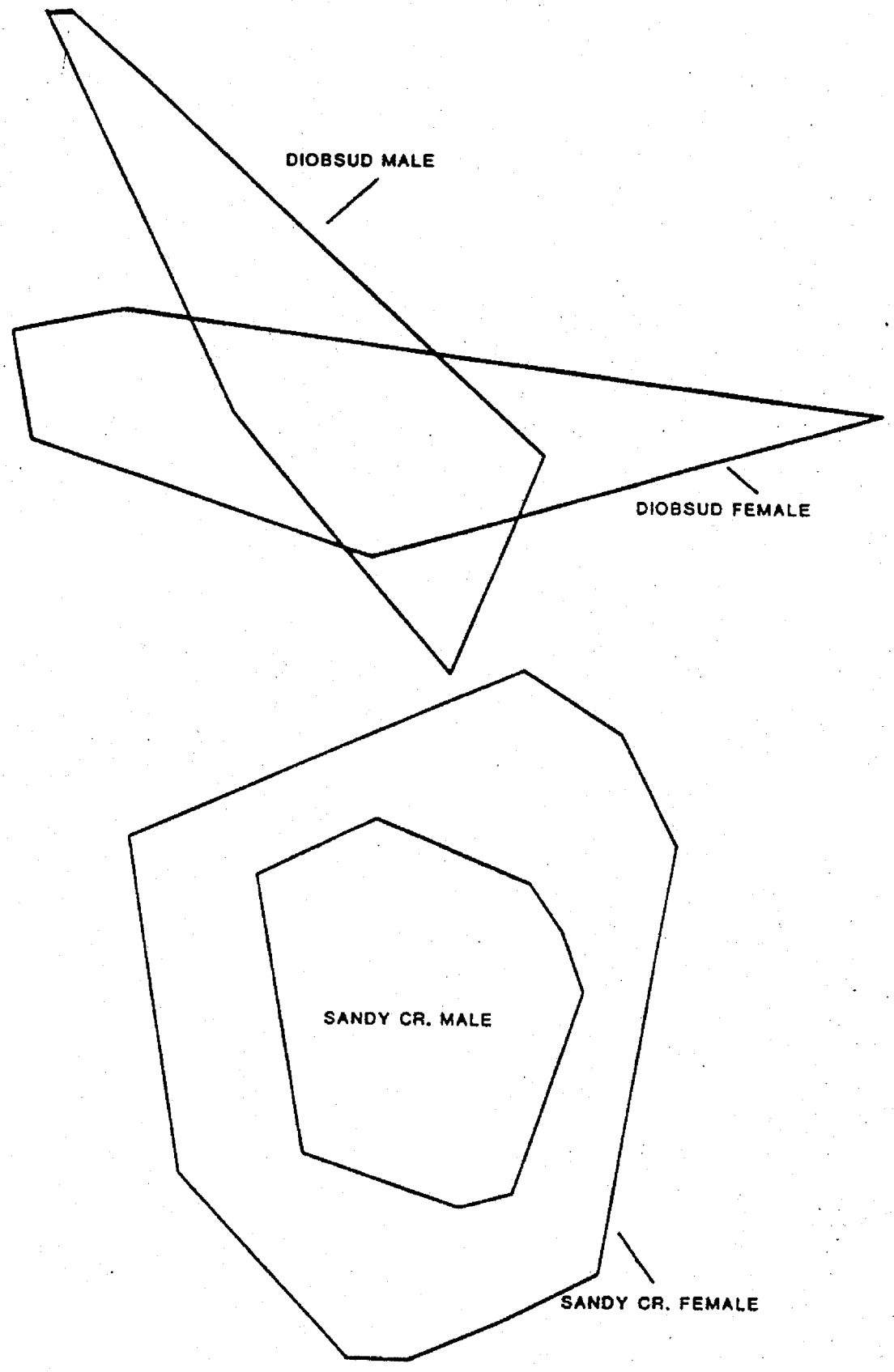

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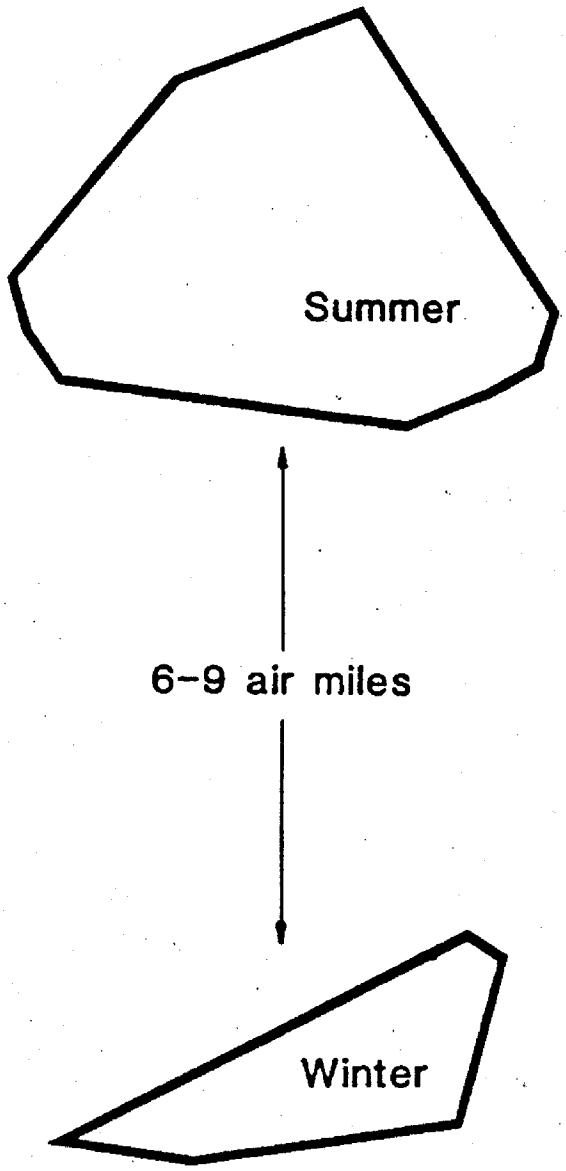

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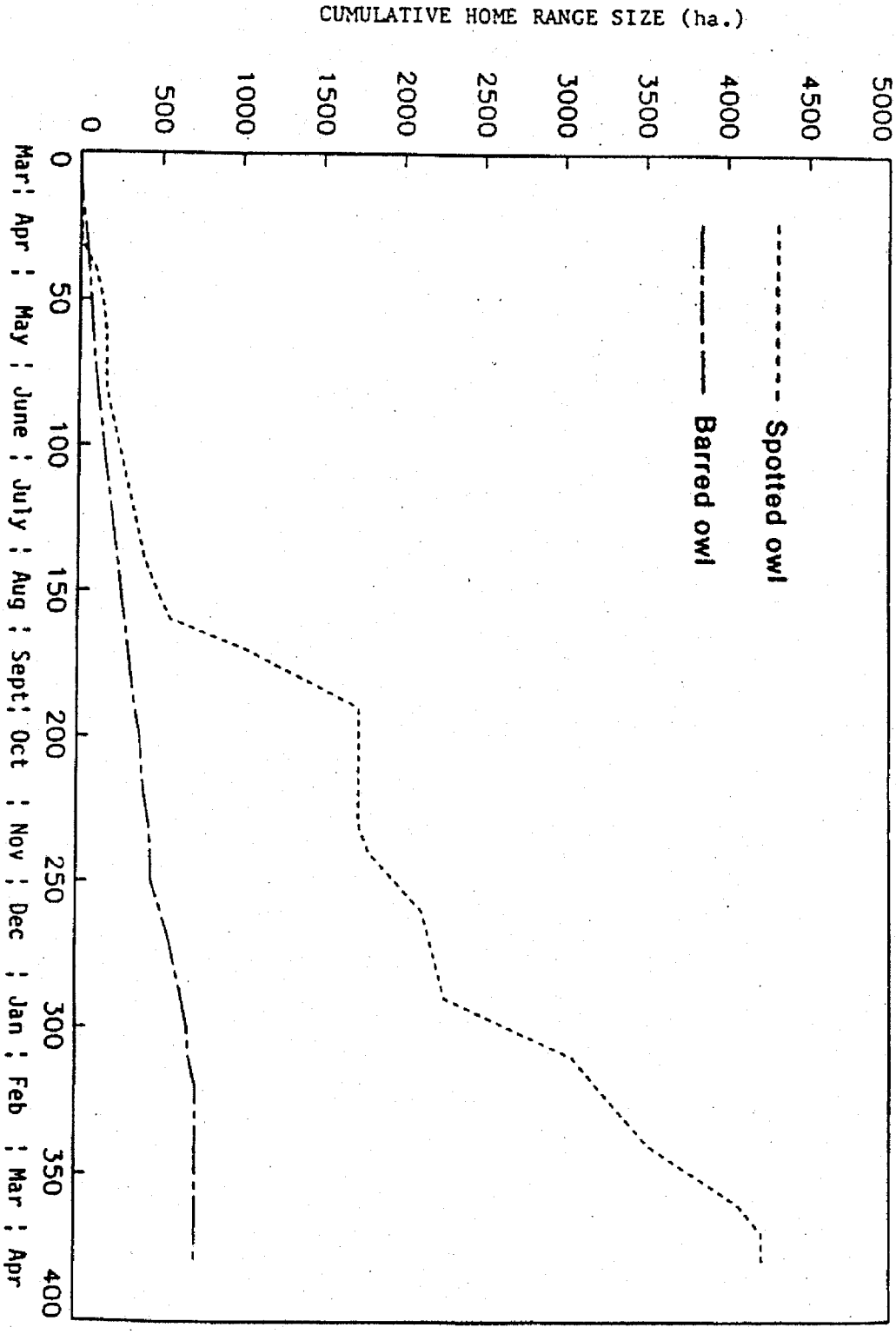
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4500
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3000
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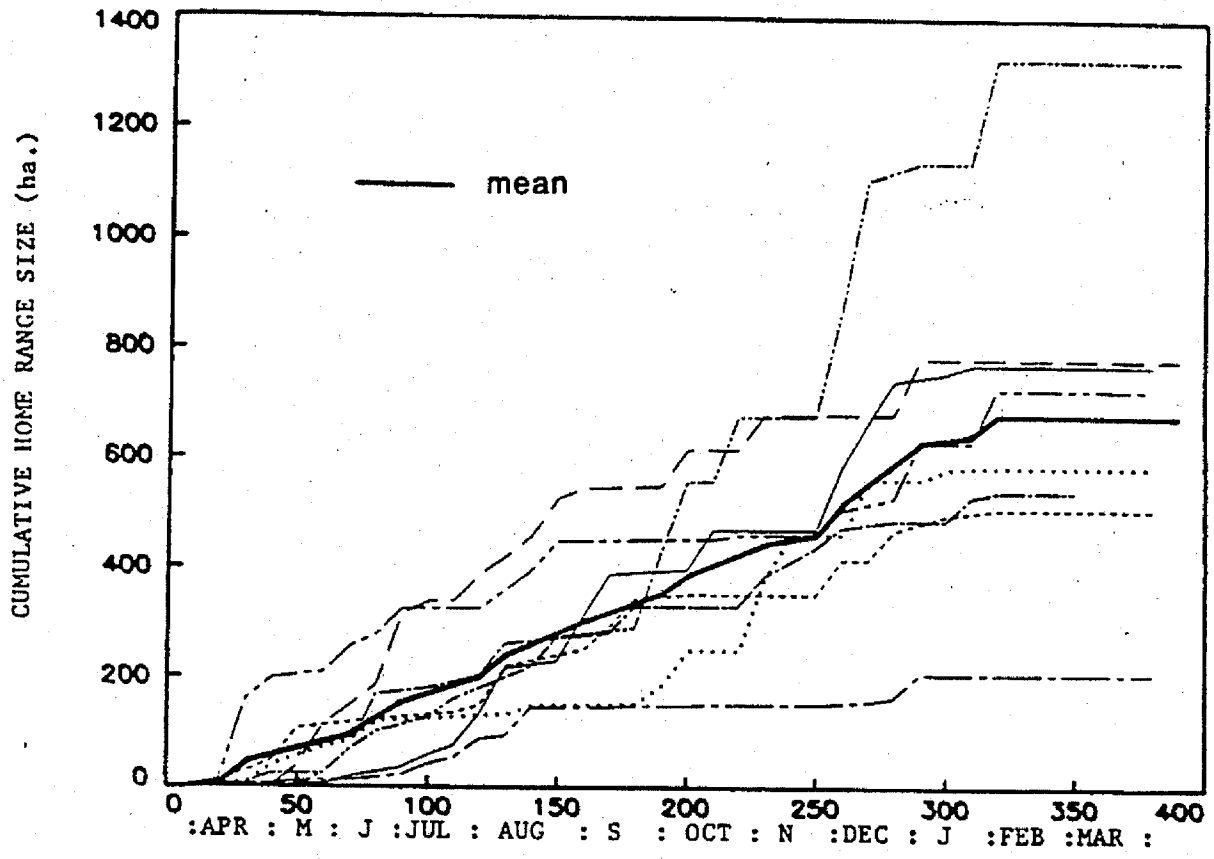

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of this species. The smaller home range size of the barred owl allows these birds to have a higher population density than spotted owls (Fig. 4). Mean nearest neighbor distances reflect this density.

Food habits differences and home range size

The extremely large home range size of the spotted owl, smaller pair home range overlap, wide winter wanderings, rapid home range growth throughout the year, early departure from core areas in the fall and late return to core areas in the spring, could be a result of the food habits specialization in this species. These factors could reflect the behavior of a population stressed by low food supplies. Spotted owls have been shown to specialize on medium sized arboreal and semi-arboreal mammals such as the flying squirrel (Glaucomys sabrinus), red tree vole (Arborimus longicaudus) and two woodrat species (Neotoma) in Oregon (Forsman et al., 1984). In Washington the owl has been shown to primarily feed on flying squirrels (Gutierrez and Carey, 1985). The barred owl appears to be very much a food habits generalist throughout its range in the eastern United States feeding on a large variety of small terrestrial mammals, small passerines, insects, amphibians, reptiles and even fish is commonly reported in the literature (Blakemore, 1940; Devereux and Mosher, 1984; Karalus and Eckert, 1974; Wilson, 1938). Errington and McDonald (1937) report that the diet

composition of the barred owl is governed by availability, ease of capturing prey and by chance. Not only are there differences in the range of prey types taken by these owls, but the spotted owl also appears to prefer prey of larger biomass. Barrows (1985) has found that spotted owls have a high porportion of larger prey items in their diet have greater breeding success than spotted owl pairs that feed on smaller prey items.

The population density of mammals declines with increasing body size with a regression slope of -.75 (Damuth, 1981). Therefore, the spotted owl will have to search for prey over a larger area than the barred owl since it is searching for fewer different prey species of larger body size and lower numerical densities. Since the spotted owl is searching for fewer prey items, individuals may have to forage over larger areas to procure these items. This will not be true during the breeding season where males and females must deliver prey items to a nest site and thus forage in smaller areas. An increase in prey availability during the summer would also allow the spotted owl to have smaller summer home ranges. The breeding (summer) home ranges of barred and spotted owl are therfore similar in size. Spotted owls may also be expected to have a larger negative effect on prey densities since they are feeding on fewer prey items. Preliminary results of several researchers have showed extremely low flying squirrel densities in spotted owl nesting areas compared to other areas (Andy Carey, USFS, pers. com.).

This may be one reason why spotted owls have a much lower breeding success than barred owls (see section on reproduction), since prey densities must recover in the summer range before another nesting attempt can be successful. We have also seen that spotted owl pairs have much less home range overlap than barred owl pairs, which could be the result of male and female owls avoiding foraging in each others use areas due to a scarcity of prey. Forsman (1980) found that spotted owl pairs in Oregon partitioned foraging areas on a spatial and temporal basis.

MacAurther and Pianka (1966) have shown that specialized predators should have longer search times when locating suitable prey items than a generalist predator, although the pursuit times would be similar. Since the barred owl can be expected to prey on a variety of acceptable food items, this owl should have shorter search times/item caught, but pursuit times would increase, as a large variety of new hard-to-catch items are sought. They also state that predators with specialized habitat preferences (few habitat patch types) would be expected to have longer traveling times/prey item caught, since specialists muct travel longer distances between habitat patches to reach a suitable patch type. The spotted owl appears to be a habitat specialist requiring old-growth coniferous forest to survive (Forsman, 1980). Therefore, one could expect the spotted owl to have larger home range sizes since it may spend more time searching for suitable prey over a larger area and spend more time traveling longer distances,

between suitable patch types. Schoener (1968) has shown that a predator whose diet consists of prey categories different in frequency from that available in the area should be feeding on relatively less dense food than a predator who is opportunistic and preying on whatever is available. He found that the home ranges of most raptors reviewed were larger if the number of prey per unit area is smaller. The fact that home range size varies with food density has been demonstrated in several studies on birds (Schoener, 1968). Therefore, barred owls may be able to sustain themselves on much smaller home ranges and have larger home range overlaps between paired individuals than spotted owls because of differences in diet.

In a discussion of spotted owl home range size, one can not overlook the fact that large areas of suitable habitat have been removed and remaining stands of old growth fragmented due to clear-cut logging practices. These negative effects will act to reduce prey densities and require owls to travel longer distances between suitable patch types. I theorize that spotted owl home ranges today are probably larger than they were historically, but feel home ranges were most likely very large even under natural conditions. I have monitored owls in relatively undisturbed areas and still find large home range sizes for these birds. Present day logging practices are probably increasing the food stress on spotted owls, and eventually, may act to tip the energy balance against this

species.

Effect of sampling procedures on home range size

Figure 10 shows the number of days it took to estimate various percentages of the total home range of an average barred owl. A total of 320 days (10.6 months) were required to estimate 100% of a barred owl's home range and 285 days (9.5 months) were needed to estimate 90% of this area. This is the main reason why I feel the estimates of barred owl home ranges from three studies in the midwest cannot be used with confidence. The average monitoring time for 13 owls studied by Nicholls and Warner (1972), and Fuller (1979), was only 114 days (3.8 months), with most of the monitoring conducted in the spring and summer when owl home ranges are small. Only two owls were monitored during the winter and only for short periods of time. The two largest home ranges reported are for birds monitored for the longest periods of time. Figure 10 shows my home range estimate at 114 days would be 200 ha (only 30% of total) while they report an average home range of 273 ha. These estimates are very similar and demonstrate the danger in estimating home range size with data sets of short duration. Since barred owl cumulative home ranges often plateau at different times of the year (Fig.9) before increasing again, researchers can be deceived into thinking that they have estimated the total home range in periods of less than 10.6 months. Elody (1983) reports an average home

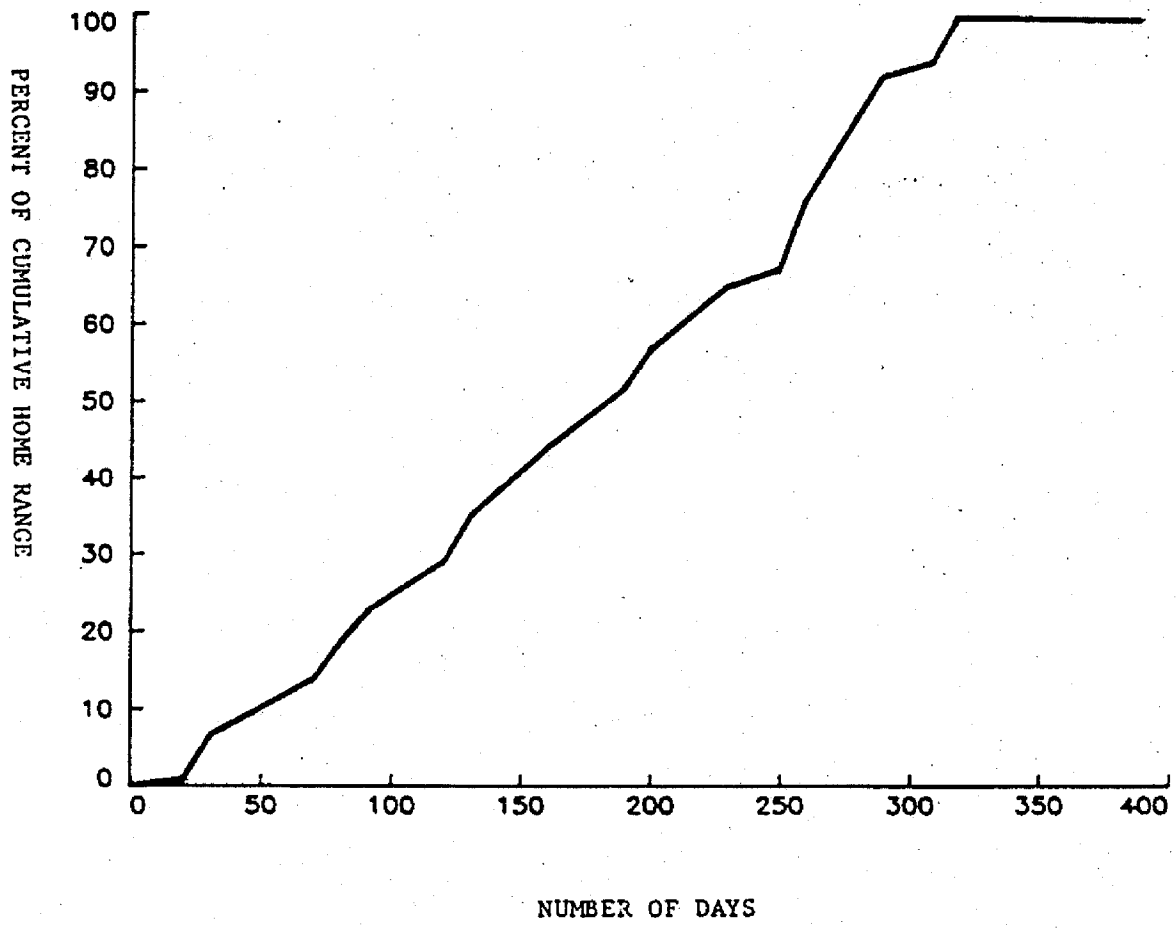

Figure 10. Percent of mean cumulative home range for 8 barred owls over a 12 month period. The figure illustrates the number of days required to estimate total home range size. Home range size was calculated using the minimum convex polygon method.

range size of 282 ha for seven radio-tagged barred owls but states that he only collected 270 total usable locations from May to August, a period of only 4 months. This is a similar to the home range estimate found by Nicholls and Fuller and is once again probably due to the effect of a short study duration combined with sampling only during summer periods.

The relocation sample size, length of the sampling period, sampling method, and variation between individual owls will all affect the estimate of total home range size for barred and spotted owls (Fig. 8 and 9). Collecting relocations for periods of less than 10.6 months will underestimate barred owl home range size and periods of less than 12 months will underestimate spotted owl home range size. Less intensive sampling strategies will also tend to skew cumulative home range graphs into a concave shape so that home range size is underestimated throughout the year, possibly never reaching a 100% estimation (Fig. 11 and 12). This problem is true for both barred and spotted owls and can be seen in Figure 11 for the Diobsud male barred owl where a less intensive sampling strategy (one relocation/week) yielded only 50 relocations throughout a 12 month period. The same relationship can be seen in Figure 12 for the Diobsud male spotted owl which had a similar sampling regime. Larger sampling intervals (smaller sample sizes) will most likely miss locating owls in certain portions of their home ranges throughout the year, thus underestimating home range size. I

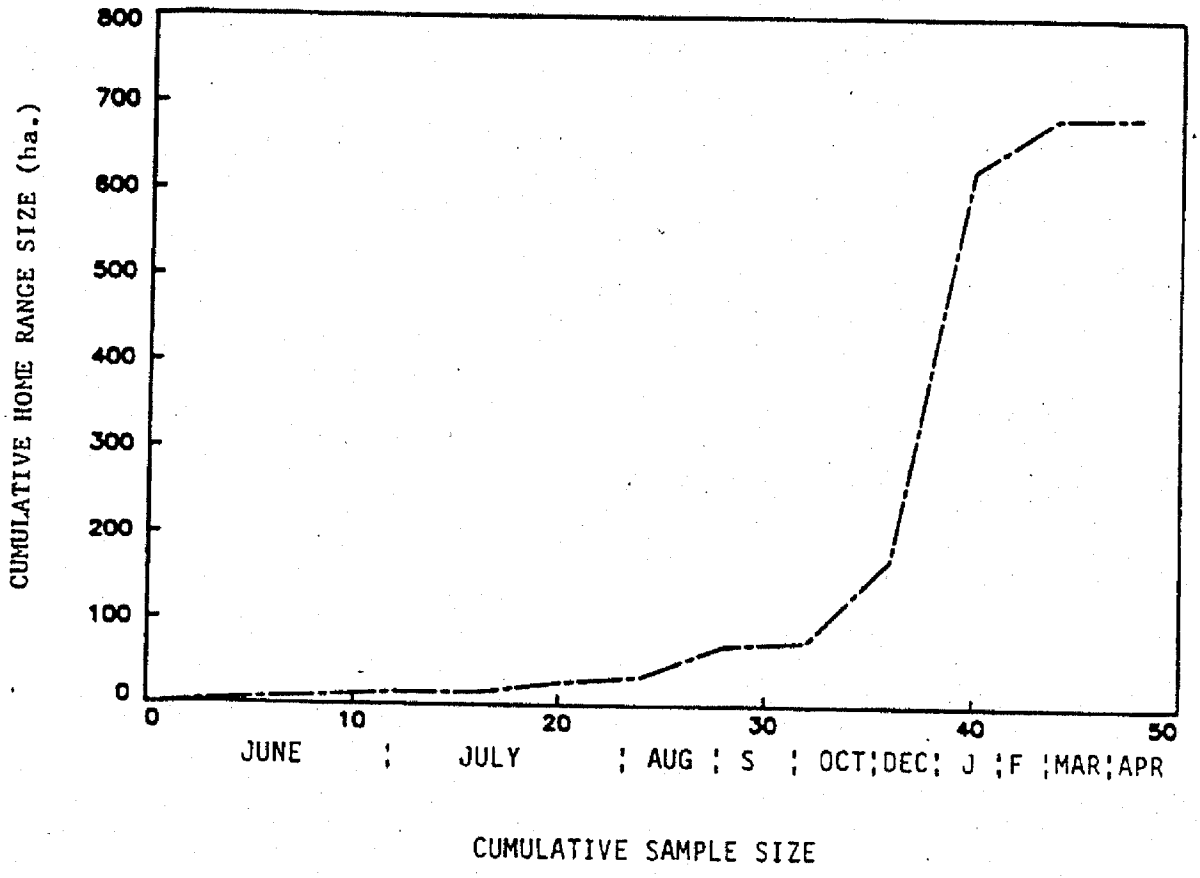

Figure 11. Cumulative home range analysis for the Diobsud male barred owl showing how convex polygon size varies with sample size and season. The monitoring period ran 11 months from 5 June 86 - 27 Apr 87.

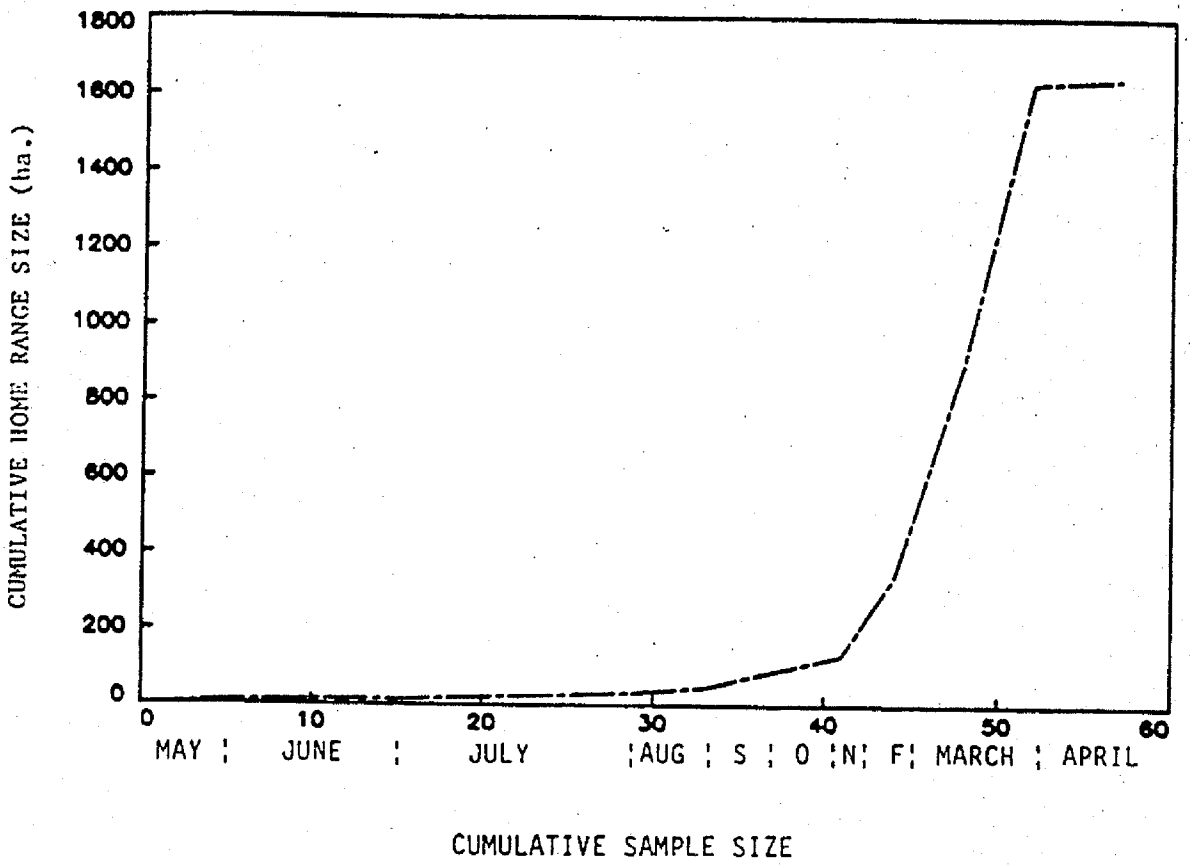

Figure 12. Cumulative home range analysis for the Diobsud male spotted owl showing how convex polygon size varies with sample size and season. The monitoring period ran 11 months from 22 May 86 - 13 Apr 87.

suspect that studies examining habitat use would also obtain biased results if small, less intensive sampling methods are employed. Since both barred and spotted owls expand their ranges significantly during the winter, missing any portion of this time period in a sampling routine will bias results. The cumulative home range graphs for individual owls can be found in the Appendix.

Home range overlap of adjacent barred owls

Figure 13 illustrates the amount of home range overlap of neighboring barred owl individuals in the study area. Mean barred owl home range overlap is 0.7% (range=0-1.7%, N=6). Barred owls appeared to rigorously defend their home ranges throughout the year with little variation in this behavior between individuals. I have found that even non-breeding resident owls aggressively defended their home ranges. During the winter, owls made occasional short excursions into an adjacent individual's home range, but these were of short duration and seldom occurred. The small home range size of the barred owl and sedentary nature of this bird in the winter, enables this owl to actively defend its territory throughout the year. Nicholls and Fuller (1987) also report that barred owls maintain nearly exclusive home ranges, expel intruders and neighbors from their ranges and vocalize to advertize the occupancy of their space. They felt that these behaviors were consistent with the criteria for territoriality.

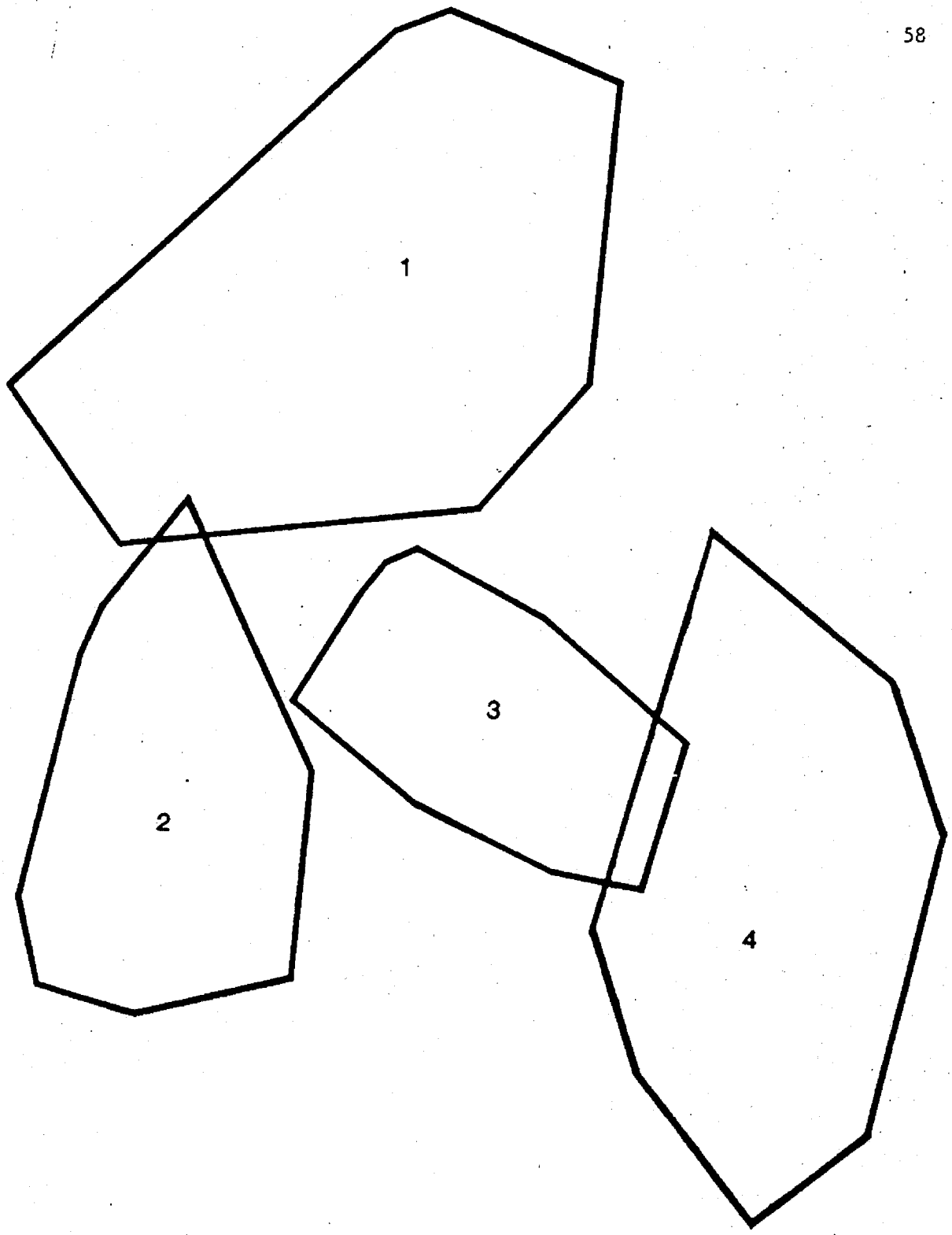

Figure 13. Home range boundary overlap of four neighboring barred owl individuals. Very little overlap exists between adjacent territories. Mean home range overlap is .7% (range=0 - 1.7%, N=6).

I agree with these observations and feel that barred owl territories correspond with their home ranges. The extremely large home ranges of the spotted owl may make an active and regular defense of home range impossible. It would be energetically very costly to defend an average spotted owl home range (over 10 sq. miles). Thus, A spotted owl territory is probably an area surrounding the nest tree and much smaller than the home range area traversed by these birds.

Comparison of home range estimators

Table 7 lists the mean summer home range estimates of barred and spotted owls using the minimum convex polygon, 95% ellipse, harmonic mean transformation and Fourier transformation methods. Very little difference exists between the estimators for this time period. The Fourier analysis gave the smallest estimate for both species. Otherwise, there is no consistent relationship in the home range size estimates between the other three methods.

Mean annual home range estimates for the four estimators can be found in Table 8. Once again the Fourier analysis gave the smallest estimate of home range size for both species. A paired T-test reveals that the Fourier analysis result is significantly different than the other three estimators for both species. No significant differences could be found between the other three methods. For barred owls, the estimates from these three

Table 7. Mean summer (March 1st-August 30th) home range estimates in hectares for 8 barred owls and 4 spotted owls using the minimum convex polygon, 95% ellipse, harmonic mean transformation and Fourier transformation methods.

	HOME RANGE ESTIMATOR			
	CONVEX POLYGON	ELLIPSE	HARMONIC MEAN	FOURIER
Barred owl	281	336	293	270
S.D.	139.3	146.7	133.9	124.3
Spotted owl	321	283	209	207
S.D.	371.3	265.5	145.5	63.6

Table 8. Mean annual home range estimates in hectares for 10 barred owls and 4 spotted owls using the minimum convex polygon, 95% ellipse, harmonic mean transformation and Fourier transformation methods.

	HOME RANGE ESTIMATOR			
	CONVEX POLYGON	ELLIPSE	HARMONIC MEAN	FOURIER
Barred owl	644	534	564	393
S.D.	293.5	174.8	234.7	219.0
Spotted owl	2,816	4,348	3,642	774
S.D.	2,841	3,730	3,346	339.1

techniques correspond closely while the estimate spotted owls are more variable. The standard deviations for spotted owls are extremely large and often approach the home range estimate itself. This may be because spotted owls traverse large areas and have many distant outlying points which can greatly affect home range estimation.

Figure 14 shows the home range boundaries of the Sandy Creek male spotted owl depicted by the harmonic mean transformation, 95% ellipse and minimum convex polygon. No graphic output was available for the Fourier transformation. The main difference between the estimators lies in their definition of home range boundaries and how these boundaries encompass outlying points. The minimum convex polygon often includes large areas that are apparently unutilized by the owls, since this method simply connects the outer relocation points. Therefore, MCP is very sensitive to outlying locations. The probability ellipse (95% ellipse) is the intensity of use of an area as described by a bivariate normal distribution. The 95% ellipse can also include large unused areas but to a lesser degree. Therefore, these two estimators will be more useful for animals that show a preference for a wide variety of habitat types and use their home range homogenously, or for areas that have an even distribution of habitat types throughout the home range.

The harmonic mean transformation provides contours or isopleths of use for a sample of relocations by calculating the

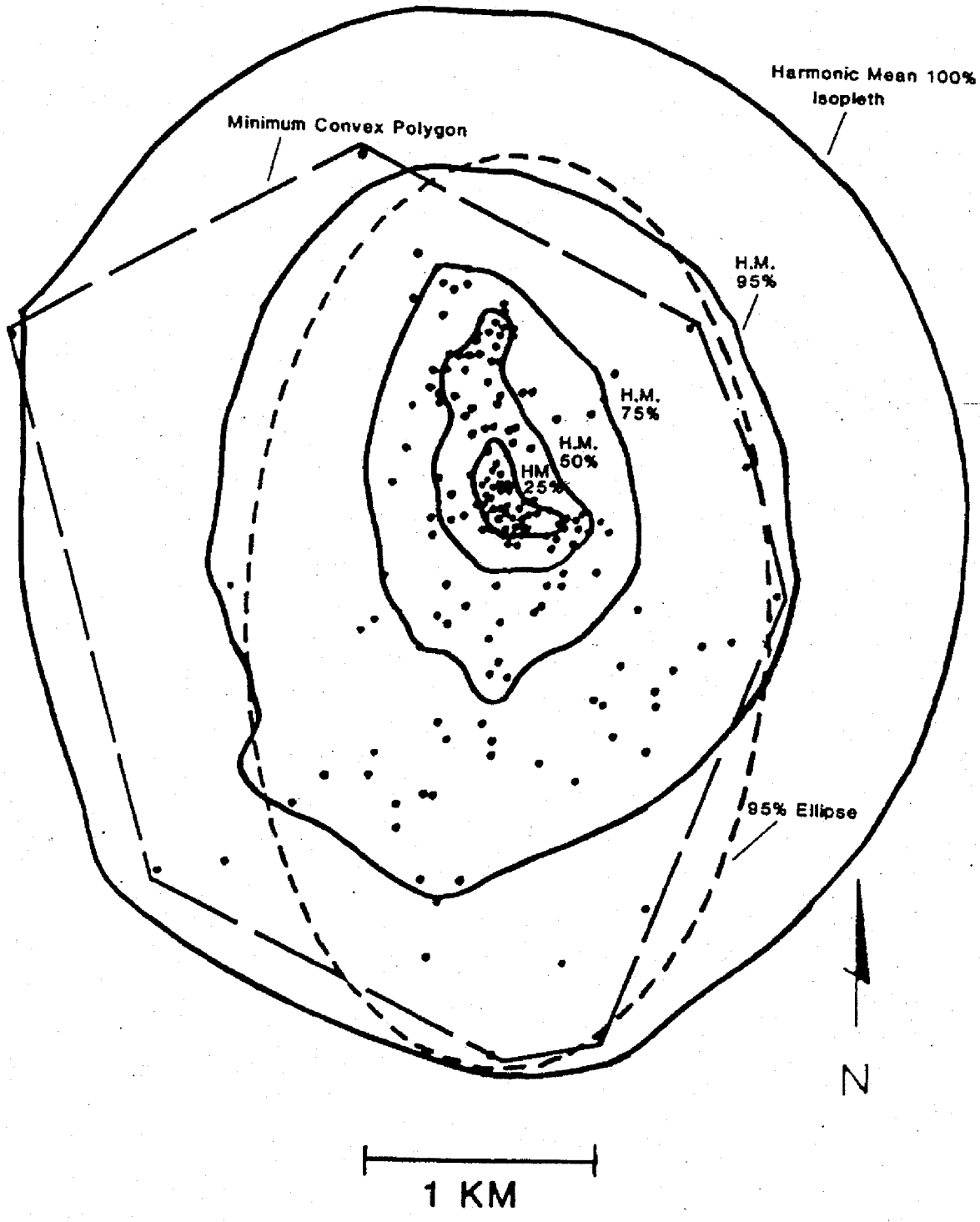

Figure 14. Home range area of the Sandy Creek male spotted owl depicted by the 95% ellipse, minimum convex polygon and the 25%, 50%, 75%, 95%, and 100% harmonic mean isopleths. The sample size is for 202 relocations.

average distance between a point on a grid and the animal locations. Figure 14 shows the 25%, 50%, 75%, 95% and 100% contours. For the purposes of this study the 95% contour was used to calculate home range size. The method automatically de-emphasizes outlying locations. This method also assumes no specific home range shape and multiple activity centers can be depicted. It provides an excellent representation of the use of space and therefore may be the most appropriate technique for habitat preference studies.

The Fourier analysis (.95 index) calculates a utilization distribution for a set of data points and also assumes no specific home range shape, provides a representation of space use and can depict multiple areas of concentrated use. It is not clear why this method consistently provided smaller estimates of a home range since no graphic output was available to me. Jaremovic and Croft (1987) state that the Fourier analysis .95 contour index excluded the greatest number of locations when compared to other estimators, resulting in more outliers for reasons that were not always clear. This method is the least understood of the four methods used.

As we have seen, the definition of home range is dependent upon the number of location points used in the calculation and on the assumptions used by the models themselves. The minimum convex polygon uses all data points in a set, lends equal weight to each point, and assumes home range can be defined by a convex

polygon. The harmonic mean approach assumes no home range shape, and can utilize any number of data points desired by the researcher. Since area estimation techniques reveal little about the ecology of an animal, new techniques are needed to examine the internal anatomy and dynamics of home ranges (Jaremovic and Croft, 1987).

Reproduction

All barred owl and spotted owl nest sites located during the study have been found in similar types of tree cavities. A larger sample of nest sites is needed to determine whether the dimensions of the cavities required by the birds are the same or significantly different. The similar body, tail and wing lengths of the two species (Table 1) suggest that cavity size requirements are probably similar.

Spotted owl reproduction in the study area can best be described as sporadic. Over a two year period I recorded a possible nine nesting opportunities for spotted owl pairs. Only one pair bred successfully out of these nine chances and this pair raised two young. Spotted owls in western Washington may breed only once every three years (Harriet Allen, pers. com.) I recorded 12 possible nesting opportunities for barred owl pairs and six (50%) of these pairs of birds successfully fledged young producing an average of 1.85 young per nest. Some barred owl pairs have successfully raised young for three consecutive years

while others have yet to produce young. The higher reproduction of the barred owl helps explain the rapid range expansion of this owl into the Pacific Northwest. The low reproductive rate of the spotted owl may be another symptom of a population stressed by low food supplies.

I have recorded a limited amount of information on the nesting chronology of barred owls. Barred owls appear to lay eggs by the end of March with young fledging by the first week in June. More information is needed to confirm this. These dates are similar to that reported by Devereaux and Mosher (1984). They report a mean egg date of March 20th (N=6 nests) and a mean fledging date of May 24th (N=2). They also report that 2.0 young were fledged from 5 active nests.

Before barred owl females lay eggs, I have noticed that females will begin to utilize very small home range areas. I have defined these as pre-breeding home ranges and calculated the size of these areas using the minimum convex polygon method. The mean pre-breeding home range size of 3 female barred owls was 15.7 ha (range=2-40 ha). The function of this behavior is unknown. I offer two hypothesis. The first is that female barred owls that are carrying eggs should not expose themselves to the risk of damaging developing eggs by hunting. Therefore it is possible that the male is feeding her at this stage of the nesting cycle. This feeding would speed up energy accumulation by the female for egg production and also enable her to conserve

energy by not hunting (Norberg, 1987). The added weight to the female from egg production already reduces her flight performance in hunts, on top of an already higher wing loading when compared to the male. Also, the female obviously has to visit the nest site in order to lay eggs. I have found pre-breeding home ranges to be centered around the nest tree. The second hypothesis concerns pair bonding and mating between the male and female. Pair bonding could occur in a shorter period of time, and copulations and feeding could occur more frequently, if the male has a precise idea of where the female can be found at any time of the day or night. This might be especially true for an owl that is nocturnal and lives in a dense forest canopy with limited visibility. Although loud vocalizations might accomplish this same routine, they would also reveal the location of the nesting area to any predators or competitors.

The mean date that females restricted themselves to pre-breeding home ranges was March 10th (range=Mar.3-Mar.17, N=3). The mean date that pre-breeding home ranges ended was March 28th (range=Mar.23-April 8, N=3). This corresponds closely with the egg laying dates for females. This home range behavior thus lasted an average of 18 days.

I am experimenting with a method to attract young barred owls to an area to count fledged young to determine productivity and possibly determine fledgling mortality over time. I have

found young fledged barred owls to be attracted to the pre-recorded calls of female adult barred owls and the hissing food begging calls of young birds. The technique needs additional evaluation but could be used to repeatedly locate young birds in an area until they disperse in the fall. To my knowledge the method has not been tried on spotted owls.

Conclusion

Spotted owl population densities are much lower than barred owl densities due to the larger home range size of this species. Since the spotted owl is an old-growth dependent species, the removal and fragmentation of old-growth forests may also have the effect of increasing the home range size of this owl. The extremely large home ranges of spotted owls, smaller home range overlap, wide winter wanderings, rapid home range growth throughout the year, early departure and late return to core nesting areas, and low reproductive rate, may be related to the food habits specialization in this species. These factors could reflect the behavior of a population stressed by a low food supply.

Researchers that are estimating the home range size of an animal need to be aware that the total relocation sample size, sampling interval, length of the sampling period, sampling method, and variation between the home range estimators used, will all effect the final home range estimate. The total sample

size, sampling interval, length of the sampling period, sampling method, and type of home range estimator used should be clearly stated. Small sample sizes with long sampling intervals and short monitoring periods will all underestimate home range size. Large differences in results can be obtained from the same data set analyzed by different home range estimators. More work is needed in the field of home range estimation to determine what constitutes an adequate sample size for each estimator, and to develop techniques to calculate the standard error and confidence intervals for the most common home range methods used.

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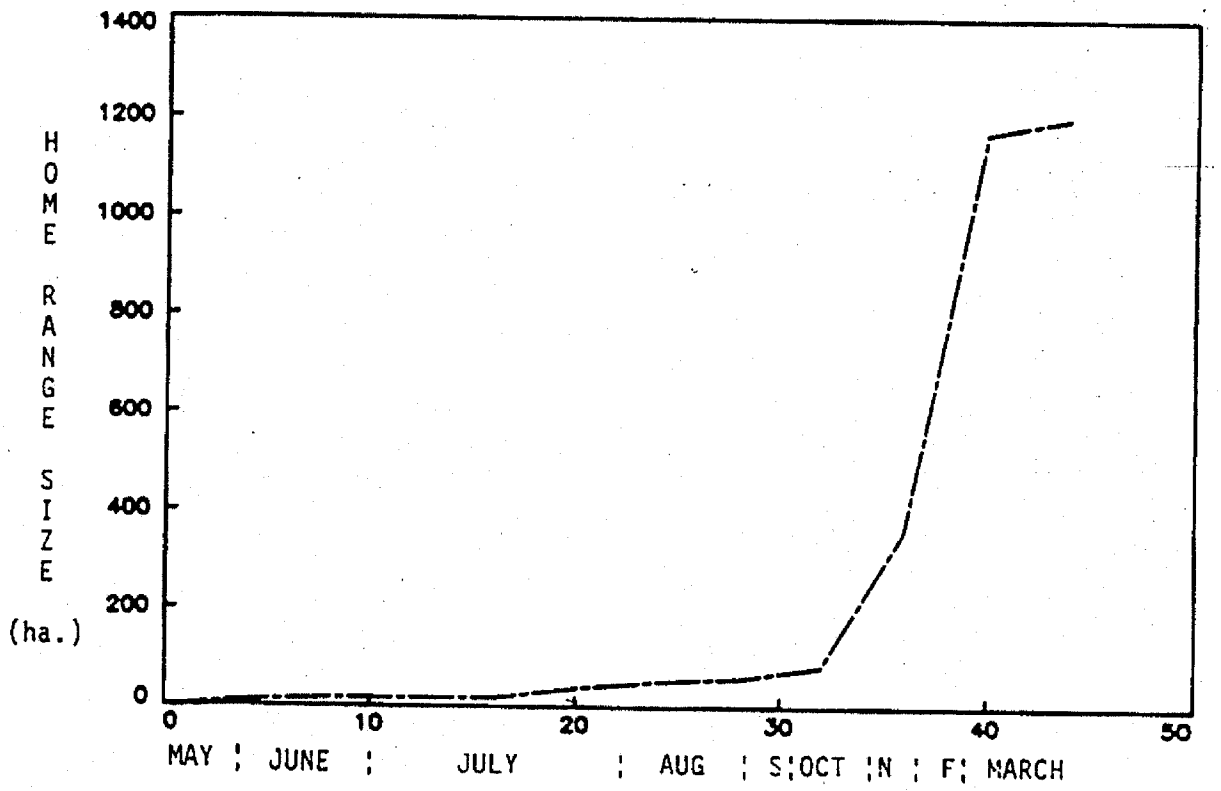
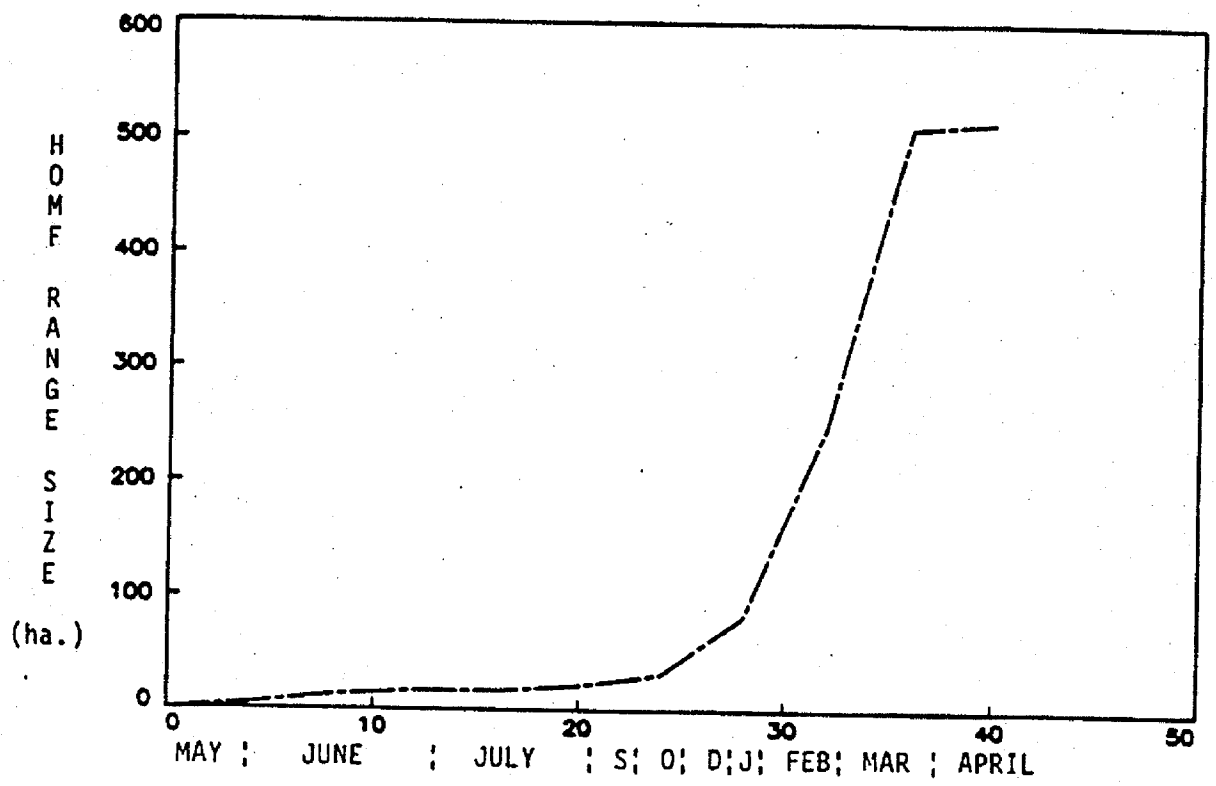
APPENDIX

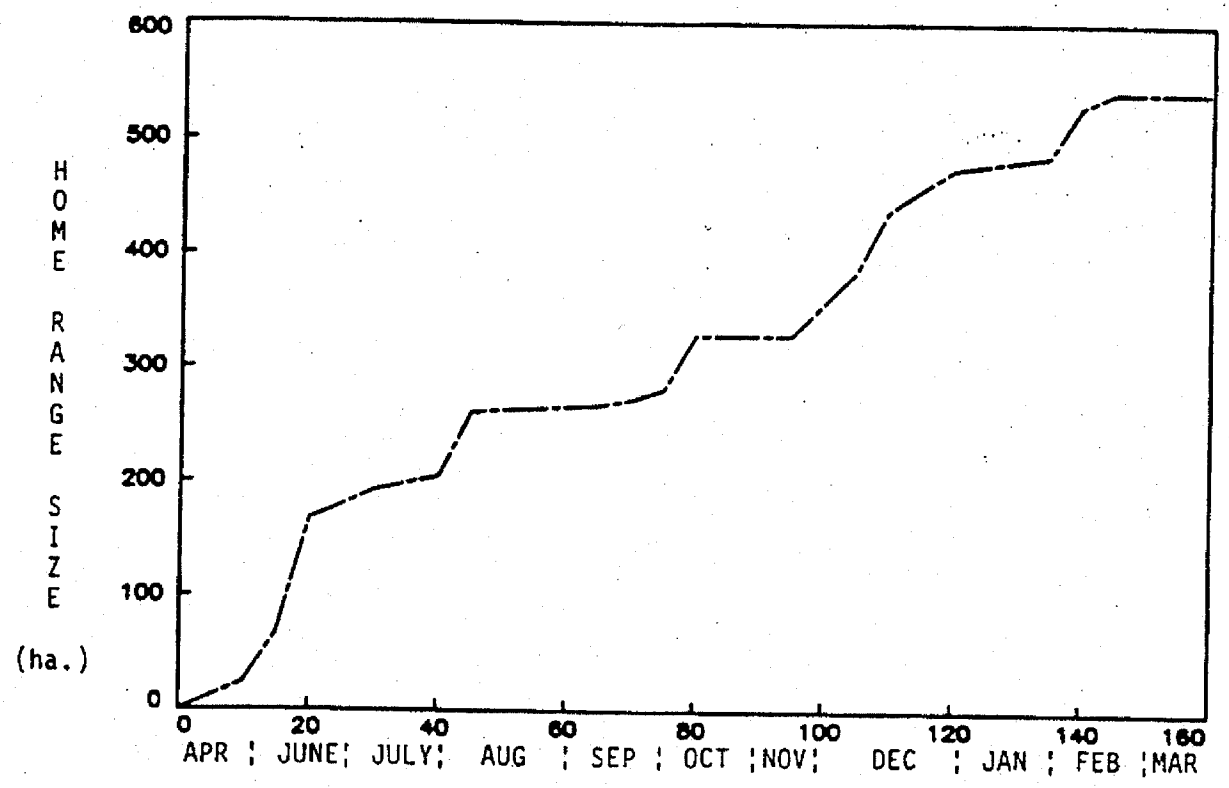
The following figures are the cumulative home range graphs for each individual spotted owl and barred owl radio-tagged, along with the dates indicating the total period that each bird was monitored.



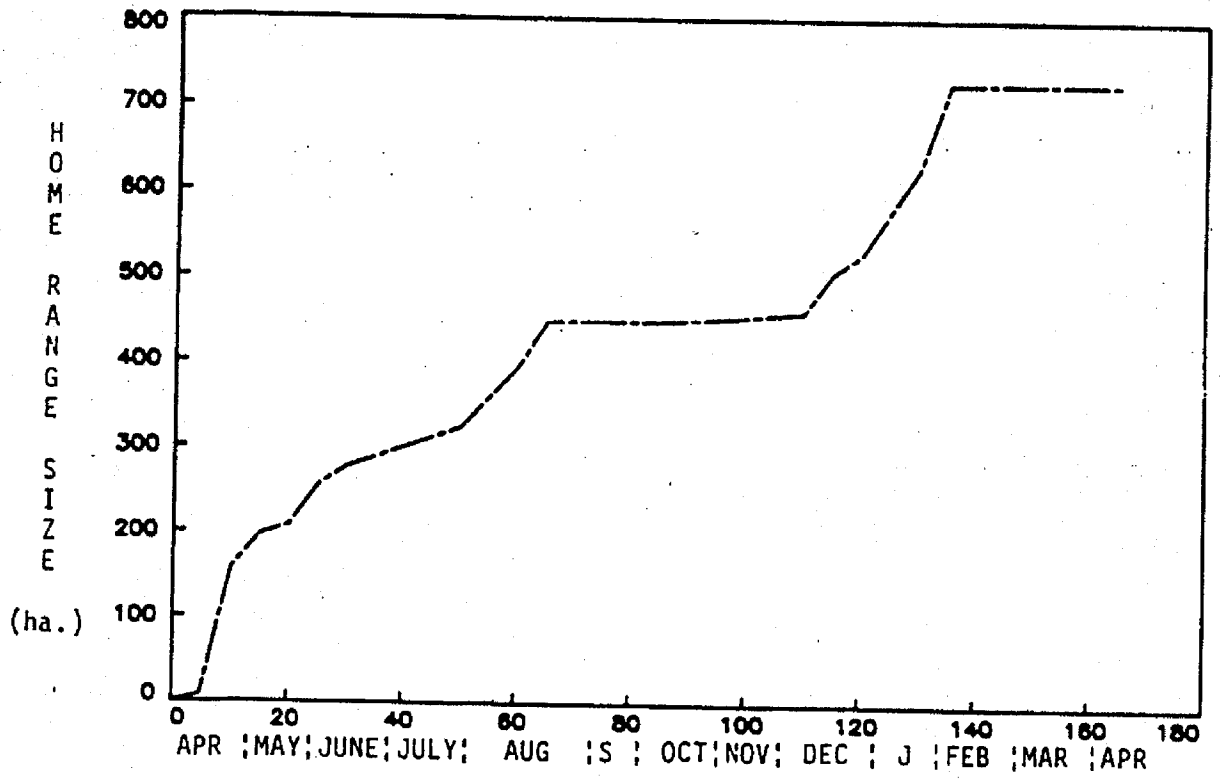
Cumulative home range analysis for the Diobsud female spotted owl showing how convex polygon size varies with sample size and season. The monitoring period ran 10 months from 29 May 86 - 15 Feb 87.



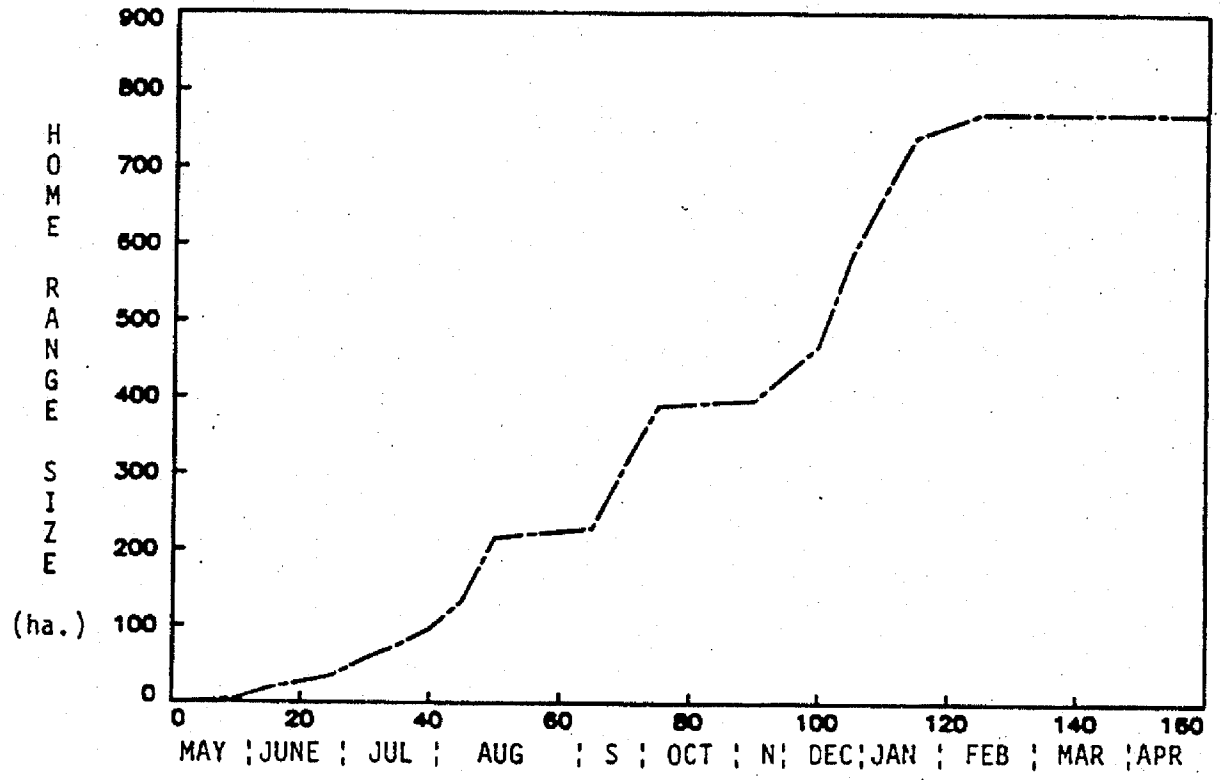
Cumulative home range analysis for the Diobsud female barred owl showing how convex polygon size varies with sample size and season. The monitoring period ran 11 months from 22 May 86 - 27 Apr 87.



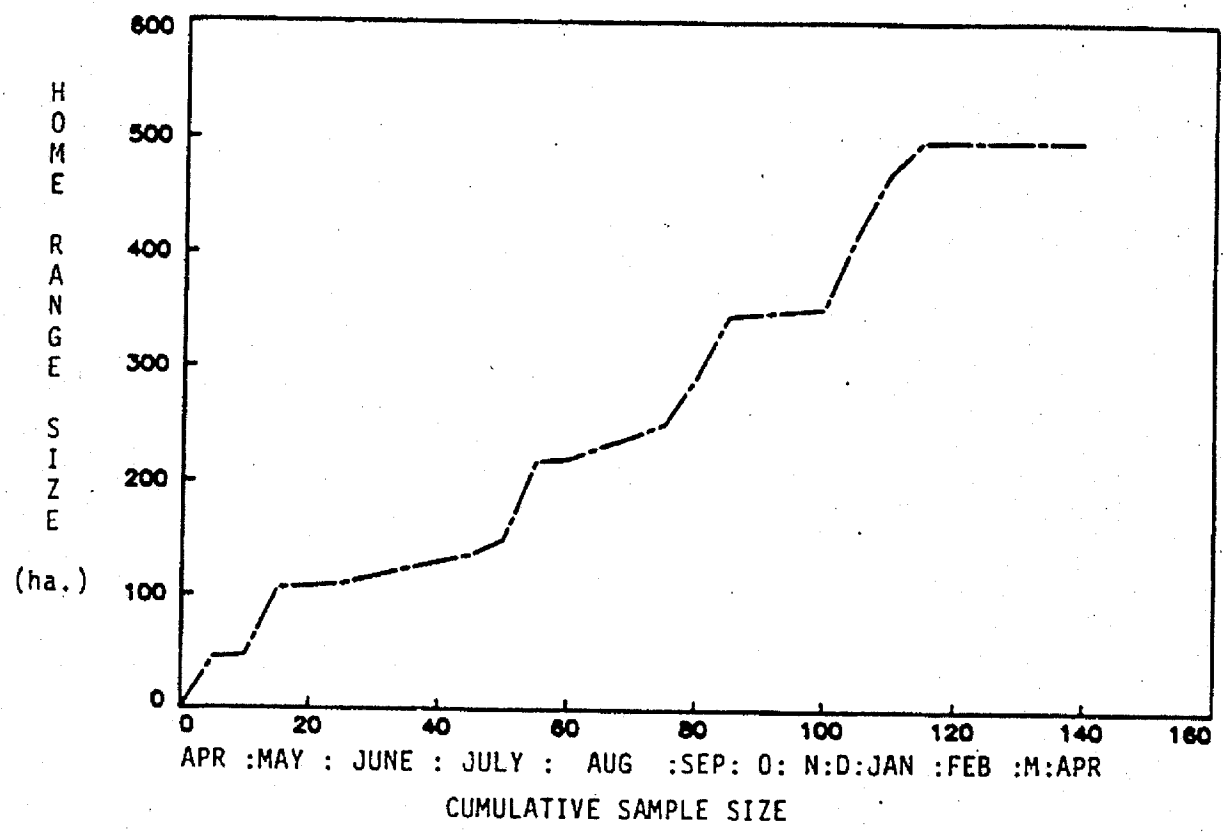
Cumulative home range analysis for the 1799 female barred owl showing how convex polygon size varies with sample size and season. The monitoring period ran 11 months from 11 Apr 86 - 2 Mar 87.



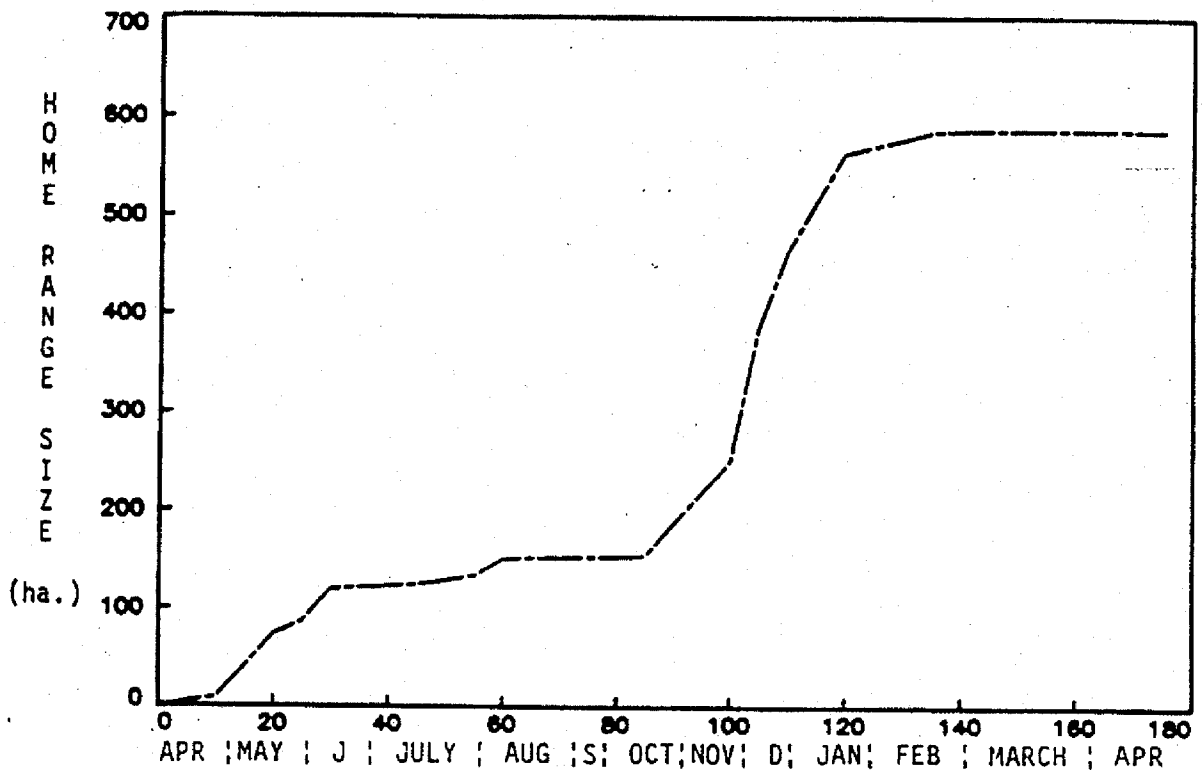
Cumulative home range analysis for the 1799 male barred owl showing how convex polygon size varies with sample size and season. The monitoring period ran 12 months from 3 Apr 86 - 10 Apr 87.



Cumulative home range analysis for the Welker barred owl female showing how convex polygon size varies with sample size and season. The monitoring period ran 11 months from 3 May 86 - 8 Apr 87.

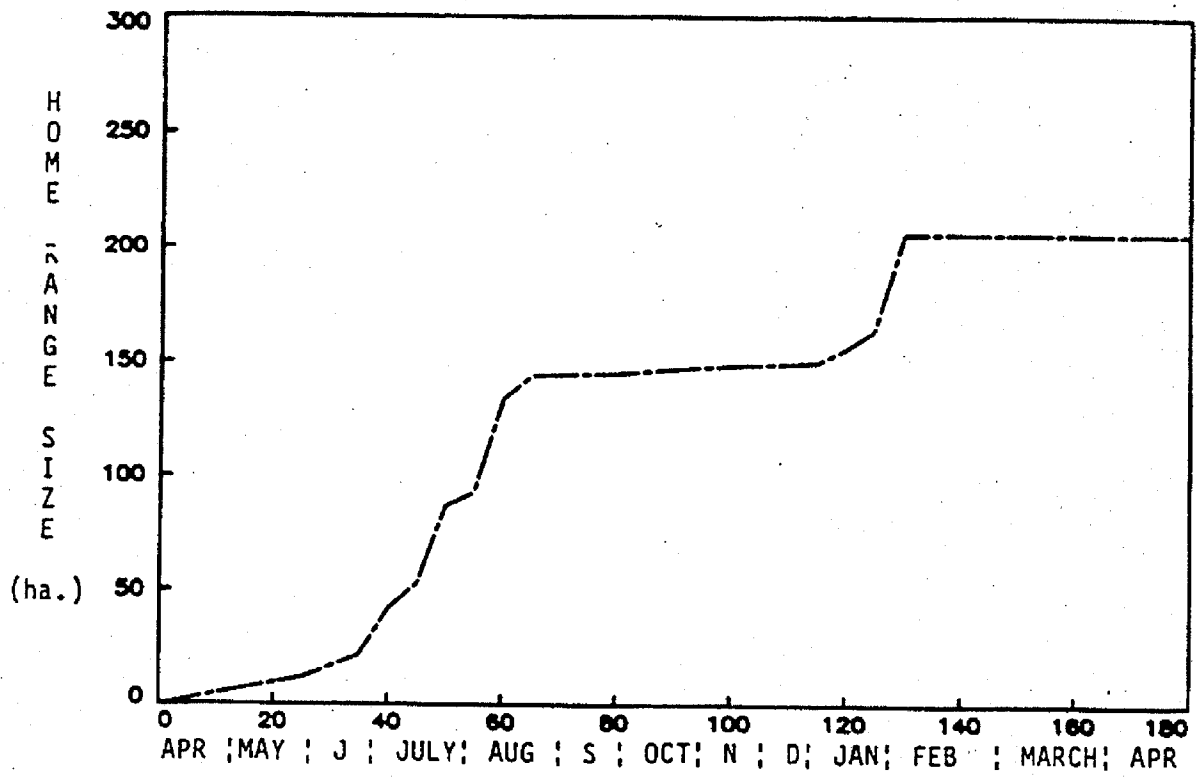


Cumulative home range analysis for the Welker male barred owl showing how convex polygon size varies with sample size and season. The monitoring period ran 12 months from 4 Apr 86 - 8 Apr 87.

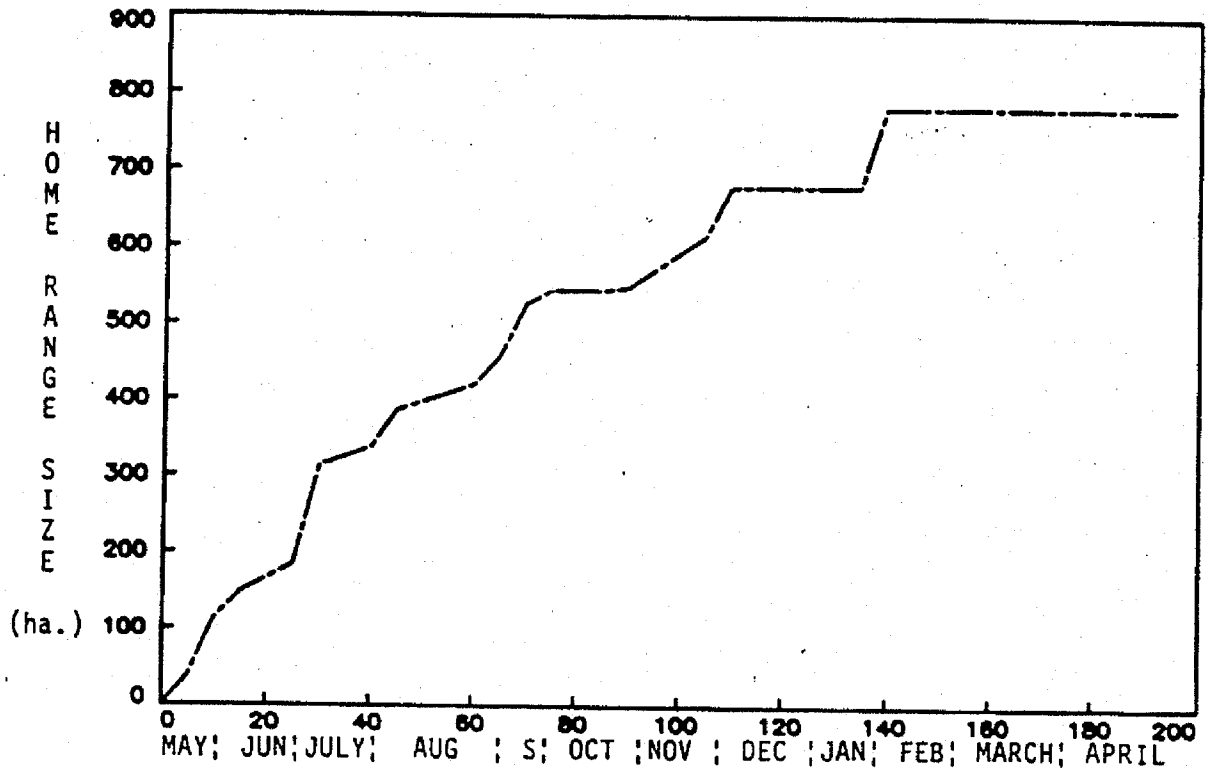


CUMULATIVE SAMPLE SIZE

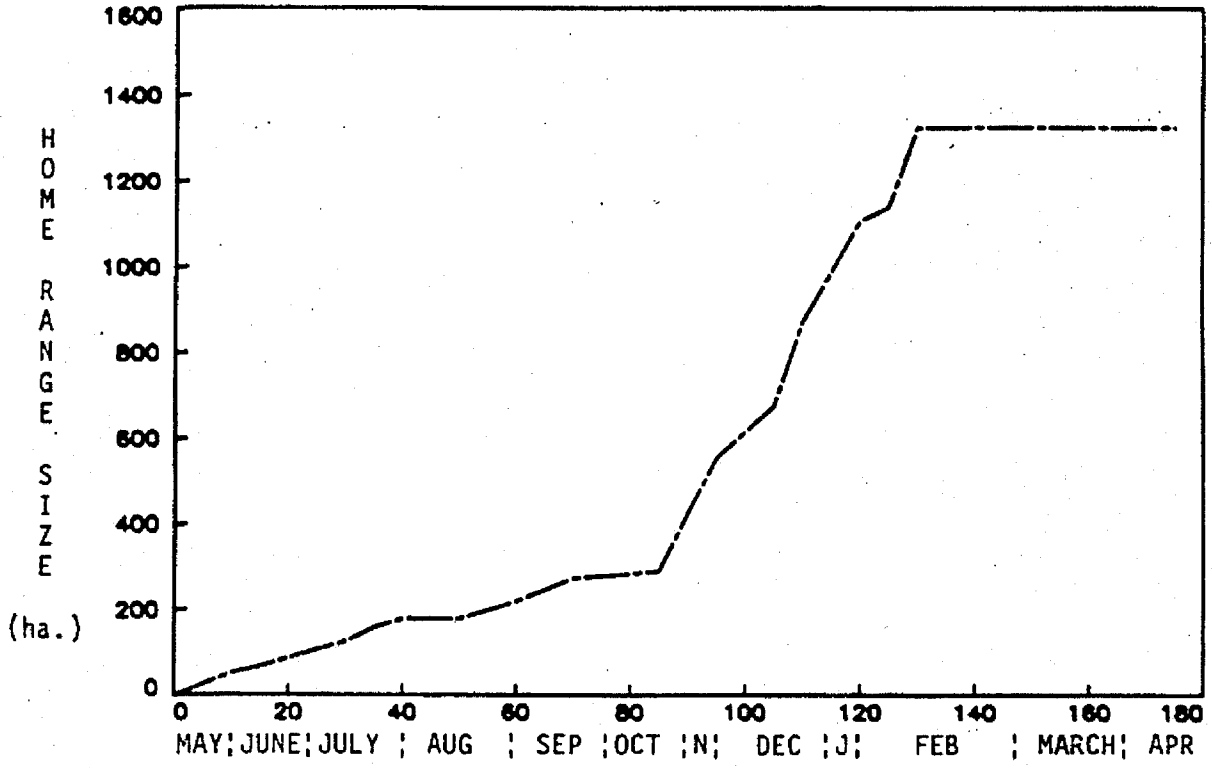
Cumulative home range analysis for the Rearing Ponds male barred owl showing how convex polygon size varies with sample size and season. The monitoring period ran 12 months from 8 Apr 86 - 8 Apr 87.



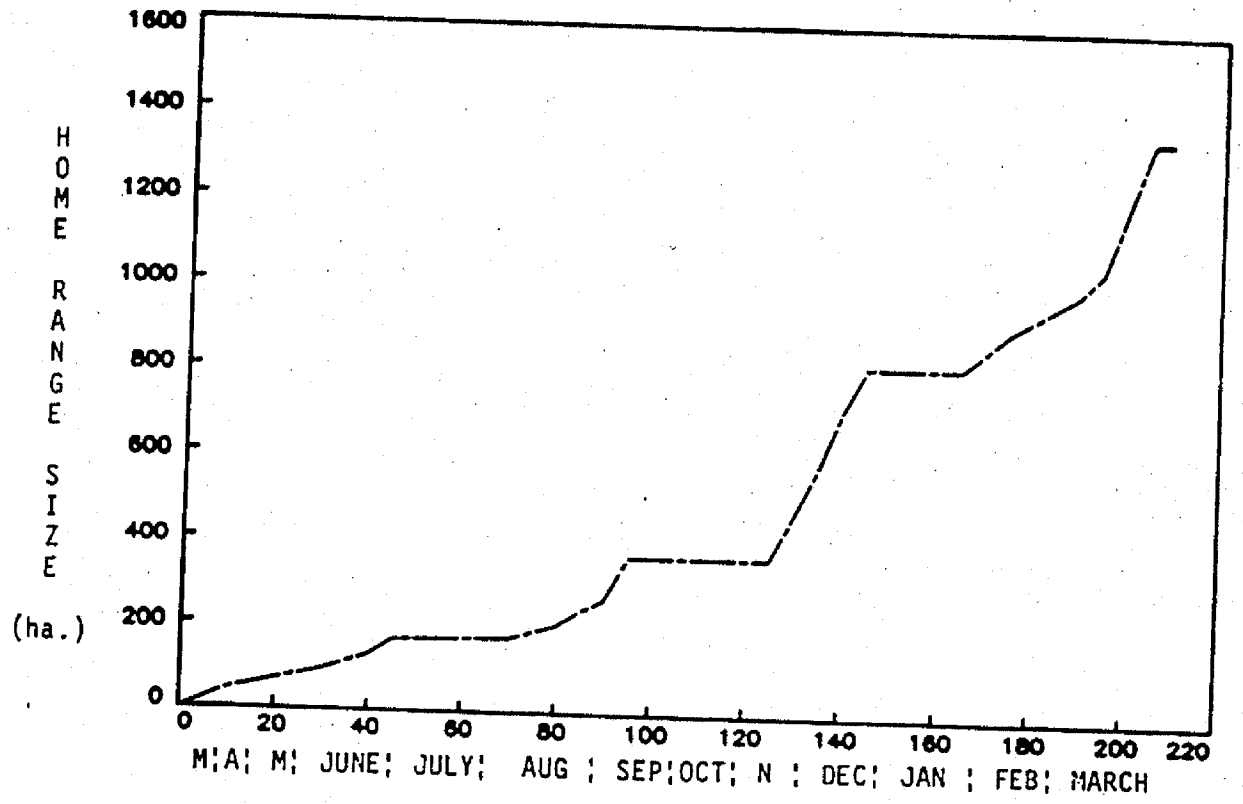
Cumulative home range analysis for the Rearing Ponds female barred owl showing how convex polygon size varies with sample size and season. The monitoring period ran 12 months from 8 Apr 86 - 8 Apr 87.



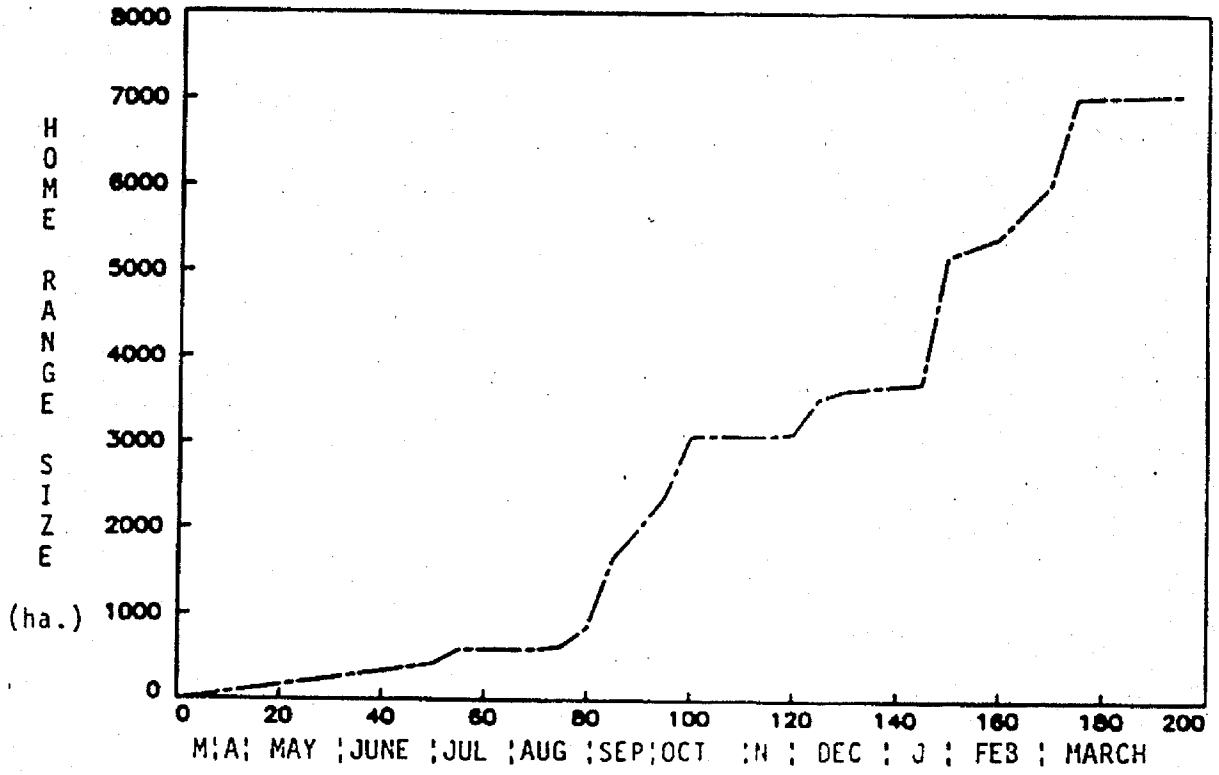
Cumulative home range analysis for the Sandy female barred owl showing how convex polygon size varies with sample size and season. The monitoring period ran 11½ months from 6 May 86 - 17 Apr 87.



Cumulative home range analysis for the Sandy male barred owl showing how convex polygon size varies with sample size and season. The monitoring period ran 11 months from 16 May 86 - 17 Apr 87.



Cumulative home range analysis for the Sandy male spotted owl showing how convex polygon size varies with sample size and season. The monitoring period ran 12 months from 11 Mar 86-31 Mar 87.



Cumulative home range analysis for the Sandy female spotted owl showing how convex polygon size varies with sample size and season. The monitoring period ran 12 months from 11 Mar 86 - 31 Mar 87.

Northern Spotted Owl 5-year Review
Publication Review

Author(s):

Title:

Type of Publication: ☐Abstract ☐Book Article ☐Conference ☐GTR ☐In Review ☐Other ☐Peer Reviewed Article ☐Pop. Article ☐Report ☒Thesis ☐Unpublished

Date of Publication:

Brief Summary:

Conclusions:

Cautions from the Author:

Pertinent Document: Yes___ No___

Work Group: Inter,

Readers:

Date Sent:

Level of Previous Review:

Level of Confidence: Findings Accepted___ Disputed____ Under Discussion___

Topics:

State/Province: ☐ BC ☐ Olympics ☐ Coast Range ☐ E Cascades ☒ W Cascades ☐ Klamath ☐ Non-Redwood Coast CA ☐ Redwood

Behavior: ☐ Dispersal ☒ Home Range

Biology:
☐ Age/Sex Composition ☐ Disease/Parasites ☒ Prey Requirements
☒ Barred Owls ☐ Energetics ☐ Predation
☐ Climate ☐ Genetics ☐ Taxonomy

Demography:
☐ Density ☐ λ ☐ Recruitment
☐ Occupancy Rates ☐ Reproductive Success ☐ Survival

Forest Ecology:
☐ Fire ☐ Management Effects ☐ Wind Throw

Habitat:
☐ Commercial Forest ☐ Fragmentation ☐ Trends
☐ Dispersal ☐ Nesting ☐ Use/Preference
☐ Foraging ☐ Roosting

Human Impacts:
☐ Disturbance ☐ Research
☐ Recreation ☐ Other

Population: ☐ Change, Risk

Techniques: ☐

Comments: