AN ABSTRACT OF THE THESIS OF

Gary Scott Miller for the degree of Masters of Science in Wildlife Science presented on March 16, 1989
Title: Dispersal of Juvenile Northern Spotted Owls in Western Oregon

Abstract approved: E. Charles Meslow

E. Charles Meslow

Dispersal of juvenile northern spotted owls (Strix occidentalis caurina) was studied in western Oregon from 1982-1985. The study was initiated to document the pattern of juvenile spotted owl dispersal, survival, habitat use, and possible effects of forest fragmentation on the dispersing juveniles in the Pacific Northwest Douglas-fir Region. Forty-eight juveniles were radio-marked 3-8 weeks after fledging and followed through dispersal or until they died or the transmitter failed. Spotted owl reproduction in western Oregon varied considerably during the 4 years of the study, with an average of 31% of pairs checked for reproductive status in 1983-1985 attempting nesting (range 14%-69%). A geographic gradient in reproductive performance appeared to exist, with greater reproduction in the south.

Juvenile owls spent an average of 104 days in the natal area after fledging. Size of areas used by juveniles prior to dispersal averaged 28 ha. Eighty-four percent of all juveniles began dispersal between mid-September and mid-October; one juvenile did not disperse.

Initial dispersal usually was rapid but most juveniles settled into well-defined areas for their first winter after the initial dispersal movements. Those juveniles surviving their first winter often began moving again in late winter or early spring. Mean maximum straight-line dispersal distance was 28 km (first-year movements only) and direction was random in most areas.

First-year survival of spotted owls was calculated from daily survival rates and yielded an estimate of 19%. The 2 main causes of mortality were starvation and avian predation. Great horned owls (*Bubo virginianus*) were the only documented avian predator. Most mortality took place in the first 6 months after fledging.

The possible effects of forest fragmentation on dispersal distance and survival, and habitat use by dispersing juvenile spotted owls was also investigated. There were no statistically significant relationships between final distance dispersed and forest fragmentation or days survived and forest fragmentation. Juveniles used a wide variety of habitats while dispersing but, based on availability, 12 of 18 juveniles showed a significant selection ($P \leq 0.05$) for old-growth/mature forests.

DISPERSAL OF JUVENILE NORTHERN SPOTTED OWLS IN WESTERN OREGON

by

Gary Scott Miller

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Dedicated to my parents
Vic and Shirley Miller

for their love, support and shared enthusiasm of both my personal and professional endeavors
and to

C. Arnold Brandt

who, even though he didn't live to see the completion of the project, provided many hours of thoughtful discussion and helped keep me aware that there are always two sides to every story

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PREFACE

This thesis has been written as two separate papers to facilitate publication of manuscripts. Part I discusses dispersal of juvenile spotted owls, specifically dispersal distance, movement patterns, and survival. Part II discusses dispersal in relation to habitat use and the possible effects of forest fragmentation on juvenile dispersal. The format is similar for both papers so there is some overlap in the introductions and study area descriptions.

DISPERSAL OF JUVENILE NORTHERN SPOTTED OWLS IN WESTERN OREGON

PART 1

DISPERSAL AND MORTALITY OF JUVENILE SPOTTED OWLS IN WESTERN OREGON

INTRODUCTION

Recent studies have shown that northern spotted owls (*Strix occidentalis caurina*) depend on old-growth forests (Solis 1983, Forsman et al. 1984, Sisco and Gutierrez 1984) and are declining in numbers as these forests are cut (Gould 1977, 1985; U.S. Fish and Wildlife Service 1982; Forsman et al. 1984, 1987). Most of the remaining harvestable old-growth forests are now restricted to federal lands of the USDA Forest Service (USFS) and USDI Bureau of Land Management (BLM). These Federal forest managing agencies are committed to maintaining viable populations of native wildlife, including the spotted owl, under terms of the Endangered Species Act of 1973 and regulations stemming from the National Forest Management Act of 1976. As the habitat of spotted owls becomes more sparse and the number of spotted owl pairs decreases, the chances increase for pairs or groups of pairs to become reproductively isolated. Isolated owls do not contribute to the maintenance of a diverse gene pool. Therefore, the distance between adjacent pairs or groups of breeding owls should be such that dispersal of juveniles can replace losses (deaths or emigrations) among existing pairs and provide for colonization of suitable, unoccupied habitats. An understanding of dispersal in juvenile spotted owls is thus basic to formulation of criteria for appropriate spacing of habitat to accomodate pairs of owls.

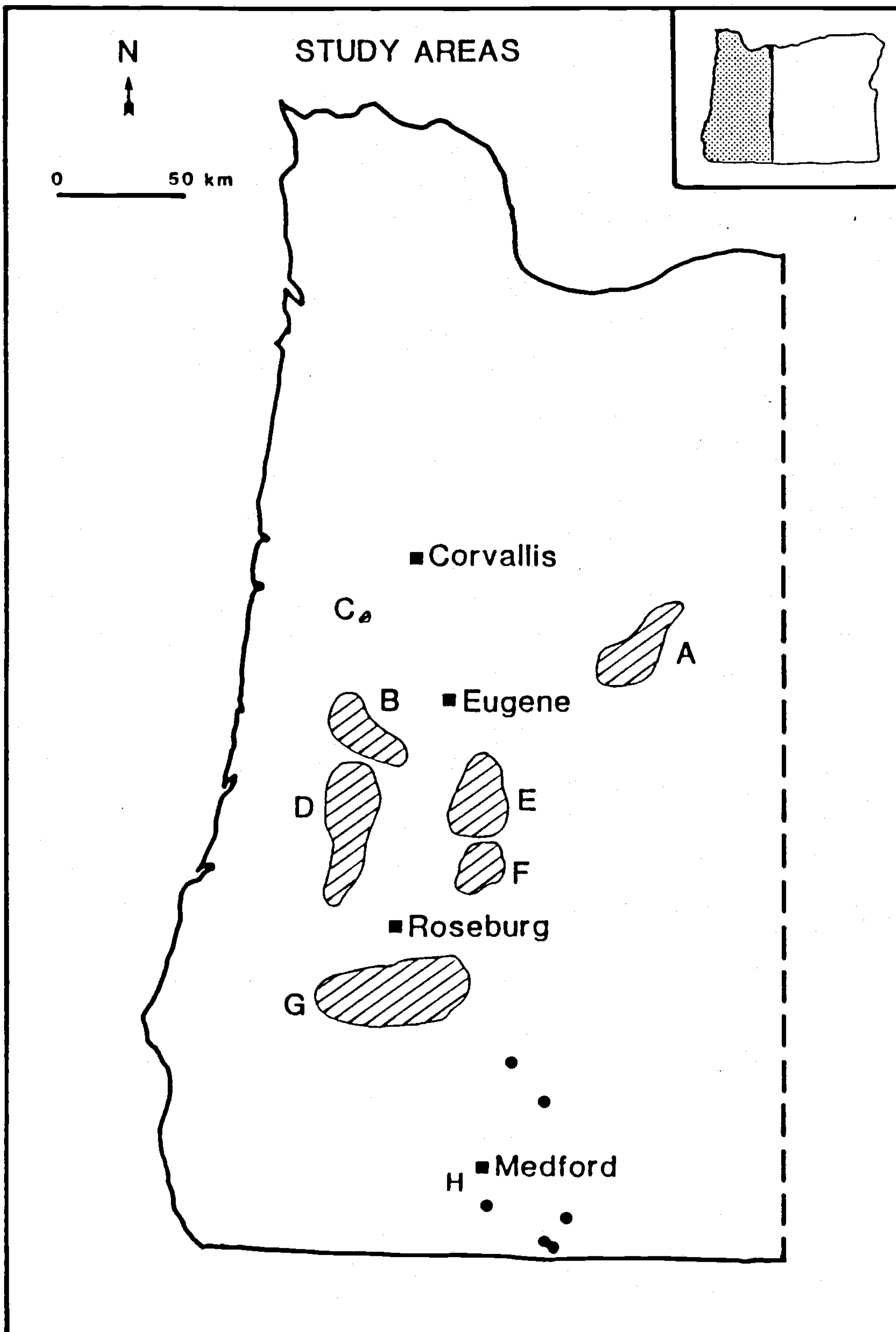
Prior to 1982, information on juvenile dispersal of spotted owls was limited. Forsman (1980) trapped and radio-marked four juveniles in late summer, but dispersal information was gathered on only two, both of which were dead by the first week in December. The farthest straight-line distances travelled from the nest were 10.1 and 16.4 km. In the spring of 1982, a radio-telemetry study was initiated in Oregon to document the pattern of juvenile spotted owl dispersal, survival, habitat use, and possible effects of forest fragmentation on dispersing juvenile spotted owls in the Pacific Northwest Douglas-fir Region. This paper describes the dispersal movements and mortality of juvenile spotted owls studied in western Oregon from 1982 through 1985.

STUDY AREAS

Juvenile spotted owls were located and followed during dispersal in 8 areas of Western Oregon (Fig. 1). Original study design called for 2 study areas chosen to contrast levels of habitat fragmentation. The less fragmented area was in the Cascades surrounding the H.J. Andrews Experimental Forest (64 km east of Eugene, Lane County); the more fragmented area was in the Coast Ranges near Lorane on Eugene District BLM lands (40 km SW of Eugene, Lane County) (Fig. 1 - A & B); both areas had been used during previous spotted owl studies (Forsman et al. 1984). These 2 areas were surveyed each year of the study (1982-85). Because of low rates of spotted owl reproduction encountered, additional areas within the Cascades and Coast Ranges were surveyed each year. The locations of reproducing pairs of spotted owls became the final determinant of study areas. In 1982, only 1 juvenile was radio-marked: Coast Ranges near Alsea, Benton County (Fig. 1 - C). In 1983, additional areas (Fig. 1) were surveyed on Eugene District BLM lands in the Cascades (E) and in the northern portion of the Roseburg District BLM in both the Cascades (F) and Coast Ranges (D). These areas (A-F) were all within the *Tsuga heterophylla* zone, the most extensive vegetation zone in western Oregon and the most important in terms of timber

Figure 1. Study area locations for juvenile dispersal study of spotted owls in western Oregon, 1982-1985. (A = H.J. Andrews Experimental Forest vicinity - Cascades; B = Eugene District BLM lands - Coast Ranges; C = Salem District BLM lands - Coast Ranges; D = Roseburg District BLM lands - Coast Ranges; E = Eugene District BLM lands - Cascades; F = Roseburg District BLM lands - Cascades; G = Roseburg District BLM lands - Transition zone; H = Medford District BLM lands).

Figure 1


N
STUDY AREAS
0
50 km
Corvallis
C
A
B
Eugene
D
E
F
Roseburg
G
Medford
H

production (Munger 1930, Franklin and Dyrness 1973). Subclimax Douglas-fir (*Psuedotsuga menziesii*) dominates most of the zone with the other major forest tree species being western hemlock (*Tsuga heterophylla*) and western red cedar (*Thuja plicata*). The *Tsuga heterophyla* Zone has a mild maritime climate with relatively dry summers and wet winters. The winter precipitation is in the form of rain at the lower elevations, especially the Coast Ranges, and snow at the higher Cascade elevations (Franklin and Dyrness 1973).

In 1984, an additional area was included in the southern portion of the Roseburg District BLM lands (Fig. 1:G). The southern Roseburg area is a transition area between the *Tsuga heterophylla* and Mixed Conifer Zones (Franklin and Dyrness 1973). In 1985, all previous areas were surveyed, as well as several areas on Medford District BLM lands (Fig. 1:H). The Medford area is within the Mixed Conifer Zone, but was included in 1985 to expand the sample of dispersing juvenile owls.

METHODS

Owl pairs were located between 15 April and 15 August each year (exception: 1982 - surveys began 1 June). Searches centered on known nest and roost sites. Area searches were generally conducted during the day. Sites were systematically walked, with the observer giving vocal imitations of the 4-note location call and contact whistle (Forsman 1976). If no response was obtained, the adjacent areas of appropriate habitat (old-growth and old-growth/mature stands) were checked. If owls were present, in most cases they responded to the observer and could then be located visually at their roost. After several unsuccessful day searches, calling was generally conducted at night before a site was classified as not occupied.

Once a pair or single adult was located during the day, a live mouse (usually _Peromyscus_ _maniculatus_) was tethered below the roost (Forsman 1983). If, on 2 days, the owl took 4 or more mice off the tether, each day, and either ate them or cached them, the pair was classified as not nesting. It is possible that birds which ate or cached mice had attempted nesting earlier but had failed. If an adult took a mouse to the nest or to young, the pair was classified as nesting.

Spotted owl reproductive survey data (above) were collected in western Oregon for 4 years (1982-1985). Only those pairs which were checked for reproductive status (reproductive survey pairs) were used to compute productivity figures. Each pair's reproductive status was assigned to 1 of 5 categories. Only those pairs falling into categories 2-5 were used in productivity calculations.

Category 1. Nesting status undertermined - a pair or single individual was located at a site (either by vocal response or sighting) but the owl(s) was not "moused" (Forsman 1983) and no young were observed.

Category 2. Nesting status undetermined, no young fledged - a pair was visually located and either moused or repeated visits to the site established that no young were fledged.

Category 3. Non-nesting - a site was checked and a pair was located early in the nesting season (during clutch initiation, brooding); pair was moused or checked several times to establish non-nesting status.

Category 4. Nest failed - nesting attempt determined early in the season (during clutch initiation, brooding) but failure documented later by mousing or repeated visits which could not demonstrate fledged young.

Category 5. Successful nesting, young fledged - fledged young were observed at the site.

Sites where only single spotted owls (either sex) were located were not used in any of the productivity calculations. The above protocol sets rather rigorous standards for classification of nesting status; it is easier to determine that a pair is nesting than to positively determine that it did not nest or did not nest successfully. Because nesting pairs are easier to locate than non-nesting pairs, estimates of reproductive parameters may be higher than the realized rates for the population.

Nesting pairs were monitored regularly to document possible failures. After the juveniles fledged (late May - mid-June), they were relocated visually at least weekly until old enough to mark with radio transmitters (3-4 weeks after fledging). Juveniles were relocated prior to radio-marking using the same general techniques used to test nesting status of adults. The observer would go to the last known location of the juveniles and give the 4-note location call and/or contact whistle. Juveniles would sometimes respond to those calls by giving the begging call (Forsman 1976). If the juveniles did not respond, an attempt was made to locate an adult. Once an adult was located, a mouse was presented; adults carried the mouse to the juveniles, revealing their location.

Juveniles were captured using a noose pole or long-handled dip net (Forsman 1983). Radio transmitter packages, consisting of AVM SM-1 modules (AVM Instrument Co., Livermore, CA) and 5 mm teflon tubing for the straps (Bally Ribbon Mill, Bally, PA), were put on the owls, using a backpack harness system (Forsman 1983). Battery life was estimated at 12-15 months. The total weight of the packages did not exceed 23 grams (3-4% body weight). U.S. Fish and Wildlife Service lock-on metal leg bands were placed on all owls captured.

Once the radio transmitters were attached, juveniles were relocated using a Telonics TR-2 receiver with scanner and a hand-held 2-element yagi antenna (Telonics, Mesa, AZ). Prior to dispersal, locations were confirmed visually on a routine basis. After the juveniles began dispersal, visual confirmation of locations became increasingly difficult to accomplish regularly. When visual confirmation was not possible, triangulation, using at least 3 radio bearings, fixed the location. Positions were plotted on USGS 7 1/2 minute orthophotoquad maps (scale 1:24,000) using the 1000-meter universal transverse mercator (UTM) grid system.

Frequently, during the initial stage of dispersal, juveniles were "lost" by ground crews. Aircraft, fitted with antennas, were employed to relocate the owls. A Cessna 172 or 182 equipped with two 2-element yagi antennas and an antenna switching system was used. After dispersal began, the individual juveniles were monitored daily, if possible. Whenever location, weather, and time permitted, the dispersing birds were located visually and roost site characteristics were determined.

Survival rate calculations were based on Trent and Rongstad (1974). Because of the variable time of fledging (late May to late June) and the fact that the exact day of fledging for a given individual was often unknown, a common anniversary date of 1 June was established to provide a reference for calculating yearly measurements (e.g., first-year survival). Spotted owl carcasses were necropsied at the Oregon State University Veterinary School's Diagnostic Lab to help determine probable cause of death.

Terminology

Several terms will be used throughout the thesis that need to be defined:

Dispersal - the movement of an individual from its natal area to a new area or succession of areas (Greenwood 1980, Shields 1982). Juvenile dispersal ceases when the individual becomes paired with a mate and fledges young. Active dispersal encompasses the time period(s) when an individual is actively moving from the natal area or a subsequent settled area. Dispersal thus spans the entire period from departure from the natal area until first successful reproduction.

Fledgling - a young owl that has left the nest but is still dependent on the adults for care (Berger 1961). The owl has not yet acquired full Basic I plumage (Forsman 1981).

Subadult - an owl that is at least 1 year old but less than 3 years old and has not yet molted its Basic I rectrices (Forsman 1981; Franklin et al. 1986).

Juvenile - a young owl during the period from fledging until it molts its Basic I (white-tipped) rectrices at approximately 26 months of age.

Adult - an owl that is at least 3 years old and has molted its Basic I rectrices.

RESULTS AND DISCUSSION

Reproductive Success

Spotted owl reproduction in western Oregon varied considerably during 1982-1985, with low levels of reproduction documented in 3 out of 4 years (Table 1. - Appendix 1) An average of 31% of the pairs checked for reproductive status in 1983-1985 attempted nesting (range =14%-69%). Mean number of young fledged per successful nest, 1983-1985, was 1.54; no broods of 3 were observed.

Information from previous years indicated variable reproductive rates are common in Oregon (Forsman et al. 1984). However, the percent of pairs which nested during 1983-1985, 31%, was half the average reported by Forsman et al. (1984:33) for similar areas, 10 years earlier (1972-1976 - ave.=62%; range 16-89%). Regional differences in reproduction also appeared to be substantial. A similar breeding failure in northern California in 1982 was reported by Gutierrez et al. (1985a). Reproduction in California during 1983-1985 averaged 52% of pairs attempting nesting (Franklin et al. 1986). In Washington, reproduction was low to nonexistent in areas surveyed each year between 1982 and 1985 (H. Allen, pers. comm.). Between 1982 and 1985, there was an apparent gradient in reproduction from south to north, with greater reproduction in California and lower reproduction in Washington.

Table 1. Spotted owl reproductive surveys in western Oregon, 1982-1985.

Categories	1982	1983	1984	1985
# Sites Birds Present	35	71	89	101
# Pairs Located	21	53	46	71
# Reproductive Survey Pairs	8[a]	48	37	66
# Pairs Attempting Nesting	4[b]	33	5	9
# Pairs Fledging Young	4[c]	31	5	8
# Young Fledged	7[d]	50	7	11

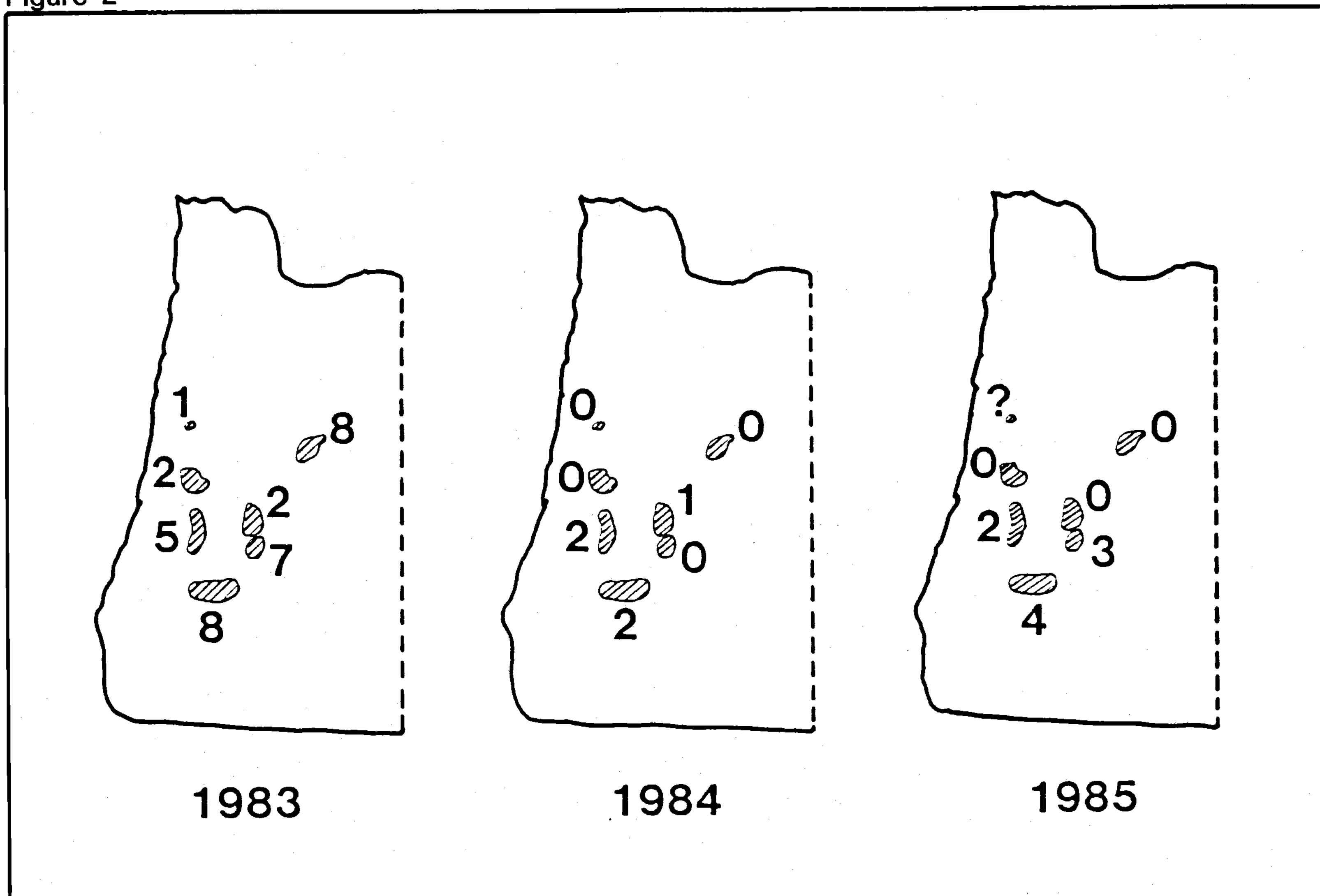
	1983	1984	1985
% of Pairs Nesting (# Pairs Nesting/ Repro. Survey Pairs)	33/48 = 69%	5/37 =14%	9/66 =14%
% of Pairs Fledging Yg. (# Successful Pairs/ Repro. Survey Pairs)	31/48 = 65%	5/37 =14%	8/66 =12%
# Young per Pair (# Young/Repro. Survey Pairs)	50/48 =1.04	7/37 =0.19	11/66 =0.17
Mean # of Young Fledged/ Successful Nest	50/31 =1.60	7/5 =1.40	11/8 =1.40

[a], [b], [c], [d], - Because value [a] was small and not representative of the 21 pairs located, values [a], [b], [c], and [d] are not appropriate for calculations of 1982 reproductive rates.

A geographic gradient in reproduction existed within Oregon as well (Fig 2). Reproduction, both in number and percent of pairs nesting and number of young fledged, was consistently higher in the southern areas (Roseburg and south) compared with the northern areas. Roseburg lies in the transition zone between the Douglas-fir/western hemlock forests, where flying squirrels (Glaucomys sabrinus) were the major prey of spotted owls, and the Mixed Conifer forests, where woodrats (especially dusky-footed woodrats Neotoma fuscipes) were the major prey (Forsman et al. 1984; Miller, unpubl. data - Appendix 2) There may be a reproductive response by spotted owls to a more stable or more available prey resource in the area from Roseburg south. Franklin et al. (1986, 1987) documented a high and consistent reproductive rate for spotted owls on a study area in northern California, where woodrats were the major prey (Solis 1983, Sisco and Gutierrez 1984). Breeding response to prey population fluctuations has been well documented in other raptors (Hoglund and Lansgren 1968, Southern 1970, Houston 1975, Adamcik et al. 1978). Obviously the population dynamics of the major prey species and predator-prey relationships demand study to resolve reproductive fluctuations exhibited by spotted owls.

Figure 2. Geographic location and number of successful spotted owl nest sites within study areas in western Oregon, 1983-1985.

Figure 2



Age at first breeding is an important parameter in demographic studies (Caughley 1977). Only 5 instances were recorded during this study where juveniles (birds less than 26 months old and still in Basic I plumage - see Forsman 1981) were paired with adults, and in only one case did a juvenile (a 2-year-old female) breed successfully (Miller et al. 1985). An additional observation in Oregon, a 2-year-old male breeding successfully, was recorded in 1986 (Wagner and Meslow 1986). Researchers in California have also documented successful breeding by 2-year-old juveniles (Barrows 1985, Franklin et al. 1986). Although breeding by 2-year-olds was considered rare, Franklin et al. (1986) found that on their study area in northern California, 1 of 11 females of known age which fledged young in 1985 was a subadult.

None of the dispersing juveniles in this study were known to have been recruited into the breeding population; all either died or transmitter failure precluded documentation of recruitment. There are probably yearly and regional differences in the proportion of breeding attempts by juveniles. Juvenile females may be more likely than males to breed during their second year. Of the 5 reports where breeding by juveniles was documented, only one was by a male (Barrows 1985, Miller et al. 1985, Franklin et al. 1986, Wagner and Meslow 1986). Over the course of the study a similar number of juveniles of each sex was encountered. It is possible that the roles, during incubation and brooding, of males versus females, coupled with the experience (age) of pair members, can explain the disparity observed.

Pre-dispersal Behavior and Movements

Juvenile behavior prior to dispersal has been well documented in Oregon (Forsman et al. 1984) and my observations did not differ significantly from those already reported. Juvenile spotted owls fledged from late May through late June; the dates varying with elevation and forest vegetation zone. Although weak flyers at fledging, most were able to make short, elevated flights within 2 weeks (Forsman et al. 1984; pers. obs.).

Siblings stayed together throughout most of the summer, often roosting in the same tree. By late August or early September, some siblings roosted apart (up to 1.6 km) for varying lengths of time. Such behavior usually immediately preceeded dispersal. Although both siblings were frequently still in the nest grove, often only 1 was associated with the adults. Thus, counts of fledglings in late summer, without the use of radio telemetry, may underestimate actual survival.

The size of areas used by the juveniles prior to dispersal (natal areas) varied considerably (Table 2), with the average being 28 ha (SD=16; n=20). Forsman et al. (1984) reported an area of 35 ha used by a single juvenile on the HJA study area, a value falling within the range used by birds in this study.

Dispersal Timing and Movements

Juveniles spent, on the average, 104 days (SD=13; n=10) in the natal area after fledging. Plumage characteristics varied at the time juveniles began dispersal, with some having full Basic I plumage (Forsman 1981) and others still having tufts of down around the sides of the head. Eighty-four percent of all juveniles began dispersal between mid-September and mid-October; the earliest dispersal date was 21 August and the latest 4 November (Fig. 3). One radio-marked juvenile did not disperse and remained in the natal area through its first winter. This bird was found dead on 10 March, apparently from starvation. The dates juveniles began dispersal corresponded with those reported in the literature (Forsman et al. 1984, Allen and Brewer 1985, Gutierrez et al. 1985a&b, Laymon 1985).

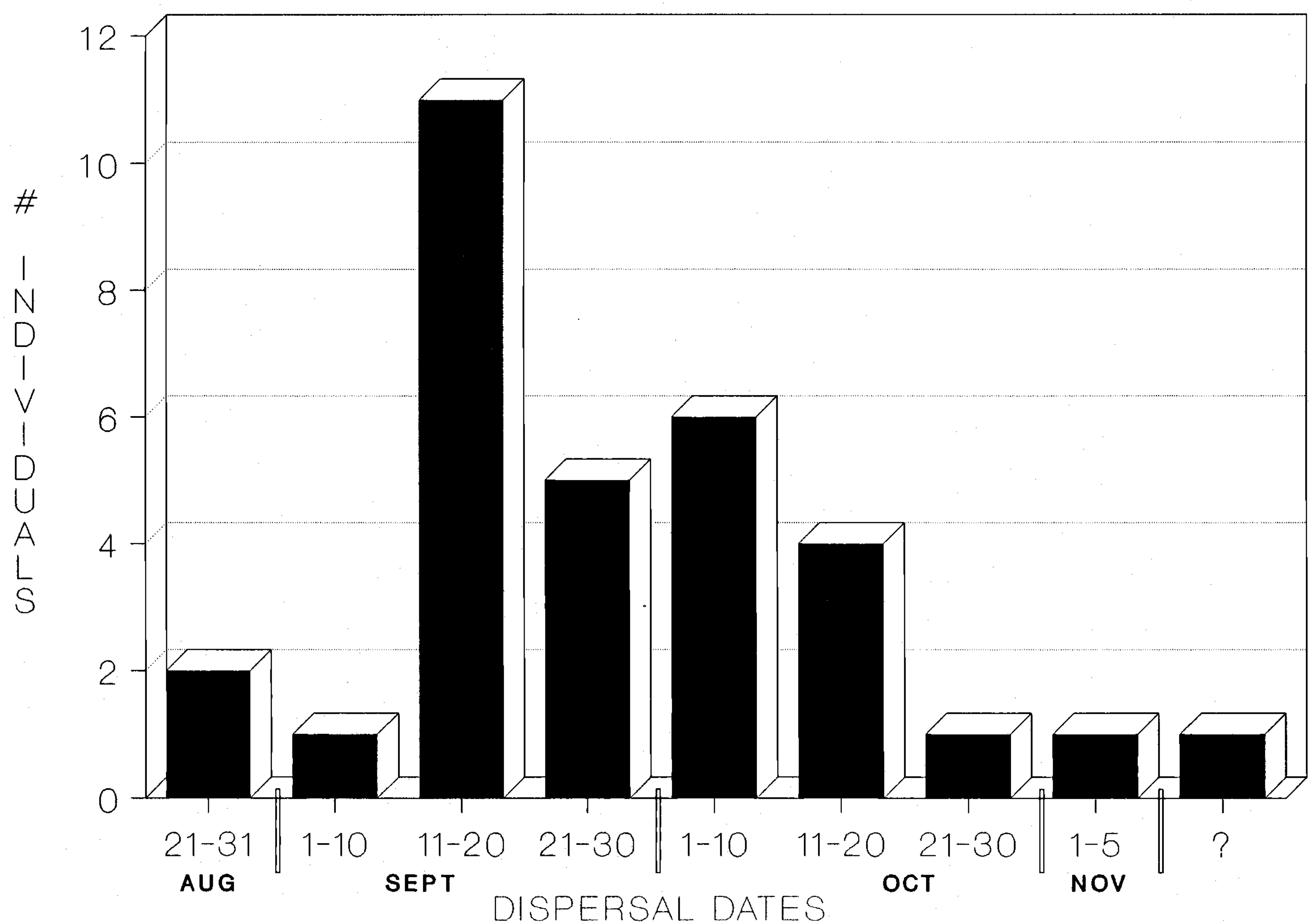
Initial dispersal usually was rapid; most active dispersal movements took place in the first few weeks after leaving the natal area. Average daily movements by juveniles (n=24) during this active phase were 1.6 km/day (min.=0.4, max.=7.7, SD=1.4). Most of the juveniles surviving the active dispersal phase "settled" into relatively well-defined areas for the rest of their first winter. "Settled" was defined as a group of locations (5

Table 2. Size of natal areas (minimum convex polygon) used by fledgling spotted owls in western Oregon, 1983-1985. Only fledglings followed to dispersal, and with locations on 10 or more days, were included.

Geographic Area	Average Use Area (ha)	SD	min. (ha)	max. (ha)
H.J. Andrews Area (Cascades; n=9)	24.6	12.7	2.2	37.4
North Umpqua Area (Cascades; n=8)	30.9	20.1	5.4	61.3
South Umpqua Area (Coast Ranges/ Cascades; n=3)	32.4	13.9	22.4	48.2
All Areas Combined	28.0	16.0		

Figure 3. Dispersal dates for radio-marked juvenile spotted owls in western Oregon, 1982-1985 (n=32). The ? represents one juvenile that never left the natal area and was found dead on 10 March.

Figure 3



INDIVIDUALS
12
10
8
6
4
2
0
21-31
1-10
11-20
21-30
1-10
11-20
21-30
1-5
?
AUG
SEPT
OCT
NOV
DISPERSAL DATES

or more) in an area of no greater than a 2.4 km radius. Settled areas, based on roost locations during the first winter period, averaged 1284 ha (SD=581; n=9) (Table 3). Two of the juveniles that settled during this winter period were monitored at night; roost locations of the 2 juveniles encompassed the majority of the foraging locations (roost locations of adult spotted owls also encompass the majority of foraging locations - Forsman et al. 1984; Miller, unpubl. data). The initial rapid dispersal movements observed with spotted owls followed the pattern seen with other raptors (Newton 1979) and in other studies of spotted owls (Gutierrez et al. 1985a&b).

Juveniles surviving their first winter often began moving again in late winter or early spring (Table 4). The timing of the resumed movement coincides with initiation of breeding activity by adults. Such birds eventually settled again into an area or radio contact was lost (radio failure). Dispersal, per se, need not cease at the end of the first year and likely continues for most juveniles at least into their second year. Movements made after the first winter settled period varied among individuals. Three juveniles made movements back toward their respective natal areas after their first winter, but then moved away again. There was no data showing that juvenile spotted owls may disperse long distances but return to the general area of birth to breed, as is seen

Table 3. Size of "settled" areas (minimum convex polygon) used by dispersing juvenile spotted owls, during their first winter, in western Oregon, 1982-1985.

Bird	Time Settled	Area (ha)	No. of Daily Locations
Juveniles which survived their first winter and began moving again			
OBM73	10 NOV 83 - 28 MAY 84	2076	119
LOC92	20 SEPT 83 - 31 MAY 84	1477	99
TC55	5 OCT 82 - 28 FEB 83	1389	26
EC69	12 OCT 83 - 18 MAR 84	2191	54
LC62	17 OCT 83 - 18 DEC 83	889	44
LC71	5 OCT 83 - 3 FEB 84	1022	23
EF80	10 OCT 85 - 28 FEB 86	1329	44
OS59	31 SEPT 85 - 21 FEB 86	491	50
MC60	27 SEPT 85 - 27 FEB 86	693	49
Juveniles which died while settled			
EF93	27 OCT 83 - 7 DEC 83	771	28
WC80	18 OCT 83 - 12 DEC 83	246	37
KC88	28 OCT 83 - 16 NOV 83	278	15
CC94	13 OCT 83 - 16 NOV 83	52	14
LLW93	8 OCT 85 - 5 FEB 86	544	26

Table 4. Dates for late winter/early spring active dispersal movements after the winter settled period for first-year juvenile spotted owls in western Oregon, 1982-1985.

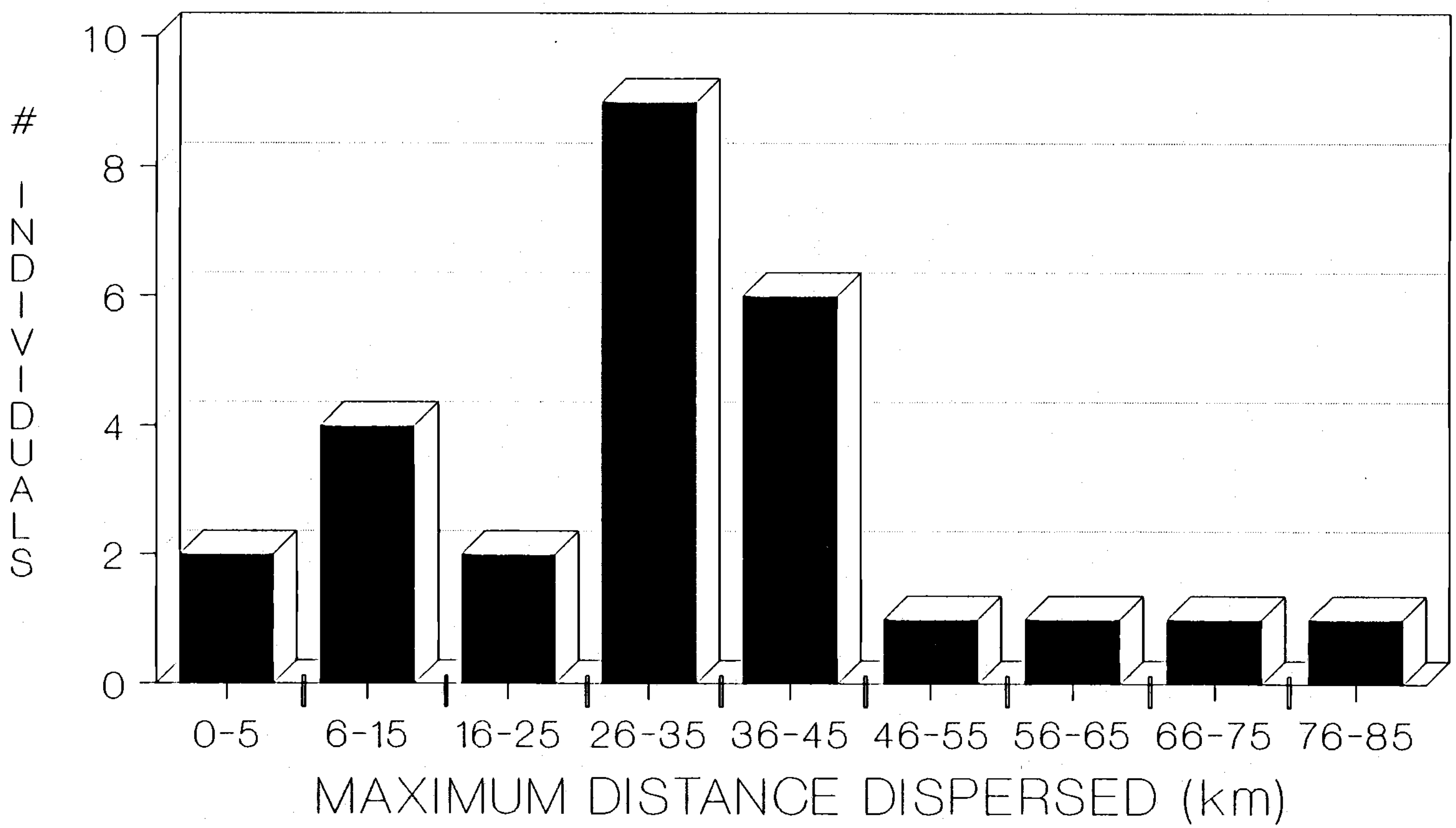
Owl	Initial Dispersal Date	Secondary Dispersal Date
TC55	16-20 Sept. 82	1 March 83
OBM73	14 Oct. 83	29 May 84
LC62	10 Oct. 83	19 Dec. 83
LC71	14 Sept. 83	4 Feb. 84
EC69	19 Sept. 83	19 March 84
LOC92	16 Sept. 83	9 April 84
EF80	21 Sept. 85	2 March 86
OS59	17 Sept. 85	22 Feb. 86
MC60	28 Aug. 85	28 Feb. 86

with some other raptors (Newton 1979, 1986). Several juveniles moved through known territories of spotted owls during the spring (breeding) period. I do not know whether resident adults were aware of the juveniles or if there were interactions between the resident adults and the dispersing juveniles. Three juveniles (2 females, 1 male) formed temporary associations, in their first spring, with potential mates. One of these juveniles (the male) shifted its use area to include more older timber. Both his winter use and spring use areas were bounded by adjacent resident pairs of spotted owls. All three instances of "pairing" by 1-year-old juveniles lasted no more than 2-3 months; the social significance of such associations could not be determined because either both of the pair members died or radio contact was lost with the juveniles before the second spring.

Mean maximum straight-line dispersal distance (Fig. 4) for all individuals combined (first-year movements only), excluding those that radio contact was lost with, was 28 km (SD=19; n=27). The median maximum dispersal distance was 27 km. Mean maximum dispersal distance, for those surviving into their second year, was 15 km (SD=8; n=5); the median maximum dispersal distance was also 15 km. Small sample sizes precluded meaningful year to year comparisons. Forsman (1980) reported dispersal distances

Figure 4. Maximum straight-line dispersal distances for radio-marked juvenile spotted owls in western Oregon, 1982-1985 (n=27).

Figure 4



INDIVIDUALS
0
2
4
6
8
10
0-5
6-15
16-25
26-35
36-45
46-55
56-65
66-75
76-85
MAXIMUM DISTANCE DISPERSED (km)

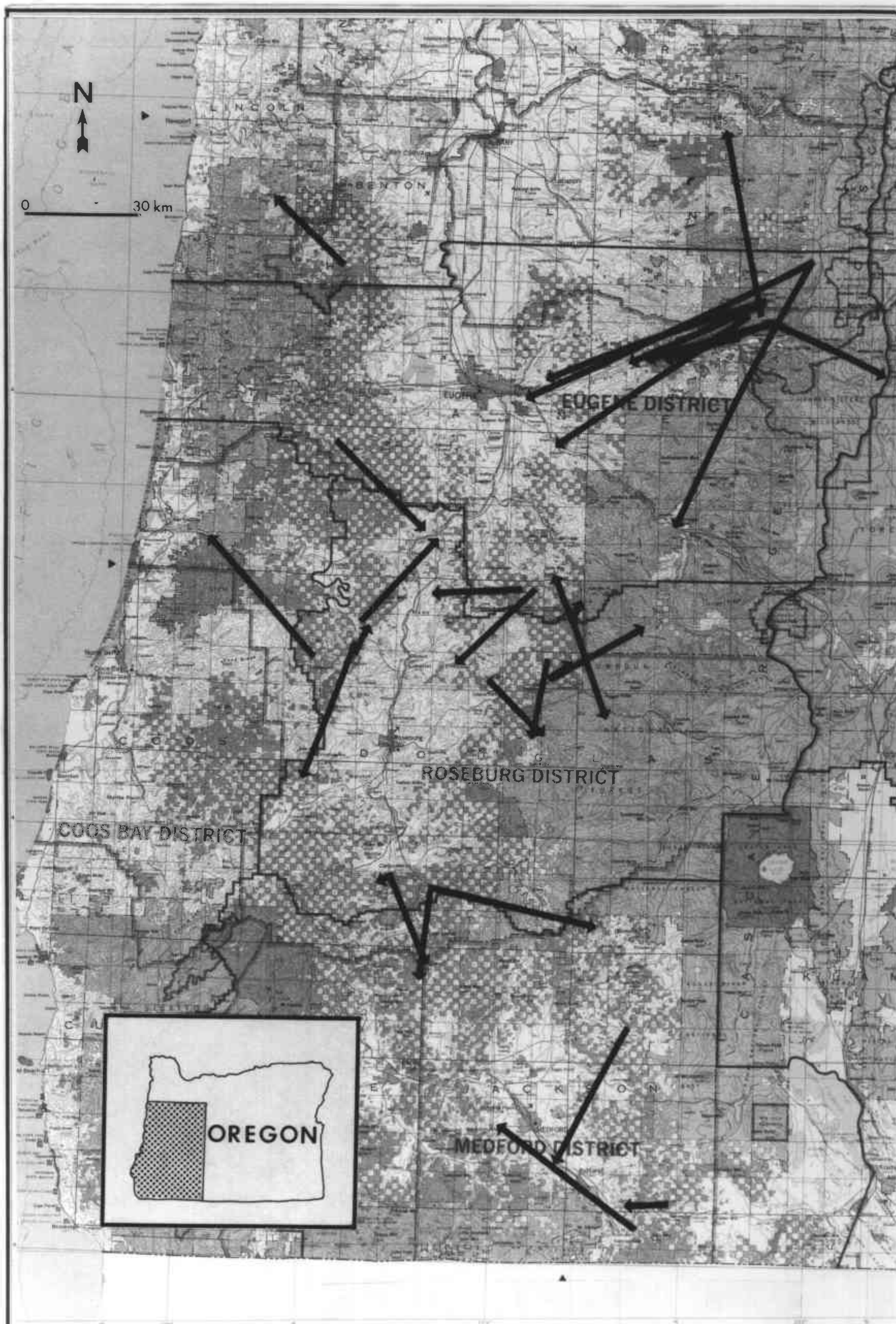
of 10.1 and 16.4 km straight-line distance travelled from the nest, but both juveniles were dead by early December.

Dispersal distances for juvenile spotted owls in western Oregon, during this study, were similar to those reported for California (Gutierrez et al. 1985b, Laymon and Barrett 1985) and Washington (Allen and Brewer 1985). Gutierrez et al. (1985b) reported an average final distance moved for 12 juveniles in northern California of 37 km, while Laymon and Barrett (1985) reported only a range of 5 to 30 km moved for 4 juveniles in the Sierra Nevada Mountains. Allen and Brewer (1985) also provided only general information on dispersal distances; movements exceeded 48 km in some cases.

Direction of movement appeared random (Fig. 5) except for the 1983 cohort dispersing off the HJA area. Six of the 9 juveniles from this area moved southwest down the McKenzie River drainage. Gutierrez et al. (1985a&b) tested dispersal direction for juvenile spotted owls in northwestern California. They found direction was nonrandom one year, but random the next. VanCamp and Henny (1975) concluded that dispersal direction of screech owls (Otus asio) in Ohio was random but distance of dispersal was not. With the spotted owl, topography, density of adult pairs, availability of prey, and habitat encountered, are likely among the factors influencing

Figure 5. Straight-line dispersal movements for all juvenile spotted owls radio-marked during study in western Oregon, 1982-1985.

Figure 5


N
0
30 km
LINCOLN
BENTON
EUGENE DISTRICT
ROSEBURG DISTRICT
COOS BAY DISTRICT
MEDFORD DISTRICT
JACKSON
OREGON

direction and distance moved. That dispersal direction appeared random is not surprising, considering the high variability of the landscape and associated factors the juveniles encountered.

Differential Dispersal by Sex

Among most avian species, females are the longer natal (juvenile) dispersers (Greenwood 1980). Only 14 dispersing juveniles were positively identified to sex, through necropsy or by behavior/vocalizations (Table 5). The mean dispersal distances for females (n=6) was 33.0 km (SD=10.6) and for males (n=7) was 26.2 km (SD=23.7). Only one juvenile (a male) did not disperse from the natal area. There was no significant difference in distances dispersed by males and females (Mann-Whitney U-test, P=0.45).

Juvenile Mortality

Of the 48 juveniles radio-marked during the study (1982-1985), 32 survived to disperse (Table 6). Radio contact was lost with 4 dispersing juveniles before the end of their first year (31 May) and an additional 2 juveniles after 31 May. First-year survival was calculated from daily survival rates (Trent and Rongstad 1974) commencing 1 June of the hatching year through 31 May the following year and yielded an estimate of 19 percent (8070 days of survival with 37 mortalities). This estimate did not include juveniles that radio contact

Table 5. Dispersal distances, by sex, for juvenile spotted owls, western Oregon, 1982-1985. Only those juveniles where the sex of the individual was positively determined (through vocalization, behavior, or necropsy results) were used in the analysis.

Males	Distance[a] (km)	Females	Distance[a] (km)
SRN95	77.3	LC71	31.2
LO92	8.0	EC69	36.0
WC80	17.6	KC88	21.3
BJ77	25.4	OS58	28.0
BJ91	7.8	BR64	43.2
LLW93	25.1	FB83	48.5
OS59	22.3		
Mean	**26.2** (SD=23.7)	**Mean**	**33.0** (SD=10.6)

[a] - Maximum straight-line dispersal distances.

Table 6 - Status of 48 juvenile northern spotted owls equipped with radio transmitters, western Oregon, 1982-1985.

Bird No.	Date Radioed	Dispersal Date	Max. Distance Dispersed[a] (km/mi.)	Final Distance (km/mi.)	Status	No. of Dispersal Roost Locations	No. of Days Survived (post-fledging)[b]	No. of Dispersal Days	Cause of Death[c]
H.J. Andrews Study Area (Cascades)									
OBM60	22 July 83	----	----	----	Dead	---	100	---	S
OBM67	11 July 83	----	----	----	Dead	---	42	---	S
OBM73	22 July 83	14 Oct 83	61.3/38.3	?	Unk.[d]	136	371?	243?	-
LC62	28 June 83	10 Oct 83	34.4/21.5	34.4/21.5	Dead	53	211	80	AP
LC70	17 July 83	14 Sept 83	28.3/17.7	?	Unk.[d]	4	141?	37?	-
LC71	17 July 83	14 Sept 83	30.6/19.1	30.6/19.1	Dead	38	316	212	U
BRR72	21 July 83	5 Oct 83	27.5/17.2	26.2/16.4	Dead	25	172	46	AP
ML66	5 July 83	----	----	----	Dead	---	101	---	S
ML76	23 July 83	17 Sept 83	47.6/29.8	?	Unk.[d]	2	127?	20?	-
UM85	7 Aug 83	18 Sept 83	38.6/24.1	?	Unk.[d]	3	127?	19?	-
UM89	17 Aug 83	11 Oct 83	59.0/36.9	58.2/36.4	Dead	10	164	32	U
SRN90	17 Aug 83	26 Oct 83	75.0/46.9	75.0/46.9	Dead	1	164	17	U
SRN95	7 Sept 83	4 Nov 83	78.0/48.1	75.8/47.4	Dead	26	192	36	S
Roseburg/Eugene BLM Study Area (Cascades)									
EC69	16 July 83	19 Sept 83	38.2/23.9	?	Unk.[d]	230	702?	656?	-
KC77	30 July 83	----	----	----	Dead	---	112	---	GHO
KC88	14 Aug 83	20 Sept 83	20.8/13.0	19.7/12.3	Dead	35	169	59	AP
EF84	2 Aug 83	----	----	----	Dead	---	73	---	AP
EF93	4 Sept 83	20 Sept 83	13.6/8.5	7.0/4.4	Dead	46	190	80	GHO
WC80	30 July 83	9 Oct 83	18.4/11.5	17.9/11.2	Dead	43	195	65	S
BJ81	31 July 83	30 Sept 83	5.3/3.3	5.3/3.3	Dead	6	155	34	U
TR82	1 Aug 83	----	----	----	Dead	---	101	---	AP
DC05	22 July 84	27 Sept 84	40.2/25.1	23.2/14.5	Dead	25	212	94	S
BJ77	16 July 85	9 Oct 85	25.6/16.0	25.6/16.0	Dead	17	213	83	U
BJ91	22 July 85	11 Oct 85	12.5/7.8	11.0/6.9	Dead	20	203	71	U
TRC92	23 July 85	----	----	----	Dead	0	284	0	S
EF80	18 July 85	21 Sept 85	30.4/19.0	26.9/16.8	Dead	88	610	498	U

Table 6 (cont.)

Bird No.	Date Radioed	Dispersal Date	Max. Distance Dispersed[a] (km/mi.)	Final Distance (km/mi.)	Status	No. of Dispersal Roost Locations	No. of Days Survived (post-fledging)[b]	No. of Dispersal Days	Cause of Death[c]
Roseburg/Eugene BLM Study Areas (Coast Ranges and Southern portion of Roseburg District)									
TC55	26 Aug 82	15 Sept 82	27.4/17.1	23.7/14.8	Dead	38	528	441	U
SF68	16 July 83	----	----	----	Dead	---	37	---	S
EDC86	9 July 83	10 Oct 83	31.0/19.4	29.3/18.3	Dead	3	146	24	U
CC94	5 Sept 83	7 Sept 83	38.2/23.9	38.2/23.9	Dead	24	169	71	U
LOC92	3 Sept 83	16 Sept 83	9.6/6.0	4.8/3.0	Dead	192	595	500	AP
UYC99	18 July 84	21 Aug 84	26.2/16.4	26.2/16.4	Dead	7	98	17	S
MC01	19 July 84	----	----	----	Dead	---	98	---	AP
CAT04	19 July 84	----	----	----	Dead	---	137	---	AP
LWC08	26 July 84	----	----	----	Dead	---	84	---	AP
LLW93	24 July 85	25 Sept 85	40.6/25.4	38.7/24.2	Dead	30	250	132	AP/S*
OS58	8 July 85	28 Sept 85	27.5/17.2	?	Unk.[d]	91	635?	516?	-
OS59	8 July 85	17 Sept 85	44.8/28.0	39.2/24.5	Dead	75	410	302	U
MC60	8 July 85	28 Aug 85	41.0/25.6	?	Unk.[d]	66	307?	219?	-
MC78	8 July 85	12 Sept 85	3.2/2.0	3.2/2.0	Dead	4	113	10	S
IM95	30 July 85	----	----	----	Dead	---	76	---	AP
Medford BLM Study Area									
RC62	11 July 85	----	----	----	Dead	---	45	---	AP
BR63	19 July 85	----	----	----	Dead	---	115	---	U
BR64	19 July 85	17 Sept 85	42.2/26.4	42.2/26.4	Dead	28	197	89	A
MM82	25 July 85	----	----	----	Dead	---	97	---	S
MM86	19 Aug 85	----	----	----	Dead	---	130	---	U
FB83	25 July 85	14 Oct 85	47.4/29.6	40.3/25.2	Dead	15	165	30	S
CH90	6 Aug 85	8 Oct 85	11.0/6.9	9.4/5.9	Dead	31	189	60	U

a/ Maximum distance dispersed is measured as the farthest straight-line distance moved from the nest.
b/ Calculated from 1 June of the fledging year.
c/ U = undetermined; S = apparent starvation; AP = avian predation; GHO = Great Horned Owl; AP/S* = ultimate cause of death was deep lacerations in the breast muscle (inflicted by an avian predator), inhibiting flight. Proximal cause of death was starvation.
d/ Unknown status of these birds means their radio signals were lost.
? Minimum number of survival and dispersal days (because radio signal was lost).

was lost with prior to 31 May. First-year survival was also estimated 2 different ways to include those juveniles where radio contact was lost. Survival days were included for the lost juveniles up to the time the radio failed. In the first case, juveniles were presumed alive (survival was 21%) and, in the second case, juveniles were presumed dead (survival was 18%). This provided a best case and worst case scenario for survival. Estimates for first-year survival for each year were calculated (Table 7), with most of the sample from 2 years, 1983 and 1985. Even though only a small proportion of owls nested in 1985, survival, especially in the Roseburg area, was greater than in 1983, a year when about 65% of the monitored pairs nested. There was a substantial difference in survival estimates for 1985 between Roseburg and Medford: juveniles from the Roseburg area survived longer than those from the Medford area. Wagner and Meslow (1987) also reported a high turnover in resident adults on their Medford study area compared to other areas.

Pre-dispersal Mortality

Forty-eight radio-marked fledglings were followed over the course of the study, with 8 dying before the end of August (17% mortality). This was half the average mortality reported by Forsman et al. (1984) for a similar

Table 7. First-year survival estimates, by year, for juvenile northern spotted owls in western Oregon, 1982-1985 (calculations based on Trent & Rongstad 1974).

1982	n = 1	TC55 -	365 days	100% Survival
	0 mortalities			
1983	n = 22	OBM73-	365 days	17% Survival
	19 mortalities	OBM60-	100 days	
		OBM67-	42 days	
		LC62 -	211 days	
		LC71 -	316 days	
		BRR72-	172 days	
		ML66 -	101 days	
		UM89 -	164 days	
		SRN90-	164 days	
		SRN95-	192 days	
		EC69 -	365 days	
		SF68 -	37 days	
		EDC86-	146 days	
		KC77 -	112 days	
		KC88 -	169 days	
		EF84 -	73 days	
		EF93 -	190 days	
		WC80 -	195 days	
		BJ81 -	155 days	
		TR82 -	101 days	
		CC94 -	169 days	
		LOC92-	365 days	
1984	n = 5	DC05 -	212 days	5% Survival
	5 mortalities	UYC99-	98 days	
		MC01 -	98 days	
		CAT04-	137 days	
		LWC08-	84 days	
1985	n = 16	(A) BJ77 -	213 days	22% Survival
	13 mortalities	(A) BJ91 -	203 days	(overall)
		(A) TRC92-	284 days	
		(A) EF80 -	365 days	
		(A) OS58 -	365 days	
	(A) = Roseburg	(A) OS59 -	365 days	Survival
	District BLM	(A) LLW93-	250 days	for
		(A) MC78 -	113 days	Region A
		(A) IM95 -	76 days	= 37%
		(B) RC62 -	45 days	
		(B) BR63 -	115 days	
		(B) BR64 -	197 days	
	(B) = Medford	(B) MM82 -	97 days	Survival
	District BLM	(B) MM86 -	130 days	for
		(B) FB86 -	165 days	Region B
		(B) CH90 -	189 days	= 6%

time period: 10 of 29 fledglings (not radio-marked) were dead by the end of August, a mortality of 35%.

For the total post-fledging/pre-dispersal period of this study, mortality was 33% (16 of 48). During each year of the study, more fledglings were seen during the nest site visit(s) immediately after fledging, than were present at the time radio transmitters were attached, 3-8 weeks after fledging. In 1983, of 33 young owls present shortly after fledging, 25 were found alive when radio-marking began. In 1984, of 7 fledglings present originally, 5 could be found at the time that the transmitters were attached. In 1985, of 19 fledglings, only 17 were accounted for when transmitters were attached. Between 1983 and 1985, of the 12 juveniles which disappeared between fledging and radio-marking, only 3 were found dead. Because of juvenile behavior, presence of adults, and the number of visits to the sites, it was most unlikely that the 9 missing fledglings were still alive. Thus the effective cohort of juvenile owls "followed" between 1982 and 1985 was 60 (48 + 12). Including the 12 missing unmarked juveniles in the sample, pre-dispersal mortality increases to 47% (28 of 60).

Of 38 juveniles located between 1983 and 1985 during a study of dispersal of juvenile spotted owls in northern California, 29 were radio-marked (Gutierrez et al. 1985b).

Pre-dispersal mortality rates of the radio-marked juveniles was somewhat lower than in Oregon: about 10% mortality for radio-marked fledglings (3/29). Gutierrez et al. (1985b) also reported additional mortality of 4 nonradio-marked juveniles which increased pre-dispersal mortality to 18%. Eight others disappeared before dispersal, bringing the total to 15 of 38 (39% pre-dispersal mortality). Laymon and Barrett (1985) reported a pre-dispersal mortality of 67% (8/12) over 3 years during a study in the Sierra Nevada Mountains of central California.

The two main causes of mortality for the pre-dispersal period, in this study, were starvation and avian predation (Fig. 6). Causes of death during pre-dispersal were similar in both Washington and California (Allen and Brewer 1985, Gutierrez et al. 1985a&b, Laymon 1985). Great horned owls (Bubo virginianus) were the only documented avian predators.

Only limited information is available documenting mortality of juvenile spotted owls (Forsman et al. 1984, Allen and Brewer 1985, Gutierrez et al. 1985b, Laymon 1985, Miller and Meslow 1985). Forsman et al. (1984) established great horned owls as predators on juvenile spotted owls, both before and during dispersal, and reported one instance of a Cooper's hawk (Accipiter cooperii) attempting to capture a recently fledged young.

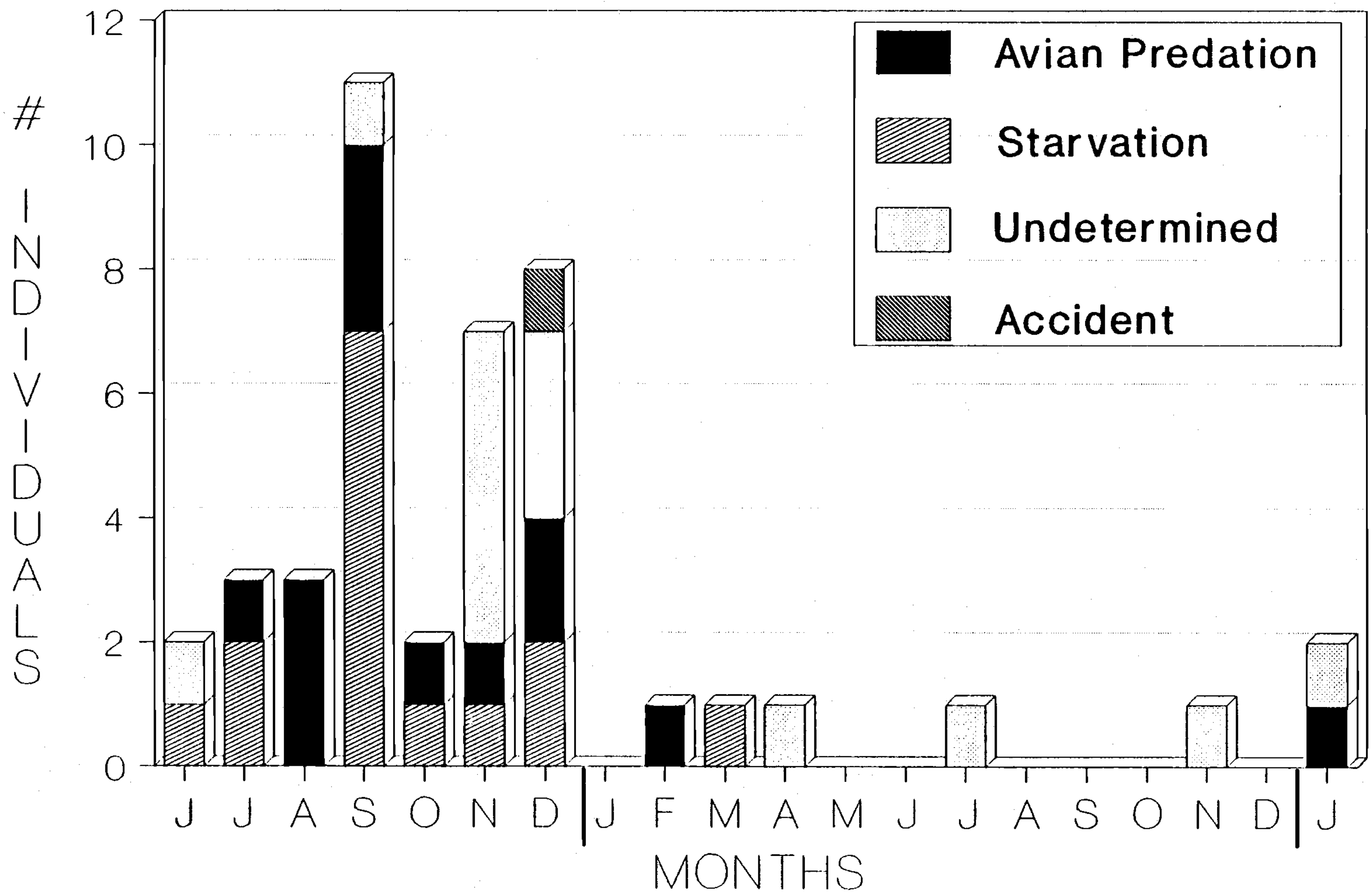
In 1986, a red-tailed hawk (*Buteo jamaicensis*) was observed to knock an adult spotted owl out of the air (F. Oliver, pers. com.). Although the owl flew off, the incident implicates red-tailed hawks as potential predators, especially on juveniles which sometimes roost on the edge of clearings or in the open. Remains of spotted owls have also been recovered from goshawk (*Accipiter gentilis*) nests in northern California (B. Woodbridge, pers. com.)

Dispersal Mortality

Of the 32 juveniles surviving to disperse, 7 were still alive at the end of their first year (31 May). Radio contact was lost with 4 others before 31 May. Of the 7 survivors, none were followed through the end of their second year. Radio contact was lost with 3 of these juveniles; the other 4 died. Starvation and avian predation (I suspect principally great horned owls) were the two main causes of dispersal mortality (Fig. 6, Table 6). Predation and starvation were not unexpected causes of mortality for fledgling and dispersing birds. These two causes of mortality have been reported for other species of owls (Southern et al. 1954, Southern 1959, Craighead and Craighead 1956, Duncan 1987). Peaks in mortality occurred during September and November/December. Starvation was the major cause of mortality in September, occurring just prior to, and immediately after dispersal

Figure 6. Timing and causes of mortality of 43 radio-marked juvenile spotted owls in western Oregon, 1982-1985.

Figure 6



INDIVIDUALS
0
2
4
6
8
10
12
Avian Predation
Starvation
Undetermined
Accident
J J A S O N D J F M A M J J A S O N D J
MONTHS

movements began, and probably coinciding with the period when the adults stop feeding the young owls. The high mortality during November and December likely was a function of dispersing juveniles securing limited food (due both to prey availability and hunting ability) with resultant declining fitness leading to starvation or increased susceptibility to predation or accidents.

Causes of mortality are difficult to document. It is especially difficult to distinguish between proximal and ultimate causes. A starving juvenile may become more vulnerable to predation so that, although the proximal cause was avian predation, the ultimate cause was starvation (to make matters more confusing, the evidence is often eaten). Parasites, although found in several of the juveniles which were necropsied, were not implicated as a mortality agent (Hoberg et al., in press).

Information on causes of dispersal mortality in spotted owls, elsewhere, is even more limited than for pre-dispersal mortality. Gutierrez et al. (1985a) suggested that the high dispersal mortality may be due, in part, to the generally limited amount of high quality habitat (old-growth) available. The possible effects of forest fragmentation and juvenile survival are addressed in Part II.

Juvenile Mortality and Population Stability

Although first-year mortality of spotted owls appears high in comparison to mortality in other species of owls (Table 8), pertinent life history data must be considered. Mortality estimates (Table 8) for species other than the spotted owl are based on band returns. The northern spotted owl population is declining (Gould 1977, 1985; U.S. Fish and Wildlife Service 1982; Forsman et al. 1984, 1987; Franklin et al. 1986). Although longevity information is limited for the spotted owl, it is assumed they may live as long as 15-20 years. Banding information from Oregon has shown several individuals still alive at age 11-15 years in the wild (E. Forsman and G. Miller, unpubl. data) and a captive female is 19 years old (E. Forsman, pers. comm.). With the combined influences of a long lived species, a declining population, and most of the suitable habitat already occupied by resident adults, a high rate of juvenile mortality was not unexpected; that the levels of juvenile mortality in this study fall within some expected range is (highly) speculative.

In 3 of the 4 years of the study, low reproduction (<20% of reproductive survey pairs fledged young - see Table 1) by the monitored adult owls was recorded. Years in which low reproductive rates were recorded may reflect generally unfavorable conditions for spotted owls (e.g. low prey availability) which would likely contribute to

Table 8. First-year and annual adult survival rates for several owl species.

Species	1st-year Survival	Adult Survival (annual)	Source
Spotted Owl	19%	85%	a
Spotted Owl	19%		b
Tawny Owl (Strix aluco)	37%	>85%	c
Tawny Owl (Switzerland)	63%	76%	d
Tawny Owl (Sweden/Finland)	33%	52%	e
Tawny Owl (Germany)	52%		f
Tawny Owl (Belgium)	42%		f
Barn Owl (NE U.S.)	33% (prior to 1948)		g
(Tyto alba)	41% (1948 - 1963)		g
Barn Owl (S U.S.)	53% (prior to 1948)		g
Barn Owl	48% (1948 - 1963)		g
Barn Owl	35%	63%	h
Great Horned Owl	42%	67%	i&j
Screech Owl (Otus asio)	30%	61%	k

a/ This study
b/ Gutierrez et al. 1985a (as estimated by Barrowclough and Coats 1985)
c/ Southern 1970
d/ Shifferli 1957
e/ Olsson 1958
f/ Delmee et al. 1978
g/ Henny 1969
h/ Stuart 1952
i/ Adamcik and Keith 1978
j/ Houston 1978
k/ VanCamp and Henny 1975

low survival of the few young produced, as well. Using the mortality rates derived from this study, production levels needed to maintain a stationary population can be calculated (Henny 1969, Henny and Wight 1969, Henny et al. 1970). Assuming that female spotted owls first breed at age 3 (Miller et al. 1985, Franklin et al. 1986), an annual adult survival rate of 85% (E. Forsman, G. Miller, unpubl. data), a first-year survival rate of 19% (this study), and a second-year survival rate of 70% (A. Franklin, pers. comm. - this value is preliminary), then the following method from Henny and Wight (1969) may be used to calculate annual production requirements needed to maintain a stationary population:

$$m = \frac{1 - s}{s_o s_1 s}$$

Where m = the average number of female fledglings produced per breeding age female (2m = the total number of young produced per breeding female assuming an equal sex ratio of fledglings.)

s = adult annual survival rate, where s = 1 - annual mortality rate.

s_o = 1st-year survival rate.

s_1 = 2nd-year survival rate.

In Table 9 I employ the above formula and present a variety of combinations of survival and production values which yield a stationary population, assuming even sex ratios and uniform breeding at age 3. For instance, using

Table 9. Population parameters requirements to maintain a stationary population given a variety of values for specific life history parameters. Bold print values are empiracal values, others are manipulated values. Underlined values indicate the parameter solved for.

Parameters	Current estimates	current prod. needs	current productivity
	A	B	C
1st-year survival	**0.19**[a]	**0.19**	s_o = 1.12
2nd-year survival	**0.70**[b]	**0.70**	**0.70**
adult survival	**0.85**[c]	**0.85**	**0.85**
productivity (2m)	**0.45**[d]	2m = 2.65	**0.45**

	D	E	F	G
1st-year survival	0.56	0.69	0.35	0.16
2nd-year survival	**0.70**	**0.70**	**0.70**	**0.70**
adult survival	**0.85**	0.90	0.90	**0.95**
productivity (2m)	0.90	**0.45**	0.90	0.90

	H	I	J	K
1st-year survival	0.78	0.99	0.49	0.23
2nd-year survival	0.50	0.50	0.50	0.50
adult survival	**0.85**	0.90	0.90	**0.95**
productivity (2m)	0.90	**0.45**	0.90	0.90

a/ - value derived from this study.
b/ - value derived from Franklin et al. 1986
c/ - value derived from unpubl. data, OCWRU.
d/ - value derived from this study, close to value used in Marcot and Holthausen 1987 (0.48).

the survival values derived from recent studies of spotted owls, the population must produce 2.65 young per adult female per year to maintain a stationary population (Table 9B). The current estimate of 0.45 young per adult female (this study) is markedly below that production requirement. To achieve a stationary population, with the current adult survival rate, second-year survival rate, and production of 0.45 yg/adult female/yr., first-year survival of 112% is required (Table 9C). Such a survival value is clearly impossible; either the adult and/or 2nd year survival estimates and/or productivity estimates are too low. Increasing either productivity (to 0.90 - Table 9D) or adult survival rates (to 90% - Table 9E) alone still results in unrealistically high generated 1st-year survival values (compare to observed survival statistics for owls in Table 8). The same is naturally true if 2nd year survival is lowered to 50% (probably a more realistic value than 70%) and either productivity or adult survival rates are increased (Table 9H&I). But, if the current estimate of adult survival is increased 5% (to 0.90) and productivity is doubled (0.45 to 0.90), the generated 1st-year survival (35% - Table 9F) is more realistic. In fact, a 37% 1st-year survival was observed for spotted owls in this study in the Roseburg area in 1985. If 2nd year survival is decreased from 70% to 50% then it does not matter which combination is used. The calculated required 1st-year survival is still higher than was observed (Table 9H,I,J). Franklin and Gutierrez (1988) reported an adult survival rate of approximately 95% for a 4 year study in northern California. If this value is used, whether 2nd-year survival is 50% or 70%, estimates of first-year survival fall very close to the values seen in this study (9G & K). Each of the parameter values presented in Table 9F, G, and K are at the high end of an array of values that I consider realistic. Thus, such a combination of parameter values would represent best-case scenarios. However, current estimates of population trends of spotted owls (Forsman et al. 1984, 1987) indicate a declining population, not the stationary population modelled (Table 9). Thus, the parameter values observed may be lower than displayed expected values (Table 9), which are based on a stationary population.

Although the juvenile mortality rates documented in this study accurately reflected the situation at the time, the rates need to be viewed in the context of a longer time series to evaluate their real significance. Obviously, the population would become extinct in a very short time if the observed low juvenile survival continued for an extended period of time, especially in conjunction with the observed low rate of productivity. The rates of population decline estimated by others (Forsman et al. 1984, 1987 (1.2%/yr); Gould 1977, 1985

(0.45%/yr)) suggest that higher rates of juvenile survival should be expected, at times, to offset the poor survival observed during 1982-1985. The population may only require good reproduction and a somewhat higher 1st-year survival every 3 to 5 years to maintain the current population trend. Instead of focusing only on the low survival of juveniles, a closer look at second year and adult survival and productivity, concentrating on obtaining more accurate estimates over an extended time period, may provide the additional insight needed to understand the population dynamics of spotted owls and the associated decline in population numbers. The model utilized here is very simplistic and based on life-table models that assume a stable age distribution. Spotted owls probably do not have a stable age distribution, but it is unknown how this might affect the conclusions based on the above model. It does, however, provide insight into the population dynamics of spotted owls. Such factors as density of owls, abundance of prey, and loss of habitat, not included in this model, are germane to an understanding of the population dynamics of spotted owls. The outcome of the modeling exercise emphasizes that the low rates of reproduction and high juvenile mortality documented in this study should raise serious concerns about the status of the population. Emphasis should be placed on accurate long term monitoring of population parameters and on incorporating fluctuations in reproduction of spotted owls and varying survival rates of adults and juveniles into stochastic population models. However, elegant and refined population models may only document the demise of the species unless appropriate management actions are undertaken.

MANAGEMENT IMPLICATIONS

Recommendations for spacing of spotted owl habitat areas (SOHAs) currently call for single pair management areas to be no further than 9.6 km apart, and clusters of 3 pairs or more to be no further than 19.2 km apart (Oregon-Washington Interagency Wildlife Committee 1980). Based on dispersal distances observed, the established spacing requirements do not seem inappropriate. Juvenile spotted owls were capable of fairly long distance movements, with dispersal movements continuing after the first year. Ninety-three percent of the juveniles travelled at least 9.6 km while 75% went at least 19.2 km. This is not to say spacing distances should be increased because of the apparent mobility of dispersing juveniles. Regardless of how far the juveniles were able to disperse, survival was very low. Dispersal distances were actually only measured for unsuccessful dispersers. Other factors such as suitable habitat for dispersing juveniles, juvenile mortality and recruitment rates, and distribution of an appropriate number of pairs to maintain the population, should all be considered in the final management recommendations. Because of limited information for some specific life history traits, management recommendations must be conservative to ensure the availability of future options. In a companion paper (Part II) other important aspects of the ecology of juvenile spotted owls are examined; i.e., dispersal of juvenile spotted owls with respect to habitat use and the possible relationships with forest fragmentation.

PART II

HABITAT USE, FOREST FRAGMENTATION, AND DISPERSING JUVENILE SPOTTED OWLS IN WESTERN OREGON

INTRODUCTION

During the past 2 decades, the effects of forest fragmentation on wildlife, especially birds, has been the subject of several studies (Forman et al. 1976, Galli et al. 1976, Robbins 1979, Whitcomb et al. 1981, Helle 1985). Both number of species and breeding densities typically decline as forest patch sizes decrease. But these studies have focused on species associated with forest interiors and bird densities as a function of stand size and insularity. Few studies have addressed the impact of forest fragmentation on a spatial scale that exceeds the home range or territory of the species in question (Small and Rusch 1989). Along with forest fragmetation, the rather recent and rapid change in forest age distributions in the Pacific Northwest, due to current logging practices, has undoubtedly had a considerable impact on wildlife species associated with large blocks of older forests (Harris 1984). Effects of stand age and the juxtaposition of stands of varying age on the distribution and numbers of wildlife species has become increasingly apparent (Wight 1974, Forsman et al. 1977, Meslow and

Wight 1975, Meslow et al. 1981, Harris et al. 1982, McGarigal and Fraser 1984). Of those species which are closely associated with older forests, the northern spotted owl (Strix occidentalis caurina) appears to be the most dependent on mature and old-growth forests (Solis 1983, Forsman et al. 1984, Sisco and Gutierrez 1984) and is declining in numbers as these forests are cut (Gould 1977, 1985; U.S. Fish and Wildlife Service 1982; Forsman et al. 1984).

Although habitat use by adult spotted owls has been studied and continues to be studied throughout much of their range (Solis 1983, Sisco and Gutierrez 1984, Forsman et al. 1984, Allen and Brewer 1985, Ganey 1988, Laymon 1988), little similar information is available concerning dispersing juvenile spotted owls. As fragmentation of forests increases and older forest stands become both smaller and separated, chances increase for pairs of owls or groups of pairs to become reproductively isolated. Spacing between pairs must be such that dispersal of juveniles can replace losses (deaths or emigrations) among existing pairs. Therefore, information on movements made by dispersing juvenile spotted owls, including survival, distances moved, and habitat use, are important in assessing management guidelines intended to insure the maintenance of viable populations.

With this in mind, a radio telemetry study was conducted from 1982-1985, to document parameters of dispersal of juvenile spotted owls in western Oregon. Survival of dispersing juvenile spotted owls and the pattern of their dispersal has been described in Part I.

In Part II, I describe 4 hypotheses concerning habitat use by dispersing spotted owls and possible interactions of forest fragmentation on survival and distance moved: 1) dispersal distance of juvenile spotted owls would be greater in more fragmented habitats than in less fragmented habitats because juveniles would have to move farther to find suitable, unoccupied sites; 2) juveniles dispersing long distances would have poorer survival than those dispersing short distances because the long distance dispersers would encounter more unfamiliar areas that may increase the risk of predation (mortality) (Greenwood and Harvey 1976); 3) survival of dispersing juveniles in less fragmented habitats would be greater than in more fragmented habitats (increased fragmentation has been shown to increase predation on some species and would also decrease the habitat suitability for spotted owls, based on information for adult spotted owls) and; 4) dispersing juveniles would show selection for older forests for roosting, as has been shown for adult spotted owls (Forsman et al. 1984).

STUDY AREAS

Study areas were located at 8 sites in western Oregon. Six of the 8 study sites were within the Western Hemlock (Tsuga heterophylla) Zone (Franklin and Dyrness 1973), dominated by subclimax Douglas-fir (Psuedotsuga menziesii). Other major tree species included western hemlock, and western red cedar (Thuja plicata). The other 2 sites occurred in the Mixed Conifer Zone; this zone is dominated by mixtures of Douglas-fir, incense cedar (Libocedrus decurrens), sugar pine (Pinus lambertiana), white fir (Abies concolor), and ponderosa pine (Pinus ponderosa) (Franklin and Dyrness 1973). The Mixed Conifer Zone contained much more of a hardwood component including pacific madrone (Arbutus menziesii), golden chinkapin (Castanopsis chrysophylla), and canyon live oak (Quercus chrysolepis), than the Western Hemlock Zone.

The specific study site locations are described in Part I (Fig. 1). Although all dispersing juveniles originated in the above 2 vegetation zones, they utilized the 3 interior valleys: the Willamette, the Umpqua, and the Rogue (Franklin and Dyrness 1973). These interior valleys are a mosaic of grasslands, agricultural lands, oak woodlands, conifer forests, evergreen shrub, and riparian communities. Much of the valley area is occupied by cities, farms, and other human developments.

METHODS

Juvenile spotted owls were located, captured, radio-marked, and monitored as described in Part I (see Methods section). Juveniles from the Medford area (see Part I, Figure 1 - H) were not included in analysis of habitat use or the effects of fragmentation, due to the different types of vegetation in that area.

Based on the study objectives, 3 relationships between survival during dispersal, distance dispersed, and forest fragmentation, were developed into testable hypotheses, along with 1 hypothesis concerning habitat use, as follows:

(1) H_A: Mean dispersal distance in more fragmented habitats is greater than in less fragmented habitats.

(2) H_A: Survival of juveniles dispersing long distances is less than the survival of owls dispersing short distances.

(3) H_A: Survival of dispersing juveniles in less fragmented habitats is greater than in more fragmented habitats.

(4) H_A: Dispersing juveniles select older forests for roosting, as has been shown for adult spotted owls.

Fragmentation Analysis

To test for possible relationships between fragmentation, survival, and distance dispersed, some definitions and methodology were needed. The following were developed:

Survival during dispersal - The days of survival starting at the time of dispersal and ending 31 May of the following year or sooner if the individual died. Because of the variable time of fledging (late May to late June) and because the exact day of fledging for many individuals was unknown, a common anniversary date for fledging (1 June) was established to provide a reference for calculating yearly measurements (i.e. first-year survival).

Dispersal distance - The straight-line distance between the natal area and the location on 31 May of the subsequent year or the location where the juvenile died.

Forest fragmentation - A numeric index for forest fragmentation was developed which combined 2 elements: a) homogeneity of the habitat older than the open sapling/pole stage of succession (Hall et al. 1985) and b) the proportion of old-growth and mature timber in the sample area. The combination of these 2 elements provided an appropriate basis to evaluate forest fragmentation as it impacted juvenile spotted owls.

The fragmentation index was derived by interpreting, from aerial photos and orthophotoquads (utilizing each National Forest or BLM district's forest stand information), the forest age classes and presence of edge, both induced and inherent (Thomas et al. 1979), between age classes and forest types present within a 1.6 km radius of the juvenile owl locations (day roost sites). For some regions (the Cascade study areas) where satellite imagery (Landsat) information was available, the Landsat imagery was used to assist interpretation. A circular sampling grid of 1.6 km radius was divided into 0.3 X 0.3 km grid cells (see Appendix 3). The 1.6 km radius was derived from the average daily straight-line dispersal movement of juvenile owls (n=24) when they were actively dispersing (min.=0.4, max.=7.7; SD=1.4). The 0.3 X 0.3 km grid cell size was selected to effectively index the amount of edge present within the 1.6 km radius. The cell size (9 ha/22 ac) was roughly the size of an average forest harvest unit, thus reflecting the landscape pattern as influenced by the size of harvest units. Within the 1.6 km radius sampling grid, 50 regularly spaced grid cell intersections were selected at which measurements (photo interpretation) of habitat were taken. Also within the sampling grid, 50 regularly spaced grid cells were selected for measurements of homogeneity (presence of edge).

Homogeneity of habitat

For the homogeneity element, the proportion of the 50 0.3 X 0.3 km cells which were homogeneous (did not contain edge) and which were filled by closed canopy forests (closed sapling/pole, mature, and old-growth) were tallied; this tally was converted to a percentage. Based on information for adult spotted owls, the open sapling/pole and younger stages were usually avoided (Forsman et al. 1984). By considering grid cells falling completely within the open sapling/pole or younger stages as fragmented, the "problem" of having large tracts of unfragmented, recently cutover areas scoring high on the homogeneity index was circumvented. Circular sampling grids containing extensive older age stands and lacking edge scored high; grids composed of young timber or areas checker-boarded by harvest units scored lower.

Proportion of old-growth/mature timber

The proportion of old-growth/mature timber within the 1.6 km radius sample grid was estimated based on the percentage of those stages present at the selected 50 grid cell intersections.

Fragmentation index

Both the homogeneity score and old-growth/mature score were used independently in correlation analyses with survival time and dispersal distance. The two scores were averaged to create a 0-1 scaled composite (fragmentation) index which was also used in correlation analyses. Each time the 1.6 km radius sample grid was positioned over a roost location of a juvenile owl, it was rotated between 0 and 45 degrees (random numbers table) to randomize the sampling cells and grid intersections with respect to any landscape pattern.

Habitat Classification

Six forest classifications were used in the analysis (see Hall et al. 1985):

Other	(0)	- Reservoirs, pastures, towns, etc.
Grass/Forb/Shrub	(1)	
Open Sapling Pole	(2)	
Closed Sapling Pole	(3)	
Large Sawtimber	(4)	
Old-growth Timber	(5)	

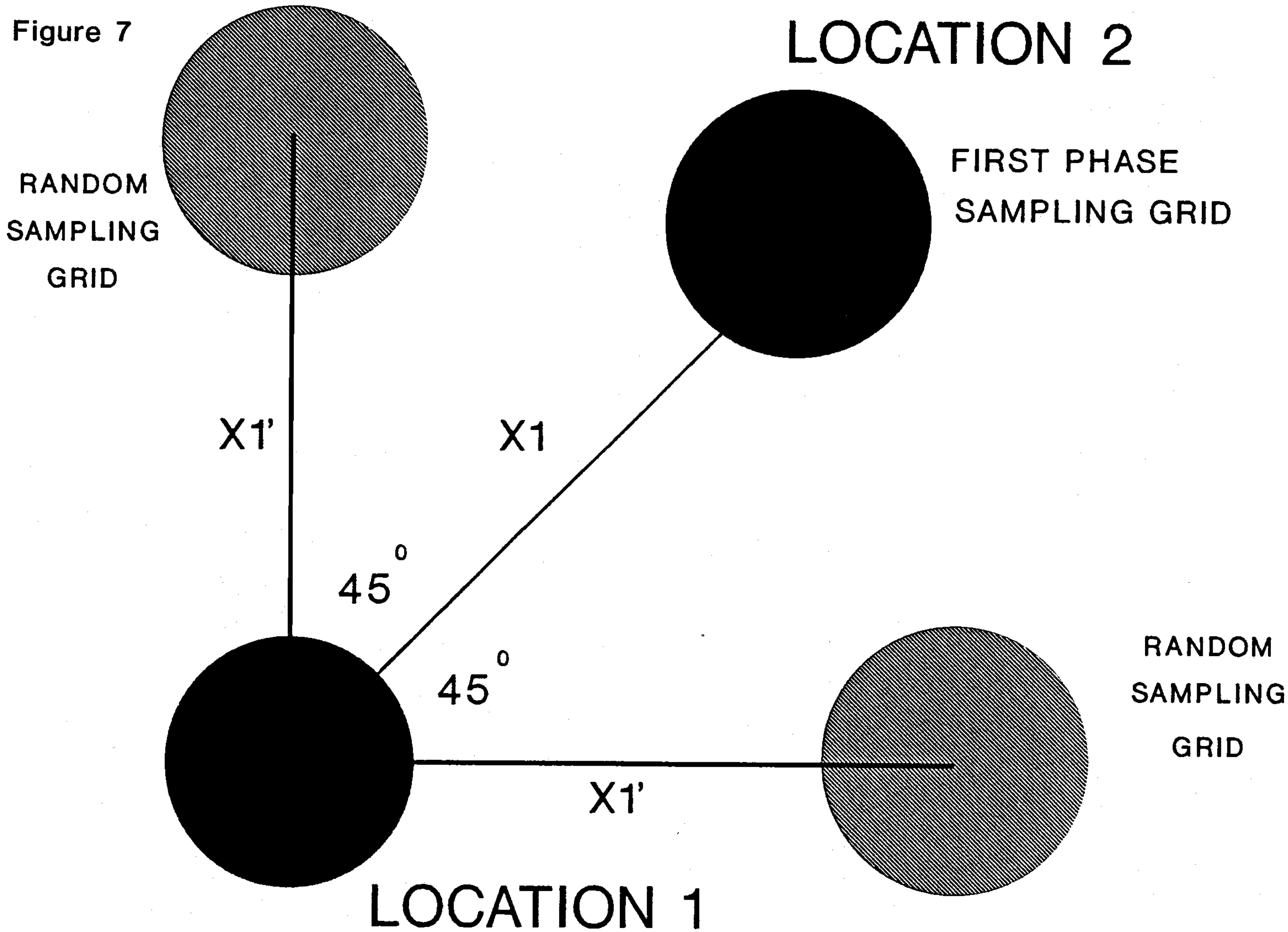
Fragmentation Analysis (Random Samples)

The objective for the second phase of the fragmentation analysis was to compare areas used by juveniles (based on fragmentation index score from the 1.6 km sampling grid - see Fragmentation Analysis) with what was available but not used.

The sampling scheme involved two "random" areas at 45 degree angles to the dispersal path and at a distance (X1') equal to the distance (X1) between consecutive roost locations (Fig. 7). If an owl "settled" during dispersal, such areas were considered separately. "Settled" was defined as a group of locations (5 or more) in an area no greater than 2.4 km radius. These settled areas had a

Figure 7. Diagram of the random sampling scheme used to determine forest fragmentation along the path of dispersing juvenile spotted owls (see text).

Figure 7


LOCATION 2
FIRST PHASE SAMPLING GRID
RANDOM SAMPLING GRID
X1'
X1
45°
45°
RANDOM SAMPLING GRID
X1'
LOCATION 1

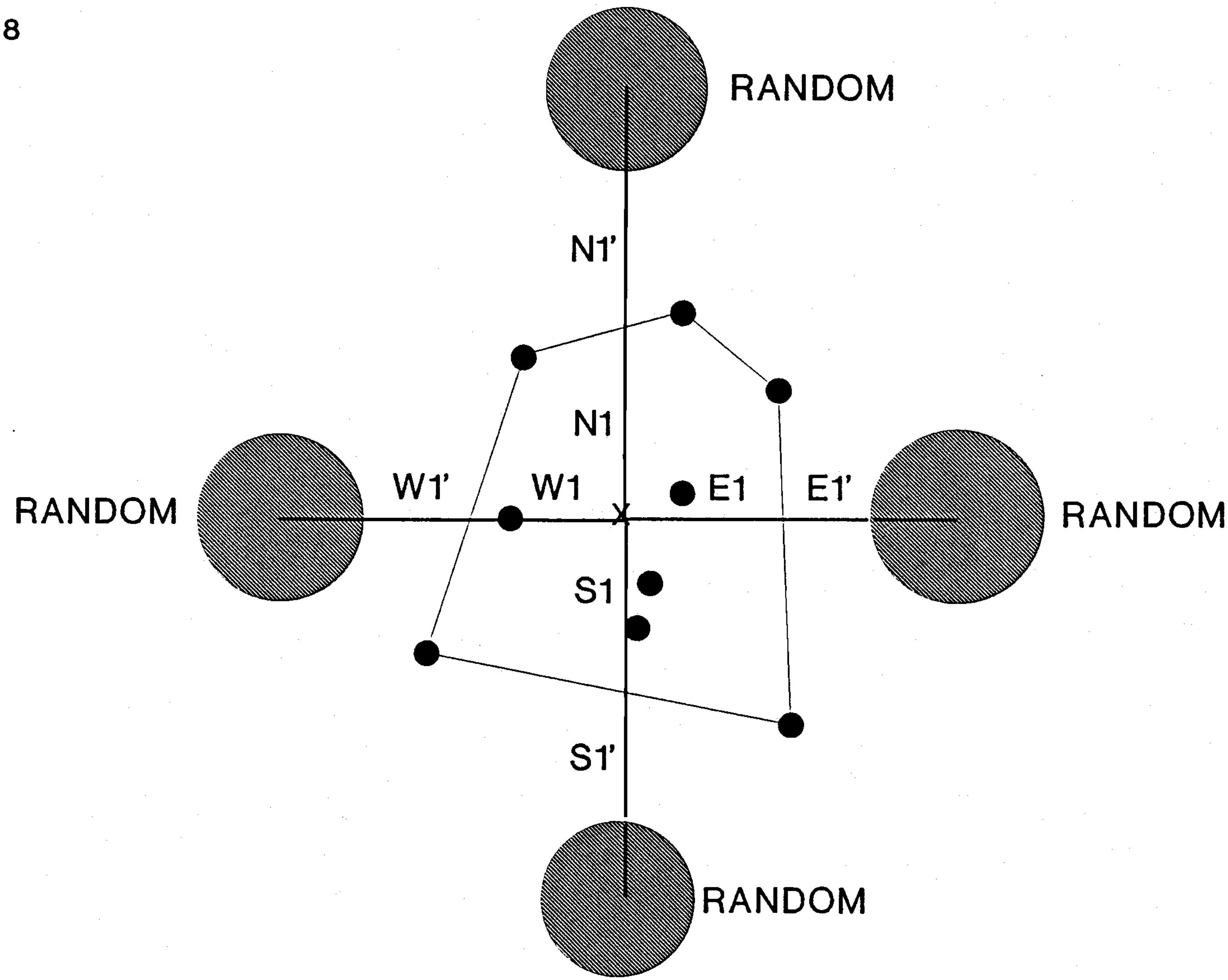
polygon drawn around them and were analyzed separately. In this situation, four "random" samples were taken in the four cardinal directions at 2 times the distance from the center of the polygon to the edge of the polygon (or at least 1.6 km from the edge of the polygon) (Fig. 8). The four random samples were averaged to provide a score and all the location scores within the polygon were averaged and compared with the average random score. Any movement by a juvenile which left the polygon and then returned was only measured with 2 random samples (at 45 degree angles) in the direction leaving the polygon. No measurement was taken for the return movement. This technique provided an opportunity to compare fragmentation scores in settled areas vs. those used during the active dispersal phase.

<u>Habitat Use Analysis</u>

The habitat sampling/classification system, described in the fragmentation analysis section, was used to compare habitats used by the juveniles for roosting (roost locations) with what was available within the immediate vicinity (within 1.6 km). Roost locations could not be obtained each day for each dispersing owl and, therefore, it was impossible to describe the exact path the owl took between roost locations. Thus, a more conservative approach to habitat use vs. availability was adopted as outlined above. Bonferroni confidence intervals were

Figure 8. Diagram of the random sampling scheme used to compare forest fragmentation around settled areas used by dispersing juvenile spotted owls (see text).

Figure 8



computed to determine if there was selection for roost habitat (Byers et al. 1984).

RESULTS

Survival, Distance Dispersed, and Forest Fragmentation

Survival - Information on survival of dispersing juvenile spotted owls was provided in Part I. All analyses in Part II, concerning juvenile survival, utilize the survival values presented in Part I (Table 7).

Dispersal distance - Mean final dispersal distance for all individuals combined (first-year movements only), excluding those owls that contact was lost with, was 29.2 km (min.=3.2, max.=75.8; SD=19.0). Individual dispersal distances used for this analysis are provided in Part I (see Table 6).

Forest fragmentation - The habitat sampling scheme seemed to effectively index landscape/vegetation patterns used by dispersing spotted owls. The values derived for individual roost locations nearly spanned the 0.0 - 1.0 (totally fragmented - unfragmented) range of the index (Table 10). Mean values for individual owls also displayed considerable variation. All means, regardless of the category measured, were skewed toward the lower scores; there were few areas in western Oregon that were not already fragmented to a substantial degree. No statistically significant relationship was observed between dispersal distance and forest fragmentation levels encountered (r^2=0.002) (Fig. 9a). Results of correlation analysis for dispersal distance and forest homogeneity and

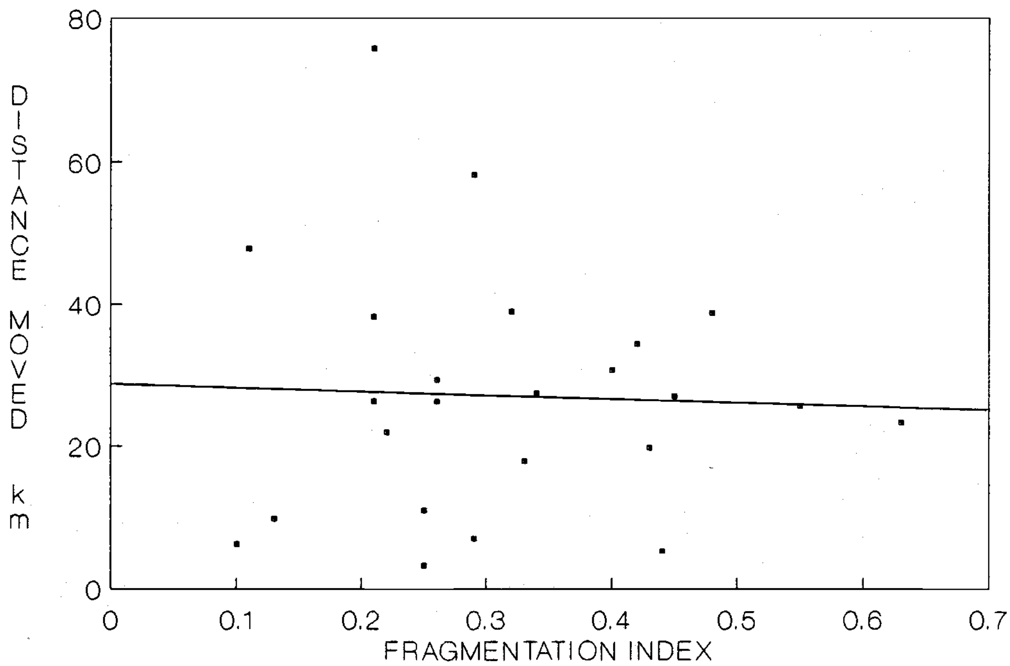
Table 10. Summary statistics for homogeneity score, old-growth/mature score, and fragmentation index score, by bird, for roost locations of dispersing juvenile spotted owls in western Oregon, 1982-1985 (n=24).

Bird No.	Mean Homogeneity Score ($\bar{x}$)	SD	Min.	Max.	Mean Old-Growth/Mature Score ($\bar{x}$)	SD	Min.	Max.	Mean Fragmentation Index Score ($\bar{x}$)	SD	Min.	Max.
LC62 (n=53)	0.50	0.15	0.16	0.74	0.34	0.08	0.20	0.70	0.42	0.09	0.20	0.67
LC71 (n=38)	0.31	0.15	0.08	0.70	0.48	0.09	0.30	0.70	0.40	0.10	0.26	0.70
BR72 (n=35)	0.22	0.11	0.12	0.60	0.30	0.07	0.20	0.42	0.26	0.08	0.17	0.43
OB73 (n=129)	0.17	0.08	0.02	0.58	0.05	0.10	0.00	0.62	0.11	0.08	0.03	0.60
UM89 (n=10)	0.32	0.17	0.06	0.56	0.25	0.29	0.00	0.66	0.29	0.20	0.04	0.61
SR95 (n=27)	0.30	0.10	0.10	0.56	0.12	0.22	0.00	0.84	0.21	0.14	0.10	0.66
EC69 (n=92)	0.21	0.14	0.00	0.52	0.05	0.05	0.00	0.30	0.13	0.08	0.00	0.31
ED86 (n=3)	0.48	0.24	0.14	0.70	0.03	0.05	0.00	0.10	0.26	0.10	0.12	0.35
DC05 (n=25)	0.55	0.17	0.06	0.74	0.71	0.17	0.06	0.86	0.63	0.16	0.06	0.77
BJ81 (n=6)	0.38	0.18	0.20	0.70	0.50	0.19	0.28	0.76	0.44	0.18	0.24	0.73
BJ77 (n=17)	0.47	0.13	0.26	0.70	0.63	0.11	0.46	0.88	0.55	0.11	0.37	0.79
BJ91 (n=20)	0.17	0.10	0.00	0.42	0.33	0.11	0.16	0.58	0.25	0.10	0.09	0.50
EF80 (n=73)	0.38	0.20	0.08	0.92	0.52	0.19	0.22	1.00	0.45	0.19	0.17	0.96
EF93 (n=46)	0.19	0.06	0.02	0.36	0.39	0.09	0.28	0.64	0.29	0.07	0.17	0.50
WC80 (n=43)	0.32	0.10	0.10	0.44	0.34	0.07	0.20	0.56	0.33	0.07	0.15	0.45
KC88 (n=33)	0.39	0.09	0.22	0.62	0.47	0.13	0.20	0.76	0.43	0.08	0.28	0.63
LO92 (n=98)	0.08	0.07	0.00	0.60	0.12	0.08	0.00	0.46	0.10	0.07	0.01	0.40
CC94 (n=24)	0.32	0.12	0.04	0.42	0.12	0.10	0.00	0.32	0.22	0.09	0.02	0.32
YC99 (n=8)	0.24	0.10	0.04	0.38	0.22	0.14	0.00	0.38	0.23	0.10	0.02	0.36
LW93 (n=30)	0.38	0.12	0.04	0.18	0.57	0.15	0.18	0.78	0.48	0.13	0.11	0.66
OS58 (n=72)	0.19	0.07	0.08	0.48	0.24	0.11	0.02	0.60	0.22	0.07	0.08	0.48
OS59 (n=71)	0.26	0.12	0.08	0.60	0.39	0.13	0.14	0.74	0.32	0.13	0.12	0.67
MC78 (n=4)	0.22	0.06	0.18	0.32	0.29	0.04	0.26	0.36	0.25	0.05	0.22	0.34
TC55 (n=32)	0.32	0.11	0.14	0.70	0.36	0.10	0.08	0.64	0.34	0.07	0.23	0.57
N=989 (roost locations)												
Min./Max for all birds combined			0.00	0.92			0.00	1.00			0.00	0.96

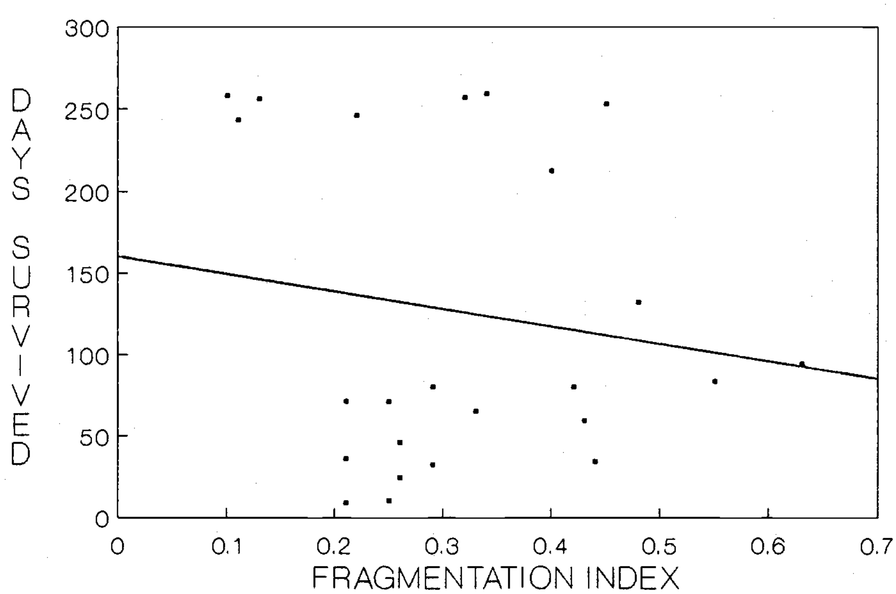
Figure 9. (A) Regression of final distance dispersed by juvenile spotted owls on a fragmentation index around the roost sites in western Oregon (r^2=0.002; n=24). **(B)** Regression of days survived by dispersing juvenile spotted owls on a fragmentation index around the roost sites in western Oregon (r^2=0.002; n=24). The fragmentation index goes from 0 (complete fragmentation) to 1.0 (no fragmentation).

Figure 9

A.


80
60
40
20
0
DISTANCE MOVED km
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
FRAGMENTATION INDEX

B.


300
250
200
150
100
50
0
DAYS SURVIVED
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
FRAGMENTATION INDEX

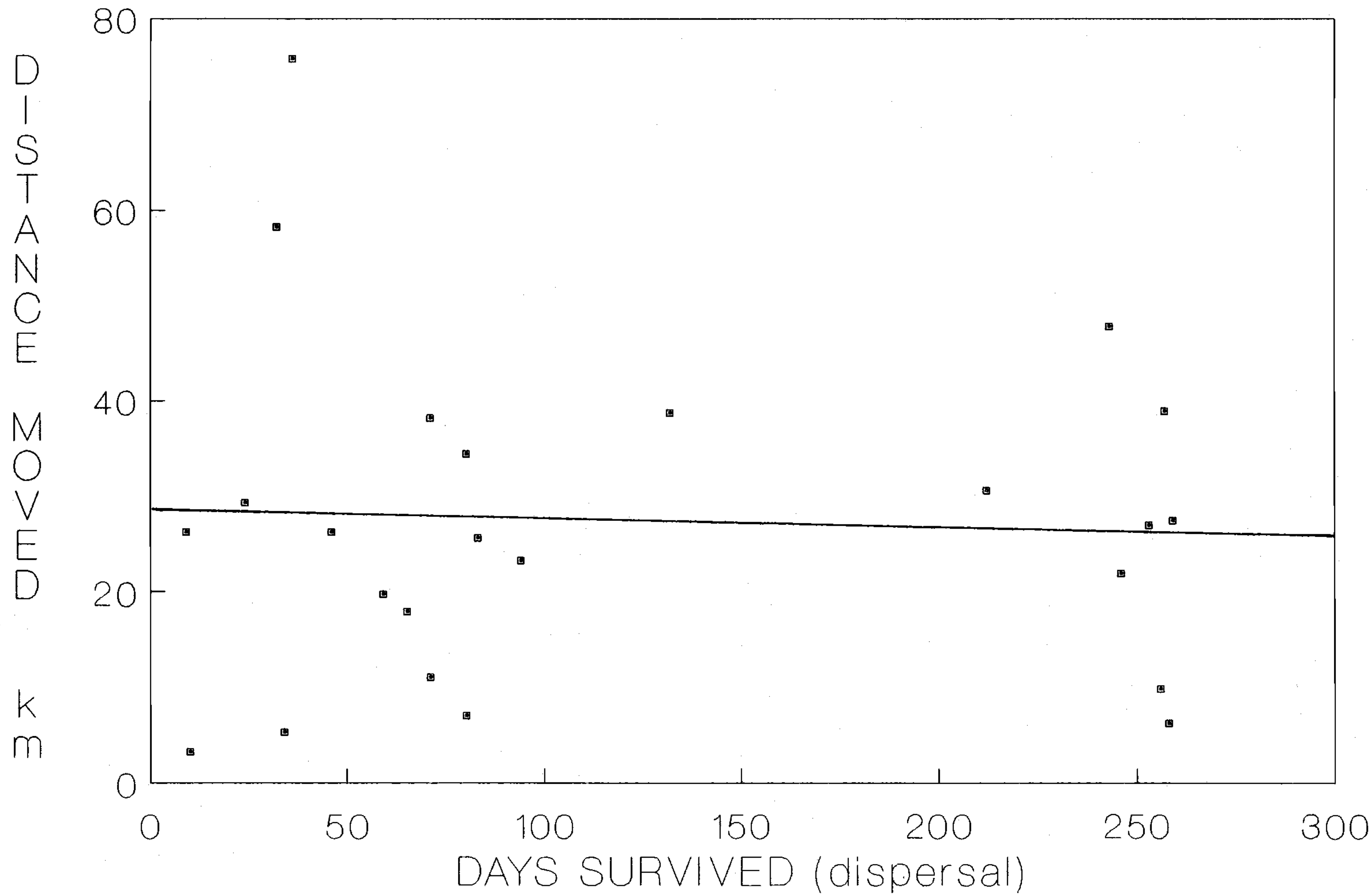
old-growth/mature forest scores also disclosed no significant relationship (see Appendix 4). Contrary to the hypothesized relationship, juveniles did not disperse farther in more fragmented habitats. There also was not a significant relationship between days survived and forest fragmentation levels experienced ($r^2=0.002$) (Fig. 9b). Results of correlation analysis for days survived and forest homogeneity and old growth/mature forest scores also disclosed no significant relationship (see Appendix 5). Neither did days survived and dispersal distance ($r^2=0.002$) (Fig. 10). Therefore, the null hypotheses that dispersal distance and juvenile survival were not correlated with the level of forest fragmentation was accepted.

Forest Fragmentation (Random vs. Roost Locations)

Along the dispersal paths, juveniles roosted in areas with a similar proportion of old-growth/mature forests to that which occurred at random locations (Fig. 11a). Juveniles also used roosts which were similar in homogeneity to those at random locations (Fig. 11b). The overall fragmentation scores for roost locations and random locations were both skewed to the more fragmented end of the scale but did not show a difference (Fig. 12).

Figure 10. Regression of final distance dispersed by juvenile spotted owls on number of days survived during dispersal in western Oregon (r^2=0.002; n=24).

Figure 10

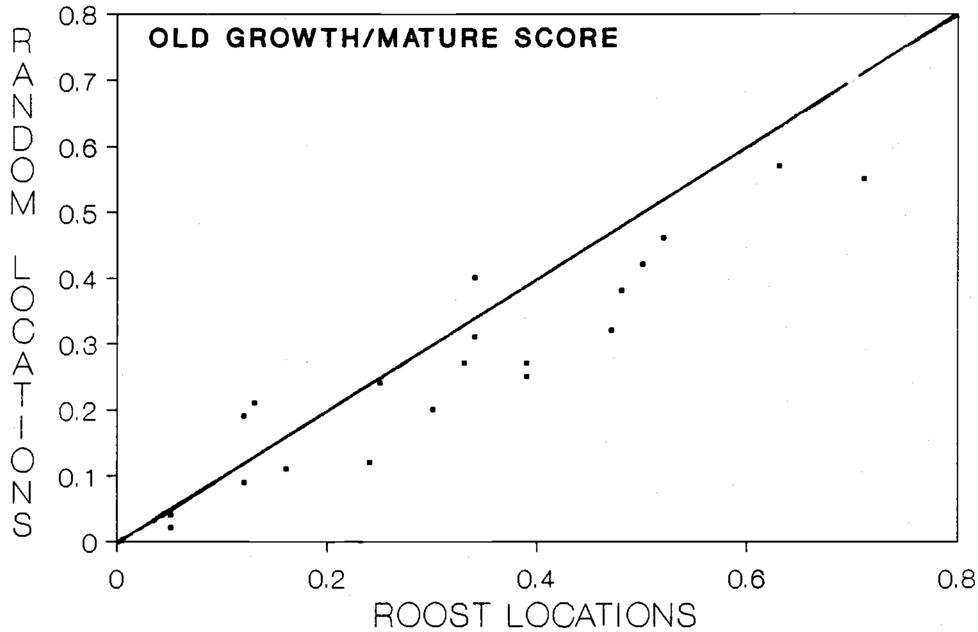


80
60
40
20
0
DISTANCE MOVED km
0
50
100
150
200
250
300
DAYS SURVIVED (dispersal)

Figure 11. **(A)** Comparison of old-growth/mature scores of roost locations for dispersing juvenile spotted owls in western Oregon and random locations along the dispersal path. **(B)** Comparison of homogeneity scores of roost locations for dispersing juvenile spotted owls in western Oregon and random locations along the dispersal path.

Figure 11

A.


OLD GROWTH/MATURE SCORE
RANDOM LOCATIONS
ROOST LOCATIONS
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8

B.

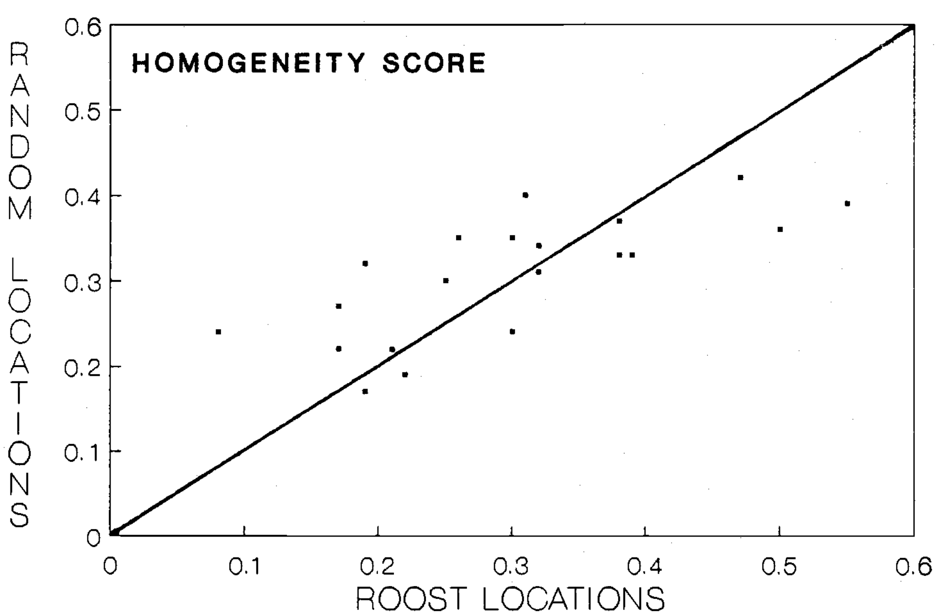
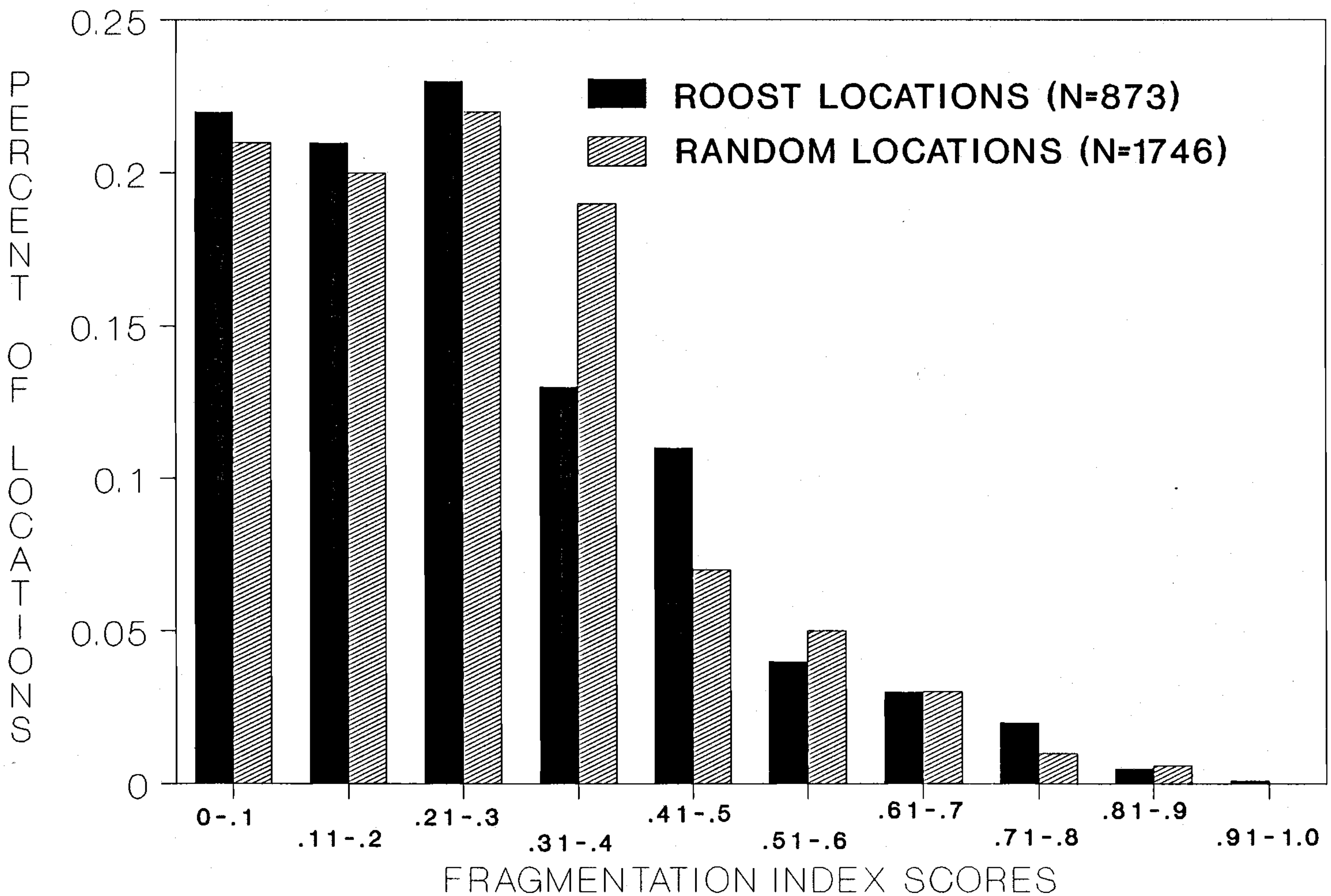

HOMOGENEITY SCORE
RANDOM LOCATIONS
ROOST LOCATIONS
0
0.1
0.2
0.3
0.4
0.5
0.6

Figure 12. Comparison of all fragmentation index scores for both roost locations and random locations for dispersing juvenile spotted owls in western Oregon, 1982-1985.

Figure 12



ROOST LOCATIONS (N=873)
RANDOM LOCATIONS (N=1746)
PERCENT OF LOCATIONS
0.25
0.2
0.15
0.1
0.05
0
0-.1
.11-.2
.21-.3
.31-.4
.41-.5
.51-.6
.61-.7
.71-.8
.81-.9
.91-1.0
FRAGMENTATION INDEX SCORES

<u>Forest Fragmentation (Active vs. Settled)</u>

There appeared to be no difference in fragmentation scores between areas where juveniles settled during dispersal and roost locations of juveniles during active dispersal (Fig. 13).

<u>Forest Fragmentation (Settled vs. Random)</u>

There was no difference in fragmentation scores between the areas where juveniles settled during dispersal and random areas adjacent to those settled areas (Fig. 14).

<u>Habitat Use</u>

Dispersing juvenile spotted owls used a wide variety of habitats, forest types and age classes, during dispersal. The young owls utilized (roosted in) everything from old-growth forests to a potted tree in downtown Medford, OR. Although juveniles often were located in different habitats, as compared to habitats commonly selected by adults (Forsman et al. 1984), mature/old-growth forests were still used a greater percentage of the time, based on availability by 17 of 18 juveniles, with 12 birds showing a significant selection ($P \leq 0.05$) based on Bonferroni confidence intervals (Byers et al. 1984) (Table 11, Appendix 6). Juveniles generally used the oldest timber available for roosting along their dispersal path. For those 18 juveniles with 20 or more roost locations, 56% of all roost locations were in old-

Figure 13. Comparison of fragmentation index scores for areas where juveniles settled during dispersal and roost locations of juveniles during active dispersal.

Figure 13

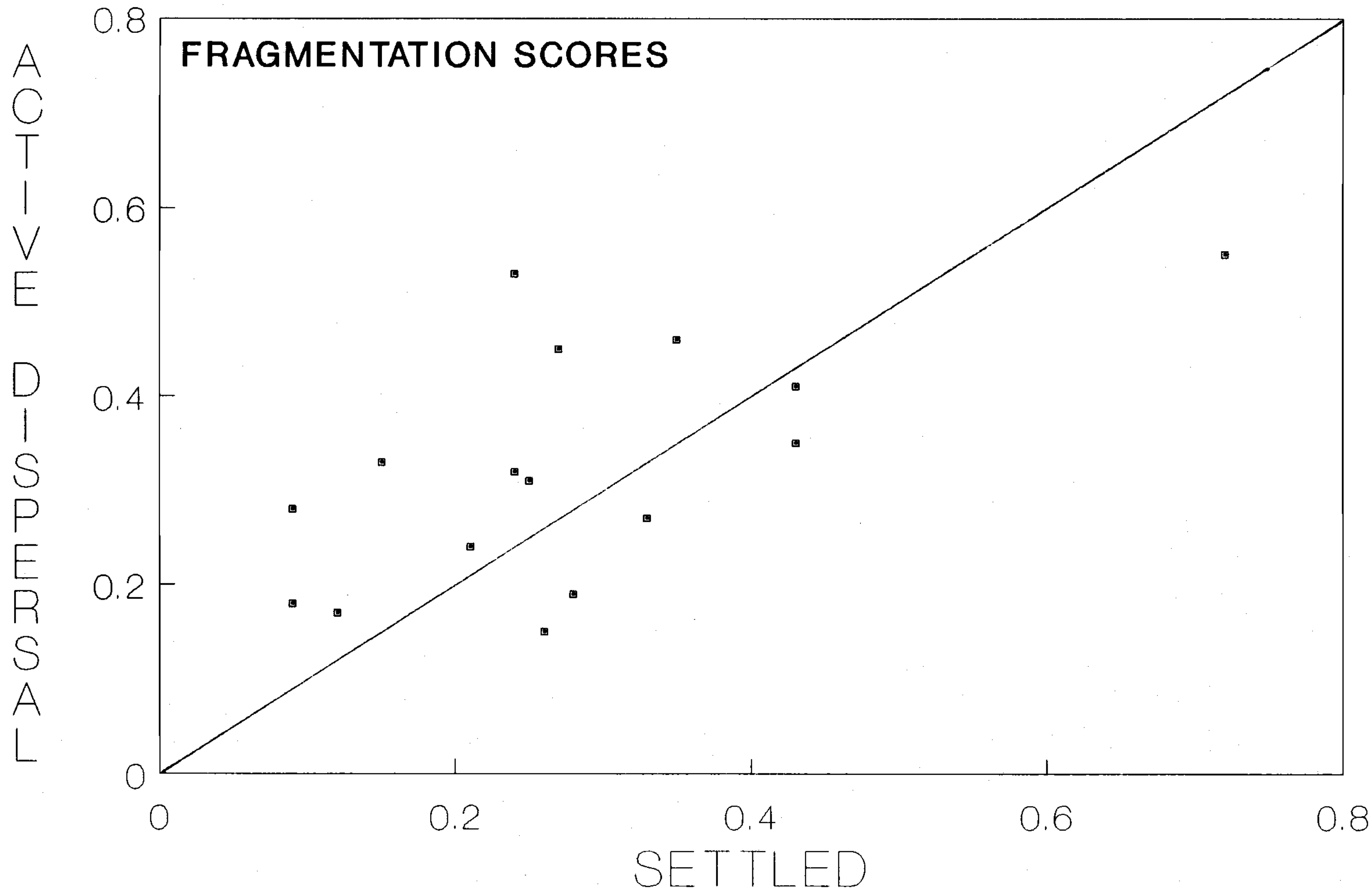

FRAGMENTATION SCORES
ACTIVE DISPERSAL
SETTLED
0
0.2
0.4
0.6
0.8

Figure 14. Comparison of fragmentation index scores for areas where juveniles settled during dispersal and random areas adjacent to the settled areas.

Figure 14

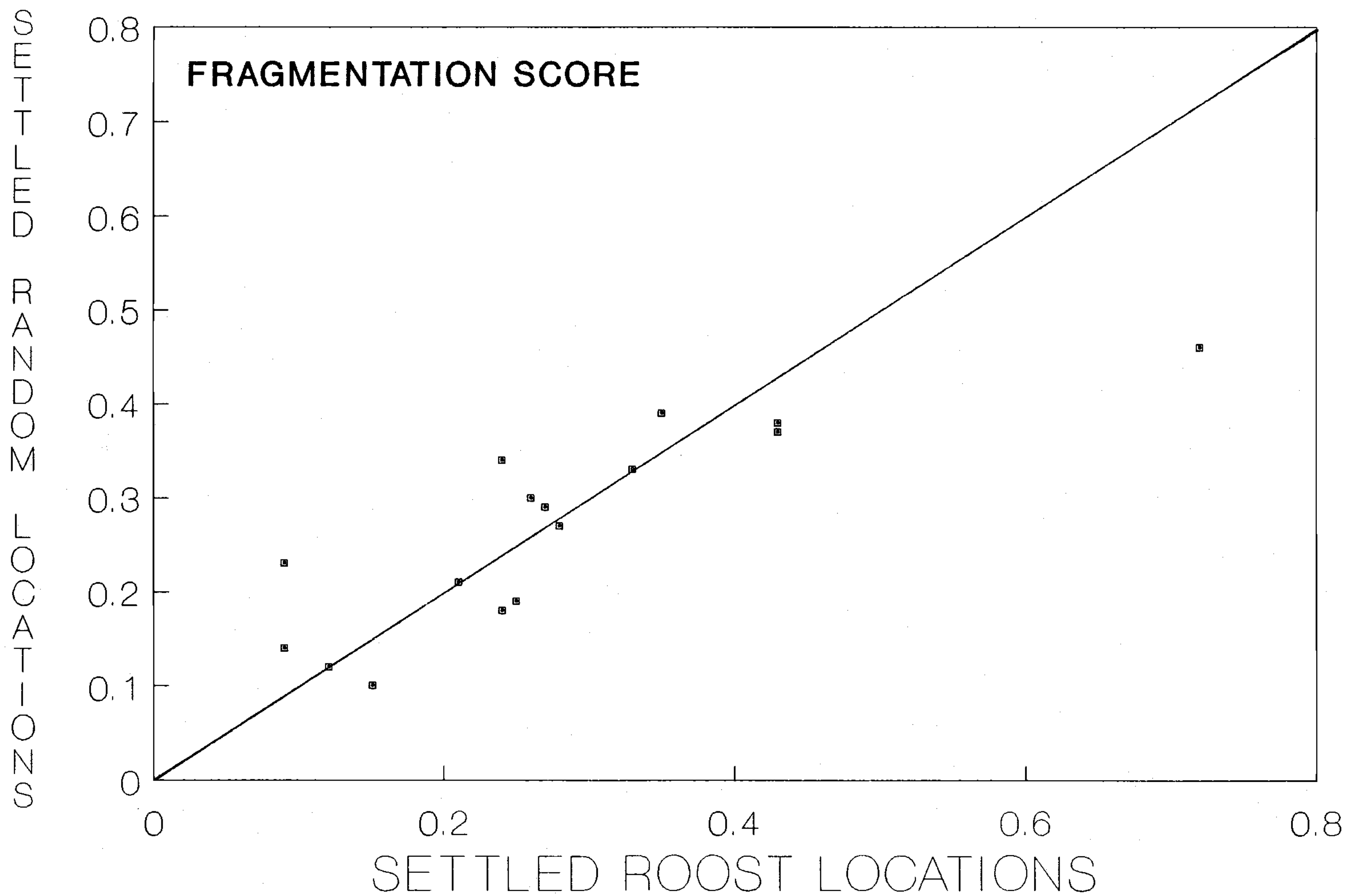

FRAGMENTATION SCORE
SETTLED RANDOM LOCATIONS
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
0.2
0.4
0.6
0.8
SETTLED ROOST LOCATIONS

Table 11. Habitat use by dispersing juvenile spotted owls in western Oregon, 1982-1985 (roost locations only).

	Number of Individuals showing selection for age classes				
Age Class	Selected for[a]	No Selection[b]	Selected against[c]	NU[d]	NA[e]
Old Growth/ Mature	12	6	0	0	0
Closed Sapling/ Pole	5	8	1	4	0
Open Sapling/ Pole	0	7	6	5	0
Grass/Forb/ Shrub	0	2	2	14	0
Other	0	5	0	9	4

a/ Used significantly more ($P \leq 0.05$) than expected based on availability.
b/ Used in similar proportion to that expected based on availability.
c/ Used significantly less ($P \leq 0.05$) than expected based on availability.
d/ Available but not used.
e/ Not available.

growth/mature forests while availability of these forests was only 27% (SD=0.21, VAR=0.043; n=930). Although the open sapling/pole class and younger composed, on the average, 48% (SD=0.18, VAR=0.034; n=930) of the available habitat, juveniles roosted in these classes only 10% of the time. The open sapling/pole class was used significantly less than available by 6 birds while the grass/forb/shrub was used significantly less by 2 birds and not at all by 14 birds.

DISCUSSION

Forest Fragmentation and Distance Dispersed

Although I hypothesized that juvenile spotted owls would disperse farther in more fragemented areas to find suitable, unoccupied habitat, that was not substantiated. Correlation analysis indicated no significant relationship between distance dispersed and forest fragmentation. However, forests in western Oregon are highly fragmented and few extensive areas which could be defined as minimally fragmented existed (outside national parks and some of the wilderness areas). Moreover, the least fragmented areas tended to be occupied by adult owls; presence of paired adults likely precluded or certainly decreased occupancy by juveniles. Thus, dispersing juveniles encountered a largely fragmented forest landscape and may have been excluded from the limited amounts of unfragmented, high quality habitat remaining by resident adults. Effects of forest fragmentation on dispersal distance has not been previously investigated, but dispersal distance of juveniles, as it relates to density of adult pairs, has been studied. If we assume spotted owl densities are higher in less fragmented areas and lower in more fragmented areas (Postovit 1977), these results may be compared with other studies. Newton and Marquiss (1983) found that dispersal distances of juvenile sparrowhawks (*Accipiter nisus*) were unrelated to densities of adult pairs. Dispersal distances in juvenile female blue grouse (Dendragapus obscurus) also were not correlated to density of adult females, but juvenile males dispersed shorter distances in years of low density of adult males in one of two cases (Hines 1986). The relatively great dispersal distances ($\bar{x}$=28 km) expressed by juvenile spotted owls in this study, compared to the relatively small areas of minimally fragmented forest available, largely negated the opportunity to examine the effects of forest fragmentation because of the wide array of forest fragmentation levels the juveniles passed through (skewed to the low end).

Forest Fragmentation and Survival

I was unable to show any significant correlation between forest fragmentation and juvenile survival. One of the main causes of juvenile mortality was avian predation, especially by great horned owls. Although it has been speculated that great horned owls are more abundant where old-growth forests are more fragmented (Dawson et al. 1987), there is only anecdotal information to support this. Increased habitat fragmentation has been shown to increase predation rates on other species. Andren et al. (1984) showed that corvid densities and the associated nest predation on simulated grouse nests were positively correlated to the proportion of agricultural lands and to the degree of forest fragmentation.

Increased nest predation has also been suggested for bird faunas in fragmented forest landscapes in Wisconsin and Maryland (Ambuel and Temple 1983, Whitcomb et al. 1981).

The lack of confirmation of the hypothesized relationship does not unequivocally refute the relevency of that relationship. For instance, the samples of dispersing owls were drawn from years when the young owls suffered high mortality; in fact, the survival rates observed fall short (in some years, far short) of those apparently required to provide recruitment sufficient to maintain a stationary population (see Part I). When sufficient data on successful dispersers are accumulated, hypothesized relationships may be confirmed.

Dispersal Distance and Survival

I hypothesized that juveniles dispersing long distances would suffer higher mortality rates than those dispersing short distances. However, I found no significant correlation between dispersal distance and juvenile survival.

Other investigators of survival and dispersal distance in birds have reached differing conclusions. Survival of juvenile male blackbirds (*Turdus merula*) dispersing longer distances was poorer than those not dispersing or dispersing short distances (Greenwood and Harvey 1976). However, Hines (1986) reported that juvenile blue grouse dispersing long distances did not survive any less well than those dispersing short distances. Juvenile blue grouse dispersing long distances found suitable habitat and were also able to maintain high rates of reproduction.

Forest Fragmentation

Random vs. Roost Locations

Comparing fragmentation scores at random locations of either actively dispersing juveniles or juveniles which had settled, showed no apparent selection by the juveniles. Although juveniles did show a selection for older forests, it apparently did not matter how the older forest was distributed or how fragmented it was. Most contiguous blocks of older forest were probably occupied by adult spotted owls, relegating the dispersing juveniles to the more fragmented areas.

Active vs. Settled vs. Random

Areas where juveniles settled, between active dispersal bouts, showed no real difference in fragmentation levels from what was used during active dispersal. Factors which influenced settling may have included the absence of resident adults (Marquiss and Newton 1981) and an adequate food source. Several juveniles also continued dispersal until a potential barrier was encountered (e.g., cities, major agricultural areas) and settled next to the barrier, often dying shortly after settling. There was no indication that the settled areas were much different, as far as levels of fragmentation, than the surrounding areas.

Habitat Use

Use of a wide range of habitats has been previously documented for juvenile spotted owls (Allen and Brewer 1985, Gutierrez et al. 1985 a&b). Gutierrez et al. (1985b) observed apparent yearly differences in use of particular forest age classes for roosting. However, these findings where based on 10 roosts in one year and 12 in the other. Juvenile owls in the current study also used a wide range of habitats while dispersing but showed selection for old-growth/mature forests for day roosts. Because spotted owls do not breed until 2 (more usually 3) or more years of age (Barrows 1985; Franklin et al. 1986, 1987; Miller et al. 1985), then the juveniles must spend much of that 2-3 year period in areas away from resident adult pairs, likely in less than optimal habitat. If most of the present suitable habitat is occupied by resident adults, only less suitable habitat is available for dispersing juveniles. Even with this being the case, juveniles still showed selection for the oldest timber available while dispersing.

Use of young forests by dispersing juvenile spotted owls is not surprising and has been shown for other species. Juvenile great horned owls dispersed over and roosted in relatively undesirable habitat and may have been excluded from protected roost sites by territorial adults (Dunstan 1970). Dispersing sparrowhawks, although reared in mature coniferous forests, spent less than 10% of their time in such habitat (Wyllie 1985). First-year sparrowhawks also used many roost sites whereas adults returned to the same locality night after night (thick conifer woodlands); first-year birds often roosted in small woods in open country and sometimes in broadleaved trees (Marquiss and Newton 1981). Marquiss and Newton (1981) suggested that adults appeared to defend the winter roosts and that first-year birds, being inexperienced hunters and unfamiliar with the area, hunted later in the day at a time when many adults were already at their roosts. Young sparrowhawks also may have avoided areas defended by dominant adults, perhaps accounting for more time spent in open country, well away from the adult nesting areas. Movements by juvenile spotted owls, after their first winter, into areas occupied by adult spotted owls were seen on several instances (see Part I - Dispersal Timing and Movements). But we were unable to document any interactions between resident adults and dispersing juveniles. Moving into areas occupied by resident birds at this time of year may have allowed the juveniles to "test" areas for vacancies during the breeding season when such vacancies would be most evident.

One reason dispersing juvenile spotted owls occupied younger stands in the more southern areas of Oregon may be associated with an abundant primary food supply. Young stands occupied by juveniles, especially in the Roseburg area and south, appeared to have high numbers of woodrats (Neotoma spp.) (based on the number of middens seen) and may have provided an available food source of optimal size prey. Greater than 80% of the pellets collected from juvenile owls, Roseburg area and south, contained woodrat remains (G. Miller, unpubl. data). While stands may have been able to support a single juvenile, the general absence or low density of spotted owl pairs in younger stands (Forsman et al. 1977) leads one to question their adequacy for reproductive adults.

Often the occurrence of a juvenile spotted owl in unusual habitat (ie. - recent clearcuts, urban and suburban areas) shortly preceded the individual's death. This scenario has also been documented by Gutierrez et al. (1985b) for spotted owls in northern California.

Summary of Forest Fragmentation Effects

While there were no significant relationships found with forest fragmentation and either dispersal distance or survival, what has become increasingly apparent is that few areas remain unfragmented in western Oregon. Fragmentation scores were heavily skewed to the lower (more fragmented) end of the indices (Fig. 12). This fact alone may have eliminated the chances of relating forest fragmentation to juvenile spotted owl dispersal. This, coupled with low juvenile survival throughout the study, confounded analyses. Rosenberg and Raphael (1986), working in mixed-conifer forests of northern California, found that relatively few vertebrate species exhibited any negative response for forest fragmentation, using partial correlation analysis, among 5 age classes of stand and insularity. Spotted owls were one of the only species that did show a response. Spotted owls were weakly correlated with stand area, being less frequently located in smaller stands, although the trend was not statistically significant. Although the effects of forest fragmentation on avian species have been documented many times in the Eastern United States (Forman et al. 1976, Galli et al. 1976, Robbins 1979, Whitcomb et al. 1981), the relatively recent fragmentation of forests in the Pacific Northwest may not have been occurring long enough for species to show a response (decline in abundance, density, etc.) to the change. We may see more pronounced relationships as the fragmentation of this area continues (Rosenberg and Raphael 1986). Perhaps equally likely, spotted owls have evolved in a relatively unfragmented landscape of older forests. Fragmentation of the Pacific Northwest has been occurring for a relatively short time and juvenile spotted owls, having evolved in contiguous forest, may select for older forest, regardless of how it is distributed or fragmented.

MANAGEMENT IMPLICATIONS

Although there was no significant relationship between forest fragmentation and juvenile survival or dispersal distance, there was significant evidence of habitat selection by dispersing juvenile spotted owls. Current spotted owl management on U.S. Forest Service lands calls for a 6-12 mile (9.6-19.2 km) spacing between designated spotted owl habitat areas (SOHAs) and, although most juveniles appear capable of travelling that distance, suitable habitat outside the managed sites must be available for the juveniles. Juvenile spotted owls dispersing long distances, but not surviving to breed, do not contribute to the population. With low adult turnover rates, a juvenile must "float", perhaps longer than its first 2-3 years, until a vacancy occurs, so that it can be recruited into the breeding population. As management continues to plan only for a portion of the existing spotted owl population (USFS 1988), the remaining areas which may contain resident pairs will continue to be harvested and juveniles will increasingly have to compete with these displaced adults for vacancies in the remaining sites. With management directed towards minimum acreages of suitable habitat, a minimum number of pairs, minimal quality of habitat, and maximum spacing, any areas of old-growth forest left between managed pairs may act as links for dispersing juveniles to use as movement corridors and use areas before the juveniles are able to be recruited into the breeding population. These "dispersal corridors" or links between SOHAs become increasingly important as most non-managed areas become even more fragmented and disjunct over time. Areas such as the Olympic Peninsula in Washington and much of the Coast Ranges in western Oregon already have lost many options pertaining to dispersal corridors or any multiple links to other populations. Effort must be expended to assure more areas are not managed into isolation. A landscape approach to management of spotted owls may be the only way to assure adequate management of spotted owl populations. Dispersal corridors and supplemental habitat areas adjacent to SOHA's may become increasingly important factors in facilitating juvenile survivorship. Specific management options to address dispersal and supplemental habitat for "stockpiling" juveniles need to be incorporated into planning for perpetuation of spotted owls.

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APPENDICES

Appendix 1. Nesting summary for northern spotted owl sites monitored from 1982-1985 in western Oregon.

LEGEND

UN-x = Undetermined, no response at site; x = number of visits.
NU = Nesting status undetermined.
NY = Nesting status undetermined, no young produced.
NS = Site not surveyed.
NI = No information for that year.
NN = Non-nesting.
NF = Nest failed.
P = Pair observed at site.
M = Only a male observed at site.
F = Only a female observed at site.
U = Owl observed, unknown sex.
RU = Two or more owls observed, relationship unknown.
_Y = Number of young fledged.

The above codes can be combined to provide a site summary for that particular year. These alpha codes, when combined, have an equivalent numeric code, or codes, used by the Oregon Department of Fish and Wildlife's (ODFW) spotted owl data base. All sites in Appendix 1 have been checked with the ODFW data base to make sure both sets of information are equivalent. Most of the codes are straight forward and easy to interpret but a few may need more clarification so these are listed below.

Classification criteria

Nesting status undetermined - used when a pair or single individual is located at a site (either a vocal response or sighting) but the owl is not moused and no young are seen.

Nesting status undetermined, no young produced - used when a pair is visually located and moused or has repeated visits to the site to confirm that no young were produced. There is some subjectivity on the observer's part.

Non-nesting - used only when a site has been checked early in the nesting season (during clutch initiation, brooding). Pair must have been located at this time and moused or checked several times during that period to determine non-nesting status.

Only those pairs which are checked for reproductive status (pairs with the NN, NY and NF codes, plus the pairs fledging young) should be used to determine the nesting statistics.

Roseburg District (BLM) biologists supplied much of the nesting information for their area and without it our sample and the area examined would have been greatly reduced.

Appendix 1 (cont.). Nesting summary for northern spotted owl sites monitored from 1982-1985 in western Oregon.

Site Name	ODFW Location Code	1982	1983	1984	1985
H.J. Andrews Area (Cascades)					
Blue River R.D.					
Blue Ridge	0107	UN-1	P-2Y	P-NN	P-NN
Blue River Resv.	0104	UN-5	P-2Y	P-NN	P-NN
Boone Creek	0861	UN-2	NS	NS	P-NY
Cone Creek	0112	UN-2	NS	NS	NS
Cook Creek	0860	NS	NS	P-NU	UN-3
Cougar Creek	0860	P-2Y	UN-3	M-NU	F-NU
Lowder	0857	NS	NS	NS	UN-3
Mack Creek	0106	UN-2	P-1Y	UN-5	M-NU
McRae/Lookout	0043	UN-6	P-2Y	UN-5	M-NU
Mona Creek	0105	M-NU	P-NN	P-NN	M-NU
Quentin Creek	0859	UN-1	M-NU	UN-3	P-NY
Starr Creek	1414	NS	NS	NS	UN-1
Tidbuck	0017	UN-2	M-NU	UN-3	M-NU
U. Hardy Creek	0863	NS	NS	M-NU	P-NY
U. Lookout Creek	0030	P-NY	P-2Y	F-NU	P-NN
U. McRae Creek	0032	UN-1	P-2Y	P-NN	P-NN
Watershed 2	0029	P-NY	P-NF	P-NN	P-NN
McKenzie R.D.					
Fish Lake	0123	UN-1	UN-1	P-NY	M-NU
Great Springs	0821	UN-2	UN-5	NS	UN-4
Lost Creek	0836	P-1Y	UN-2	UN-4	UN-4
Norwegian Creek	0829	UN-1	NS	NS	UN-1
Owl Creek	0834	UN-1	P-NU	F-NU	M-NU
Potato Hill	0820	P-NU	P-NY	P-NY	P-NN
Smith Reservoir	0822	P-NY	UN-1	UN-3	P-NY
Smith Ridge	0824	P-2Y	UN-2	F-NU	UN-3
Smith River (end)	0671	NS	P-2Y	M-NU	P-NN

Siuslaw National Forest - Waldport R.D.					
Cummins Creek	1751	NI	M-NU	P-NY	P-NY

Appendix 1 (cont.).

Site Name	ODFW Location Code	1982	1983	1984	1985
Eugene BLM Study Area (Cascades)					
Box Canyon	0153	NS	NS	NS	UN-4
Brush Creek	0143	NS	NS	NS	P-NY
Buck Creek East	0167	NS	NS	NS	UN-4
Clark Creek	0148	P-NU	UN-2	NS	P-NY
Deer Mountain	0528	P-NU	NS	P-NU	NS
Dry Creek	0146	F-NU	UN-2	P-1Y	UN-7[a]
Eagles Rest	0144	UN-1	NS	NS	P-NY
Edwards Creek	0150	P-NU	P-1Y	P-NN	P-NN
Green Mountain	0169	NS	P-2Y	NS	UN-4
Hoodoo Mountain	0165	NS	NS	NS	UN-3
Horn Butte	0120	M-NU	NS	P-NY	P-NN
Lily Creek	0141	P-NU	NS	NS	M-NU
Lost Creek	0162	P-NU	P-NU	NS	M-NU
Martin Ridge	0152	NS	NS	NS	UN-3
E. Fork Mosby Cr.	0142	F-NU	M-NU	M-NU	M-NU
M. Fork Mosby Cr.	0530	F-NU	NS	NS	P-NY
W. Mosby/Miles Cr.	0145	NS	NS	NS	UN-4
Lick Creek	0522	NS	NS	M-NU	?
Sharps Creek	0137	NS	NS	M-NU	P-NU
Shea Cr./Dahl Cr.	0149	M-NU	UN-4	M-NU	P-NN
Smith Creek	0147	UN-1	UN-1	NS	P-NY
Trout Creek	0515	NS	NS	NS	UN-3
Walker Creek E.	0132	NS	NS	NS	P-NY
Eugene BLM Study Area (Coast Ranges)					
Alma	0518	P-NU	P-NY	M-NU	UN-6
L. Buck Creek	0015	P-NU	UN-2	M-NU	P-NY
U. Buck Creek	0019	UN-1	NS	NS	UN-4
Doe Hollow	0025	NS	M-NU	P-NY	P-NY
Dogwood Creek	0517	NS	NS	UN-3	UN-4
Edris Creek	0081	NS	P-2Y	UN-11	UN-6
Fish Creek	0161	NS	NS	NS	UN-4
Gall Creek	0133	NS	P-NU	M-NU	P-NY
Haight Cr. Campgr.	0129	UN-2	UN-2	U-UN	P-NN
High Point	0516	NS	P-NY	UN-7	P-NY
Knowles Creek	0136	P-NU	UN-3	M-NU	P-NY
Letz Creek	0018	UN-2	U-UN	P-NY	P-NN
Luyne Creek	0130	NS	NS	M-NU	UN-4
Miller Creek	0160	NS	NS	NS	UN-5
Oat Creek	0158	NS	NS	M-NU	UN-5
Pugh Creek	0109	NS	P-NY	M-NU	P-NY
Saleratus Creek	0134	NS	UN-4	M-NU	NS
Shaw Creek	0131	NS	M-NU	UN-1	UN-6[b]

Appendix 1 (cont.).

Site Name	ODFW Location Code	1982	1983	1984	1985
Eugene BLM Study Area (Coast Ranges)-(cont.)					
Siuslaw Falls	0004	P-NY	P-2Y	P-NN	UN-8[b]
Turner Creek	0523	P-NU	NS	F-NU	UN-3
Waite Creek	0135	UN-1	NS	M-NU	P-NN
Walker Creek	0159	NS	NS	UN-2	M-NU
Whittaker/Bounds	0155	M-NU	UN-2	M-NU	UN-4
Wolf Creek	0082	NS	NS	P-NU	P-NN
Salem BLM (Coast Ranges)					
Record Creek (South Sulman)	0218	M-NU	UN-3	UN-3	NI
Tobe/Rock Creek	0217	P-2Y	P-NF	UN-5	NI
Roseburg BLM Study Area (Cascades - N. Umpqua)					
Bobcat Creek	0309	NS	NS	NS	P-NU
Francis Creek	0312	NS	P-NY	UN-4	P-NU
Gossett Creek	0355	NS	P-1Y	NS	NS
Honey Creek	0510	P-NU	P-NY	P-NU	P-NY
Joker Creek	0304	NS	P-NY	P-NY	P-2Y
Kelly Creek	1794	NS	P-2Y	P-NN	P-NY
Lost Bucket Creek	0351	NS	P-NY	UN-1	UN-2
Red Pond	0360	NS	F-NU	UN-2	NS
Ringtail Creek	0305	NS	P-2Y	F-NU	P-NY
E. Fork Rock Cr.	0356	P-NU	P-2Y	P-NU	P-1Y
Scaredman Creek	0309	NS	UN-4	UN-1	M-NU
Shoup Creek	0511	NS	NS	NS	M-NU
Stoney Creek	0354	M-NU	NS	NS	F-NU
Trail Creek	0304	NS	M-NU	M-NU	P-1Y
Trapper Creek	0311	NS	P-1Y	P-NN	P-NN
Wapiti Creek	0350	NS	P-2Y	P-NU	P-NN
Roseburg BLM Study Area (Coast Ranges - Drain)					
Agony Ridge	0386	M-NU	P-2Y	M-NU	P-NN
Basin Creek	0277	NS	M-NU	UN-1	P-NY
Caseknife Creek	0280	NS	P-NY	P-NN	P-NN
Elk/Beaver Creek	0016	NS	NS	M-NU	NS
Cougar Creek	0288	NS	NS	P-NY	P-NU
Deadman Butte (Brush Creek)	0267	NS	F-NU	UN-9	M-NU
Eagles View	----	NS	NS	NS	M-NU

Appendix 1 (cont.).

Site Name	ODFW Location Code	1982	1983	1984	1985
Roseburg BLM Study Area (Coast Ranges - Drain)-(cont.)					
Halfway Creek	0264	NS	P-NY	M-NU	P-NN
Hancock Creek	----	NS	NS	P-NU	UN-2
Hubbard Creek	0282	NS	NS	M-NU	M-NU
Little Canyon Cr.	0272	NS	P-1Y	P-NN	P-NN
L. Little Wolf Cr.	0285	UN-2	UN-5	P-2Y	P-NN
L. Little Wolf II	0285	NS	NS	NS	P-1Y
U. Little Wolf Cr.	0388	NS	UN-3	UN-2	P-NF
Lookout Mountain	0263	UN-3	UN-5	M-NU	P-NN
Lost Creek	0387	M-NU	P-1Y	P-NN	P-NN
Marvin Gardens	0271	UN-3	UN-3	UN-3	M-NU
Maupin Road	1359	NS	NS	P-NY	P-NN
Middle Ridge	0390	NS	P-NU	F-NU	M-NU
Miner Creek	0279	M-NU	P-NU	P-NN	P-NN
Parker Creek	1360	NS	NS	M-NU	UN-3
Petersen Point	0261	NS	P-NY	M-NU	P-NN
Private Pair	0385	NS	M-NU	P-NN	P-NN
Radar Creek	0275	P-NU	P-2Y	M-NU	P-NN
Riverview	0281	NS	P-2Y	P-NN	P-NN
Rookery	0392	UN-1	M-NU	M-NU	P-NN
Saddle Butte	0265	NS	M-NU	M-NU	UN-2
Smith River	0381	NS	M-NU	P-NU	M-NU
S. Fork Smith Riv.	0260	M-NU	P-NY	P-NN	P-NN
Squaw Creek	0514	NS	NS	P-NN	P-NU
Thistleburn Creek	0266	NS	P-NY	M-NU	P-NN
Whiskey Camp Cr.	0278	NS	P-NY	M-NU	P-NN
Yellow Creek	0391	NS	NS	P-1Y	F-NU
Roseburg BLM Study Area (South Umpqua)					
Bear Gulch	0365	NS	UN-5	UN-2	F-NU
Buck Creek	0376	NS	UN-6	UN-2	P-1Y
Burnt Mountain	0378	NS	UN-1	P-NN	P-NN
Cattle Creek	0373	NS	P-1Y	P-2Y	P-NY
Darby Creek	0375	NS	P-2Y	M-NU	P-NN
Dice Creek	0368	NS	P-1Y	P-NN	P-NN
Dice Creek Trib.	0370	NI	P-1Y	P-NN	M-NU
Gravel Creek	0302	NS	UN-6	NS	UN-2
Iron Mountain Cr.	0308	NS	P-2Y	M-NU	P-1Y
Lettitia Creek	0293	NS	UN-5	UN-1	UN-1
U. Middle Creek	0303	NS	UN-6	M-NU	M-NU
Mitchell Creek	0299	NS	P-1Y	P-1Y	P-2Y
O'Shea Creek	0298	NS	M-NU	M-NU	P-2Y
Riser Creek	0292	NS	UN-1	NS	NS

Appendix 1 (cont.).

Site Name	ODFW Location Code	1982	1983	1984	1985
Roseburg BLM Study Area (Coast Ranges - Drain)-(cont.)					
Shively Forks	0297	NS	UN-2	NS	UN-1
Shively/Poole	0289	NS	P-NY	P-NN	P-NN
Slide Creek	0294	NS	M-NU	NS	NS
Sugar Pine Ridge	0306	NS	UN-3	P-NU	UN-1
Tater Hill	0295	NS	P-NU	M-NU	M-NU
Turkey Creek	0306	NS	P-1Y	P-NN	M-NU
Wood Creek	----	NS	P-1Y	M-NU	UN-6
Unnamed	----	NS	NS	NS	M-NU
Unnamed	----	NS	NS	NS	M-NU

Appendix 2. Food habits of northern spotted owls in western Oregon.

Food habits of spotted owls have previously been described for various areas in Oregon (Forsman et al. 1984). During the present study, pellets were collected within the various western Oregon study areas (Fig A) and are summarized by study area (Tables I-VIII). Comparisons are made with Forsman et al. (1984) for 2 areas that overlapped; information from 6 additional areas are presented which are not represented in the Forsman et al. data set.

The present study collected pellets within 2 areas sampled by Forsman et al. (1984) (the central Cascades - H.J. Andrews area and the central Oregon Coast Ranges). Sample sizes varied but the same 6 prey species were the most numerous in both studies and maintained the same order and importance in the diet in the central Coast Ranges (Table Ib & IIb). In the central Cascades, the same 7 prey species were the most numerous in both studies, with the northern flying squirrel being the most numerous and accounting for the highest percent of biomass. The red tree vole (Phenacomys longicaudus) and the western red-backed vole (Clethrionomys occidentalis) switched in both percent of total prey and biomass; this may be explained by the dates of pellet collection. This study collected pellets mainly during the spring and summer, when red-backed voles are more common in the diet in the Andrews area (E. Forsman, pers. comm.). Forsman et al. (1984) reported on pellets collected throughout the year, with red tree voles being more predominant in the diet during the winter.

The other areas where pellets were collected provide information for the areas from the Mixed Conifer Zone and transition area between the Western Hemlock Zone and Mixed Conifer Zone. Although flying squirrels are the major contributor to the biomass in the northern study areas (within the Western Hemlock Zone), woodrats become much more important in the southern areas, through the transition area and into the Mixed Conifer Zone/Mixed Evergreen Zone. Woodrats in the south Umpqua area (Mixed Conifer/Mixed Evergreen Zone) make up almost 63% of the biomass.

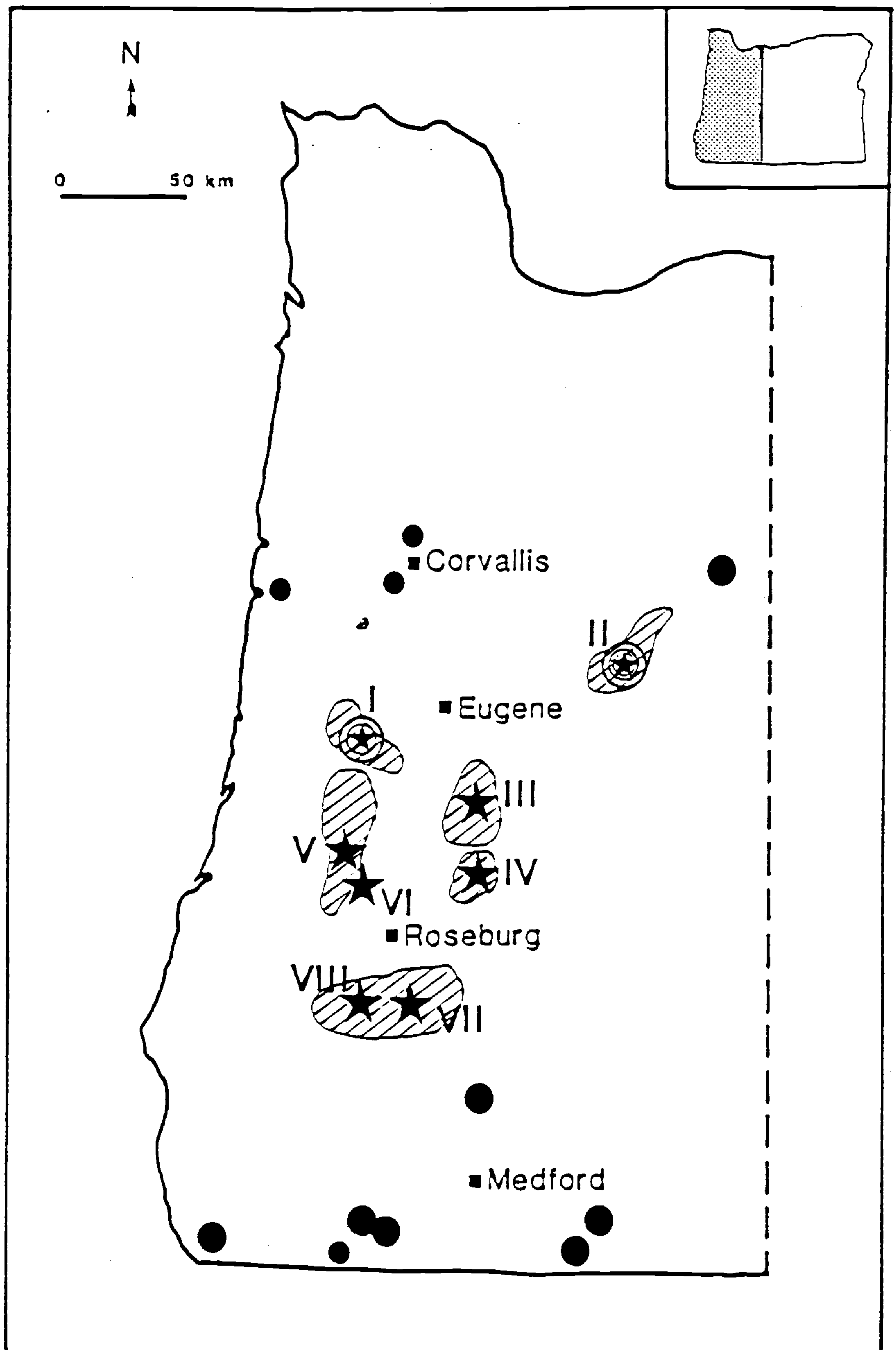
Roseburg District (BLM) biologists provided the majority of the pellets used in the analysis for the Roseburg vicinity. In return I hope this analysis is of some help to them.

LEGEND TO AREAS

Area where pellets were collected	Vegetation Zone
Central Oregon Coast Range	Western Hemlock
Central Cascades	Western Hemlock
Cascades (Eugene BLM)	Western Hemlock
North Umpqua (Roseburg BLM)	Western Hemlock
Southern Oregon Coast Ranges	Western Hemlock
Southern Oregon Coast Ranges (valley margins)	Interior Valley
South Umpqua (Roseburg BLM)	Mixed Conifer/ Mixed Evergreen
Dillard (Roseburg BLM)	Mixed Conifer/ Mixed Evergreen

Appendix 2 (Figure 15). Map of western Oregon showing locations where food habits information is available. The ● represents locations described in Forsman et al. (1984). The ✪ represents areas where the present study and Forsman et al. overlap. The ★ represents new locations described by this study. The number next to several of the areas indicate which table should be consulted in Appendix 2.

Figure 15


N
0
50 km
Corvallis
II
I
Eugene
III
V
IV
VI
Roseburg
VIII
VII
Medford

Appendix 2 (Ia). Diet of spotted owls in the central Oregon Coast Ranges[a].

	Percent of Total Prey				Percent of Biomass
	1982 (27)	1983 (84)	1984 (18)	(T) (129)	All Years (9,974 g)
MAMMALS					
N. flying squirrel	40.7	31.0	55.6	36.4	54.2
Woodrat spp.	7.4	4.8	----	4.7	15.9
Red tree vole	----	29.8	5.6	20.2	7.0
W. red-backed vole	7.4	9.5	11.1	9.3	2.8
Deer mouse	25.9	10.7	5.6	13.2	3.7
Lagomorph spp.	----	1.2	11.1	2.3	6.5
Other mammals	3.7	6.0	11.1	6.2	5.4
BIRDS	11.1	7.1	----	7.0	4.5
INSECTS & ARACHNIDS	3.7	----	----	1.0	tr.

a/ Specific sites within the central Oregon Coast Ranges were Tobe Creek/Rock Creek (Salem District BLM), Alma, Buck Creek, Edris Creek, Haight Creek, High Point, Letz Creek, Luynne Creek, and Siuslaw Falls (Eugene District BLM).

Appendix 2 (Ib). Comparison of diets for spotted owls in the central Oregon Coast Ranges, from pellets collected between 1970-1980 (Forsman et al. 1984) and 1982-1984 (this study).

	Percent of Total Prey		Percent of Biomass	
	This Study (129)	Forsman (1,214)	This Study (9,974)	Forsman (103,961)
MAMMALS				
N. flying squirrel	36.4	35.2	54.2	47.2
Woodrat spp.	4.7	4.9	15.9	15.3
Red tree vole	20.2	19.1	7.0	6.0
W. red-backed vole	9.3	5.5	2.8	1.5
Deer mouse	13.2	11.7	3.7	3.0
Lagomorph spp.	2.3	4.3	6.5	16.5
Other mammals	6.2	8.2	5.2	7.7
BIRDS	7.0	3.0	4.5	2.5
INSECTS & ARACHNIDS	1.0	7.8	tr.	tr.

Appendix 2 (IIa). Diet of spotted owls in the central Cascades[a], western Oregon.

	Percent of Total Prey					Percent of Biomass
	1982 (181)	1983 (353)	1984 (36)	1985 (10)	(T) (580)	All Years (57,702)
MAMMALS						
N. flying squirrel	35.4	32.9	44.4	60.0	34.8	40.3
Bushy-tailed woodrat	11.0	6.2	----	----	7.2	19.3
Red tree vole	3.9	11.3	2.8	----	8.3	2.2
W. red-backed vole	21.0	13.6	16.7	20.0	16.2	3.7
Deer mouse	2.2	11.0	5.6	----	7.8	1.7
Snowshoe hare	6.6	8.8	2.8	----	7.9	22.3
Other mammals	14.4	13.3	27.8	20.0	14.7	7.9
BIRDS	5.5	2.3	----	----	3.1	2.5
INSECTS & ARACHNIDS	---	1.0	----	----	tr.	tr.

a/ Specific sites within the central Cascades area were Blue Ridge, Quentin Creek, Blue River Reservoir, Mona Creek, Watershed II, Mack Creek, McRae/Lookout Creek, Upper Lookout Creek, Upper McRae Creek, Cougar Creek (Blue River Ranger District), Fish Lake, Smith Ridge, Smith River, Lost Creek, King Creek, Smith River (end), Wildcat, and Potato Hill (McKenzie Ranger District). All sites were located on the Willamette National Forest.

Appendix 2 (IIb). Comparison of diets for spotted owls in the central Cascades, western Oregon, from pellets collected betweem 1972-1978 (Forsman et al. 1984) and 1982-1985 (this study).

	Percent of Total Prey		Percent of Biomass	
	This Study (580)	Forsman (817)	This Study (57,702)	Forsman (69,246)
MAMMALS				
N. flying squirrel	34.8	42.4	40.3	57.5
Bushy-tailed woodrat	7.2	2.2	19.3	6.9
Red tree vole	8.3	13.3	2.2	4.2
W. red-backed vole	16.2	9.2	3.7	2.5
Deer mouse	7.8	8.7	1.7	2.3
Snowshoe hare	7.9	2.5	22.3	15.0
W. pocket gopher	4.5	3.6	3.9	3.6
Other mammals	10.2	11.5	4.0	6.0
BIRDS	3.1	3.1	2.5	1.9
INSECTS & ARACHNIDS	tr.	3.4	tr.	tr.

Biomass is in grams

Appendix 2 (III). Diet of spotted owls in the Oregon Cascades[a] (Eugene BLM), 1983-1985.

	Percent of Total Prey	Percent of Biomass
	(87)	(11,610 g)
MAMMALS		
N. flying squirrel	14.9	12.9
Woodrat spp.	27.6	54.8
Red tree vole	20.7	4.2
W. red-backed vole	4.6	0.8
Deer mouse	3.5	0.6
Lagomorph spp.	10.3	22.0
Other mammals	13.8	4.5
BIRDS	3.5	1.8
INSECTS AND ARACHNIDS	1.2	tr.

a/ Specific sites within the Cascades area (Eugene BLM) were Dry Creek and Edwards Creek.

Appendix 2 (IV). Diet of spotted owls in the North Umpqua area[a], (Roseburg District BLM), western Oregon.

	Percent of Total Prey			Percent of Biomass
	1983 (294)	1985 (101)	(T) (395)	All Years (45,165 g)
MAMMALS				
N. Flying Squirrel	41.5	36.6	40.3	40.5
Woodrat spp.	12.9	16.8	13.9	32.3
Red tree vole	14.6	10.9	13.8	3.2
W. red-backed vole	5.4	5.9	5.6	1.1
Deer mouse	5.8	2.0	4.8	1.0
Lagomorph spp.	7.5	6.9	7.4	17.6
Other mammals	2.7	8.9	4.3	1.9
BIRDS	4.8	4.0	4.6	2.4
INSECTS & ARACHNIDS	4.8	7.9	5.6	tr.

a/ Specific sites in the North Umpqua area used in the analysis were Ringtail, Wapiti, Trapper Creek, Trail Creek, Bid-Joker, East Fork Rock Creek, Grizzly Creek, and Kelly Creek.

Appendix 2 (V). Diet of spotted owls in the southern Oregon Coast Ranges[a] (Roseburg BLM), 1984-1985.

	Percent of Total Prey			Percent of Biomass
	1984 (34)	1985 (31)	(T) (65)	All Years (8,634 g)
MAMMALS				
N. flying squirrel	20.6	19.4	20.0	17.3
Woodrat spp.	20.6	32.3	26.2	52.8
Red tree vole	14.7	12.9	13.8	2.8
W. red-backed vole	----	----	----	----
Deer mouse	2.9	3.2	3.1	0.5
Lagomorph spp.	5.9	12.9	9.2	20.8
Other mammals	23.5	9.7	16.9	3.0
BIRDS	5.9	3.2	4.6	2.8
INSECTS & ARACHNIDS	5.9	6.5	6.2	tr.

a/ Specific sites within the southern Oregon Coast Ranges were Agony Ridge, Little Wolf Creek, Lower Little Wolf Creek, and Upper Little Wolf Creek.

Appendix 2 (VI). Diet of spotted owls in the southern Oregon Coast Ranges[a] (valley margins - Roseburg BLM), 1980-1985.

	Percent of Total Prey	Percent of Biomass
	(298)	(34,064 g)
MAMMALS		
N. flying squirrel	15.8	15.9
Woodrat spp.	25.2	59.2
Red tree vole	27.5	6.5
W. red-backed vole	7.0	1.4
Deer mouse	5.7	1.1
Lagomorph spp.	4.7	12.3
Other mammals	6.0	1.9
BIRDS	2.7	1.6
INSECTS & ARACHNIDS	5.0	tr.

a/ Specific sites within the southern Oregon Coast Ranges (valley margins) were Lost Creek, Yellow Creek, Little Canyon Creek, Riverview, and Sugar Pine Ridge.

Appendix 2 (VII). Diet of spotted owls in the south Umpqua Resource area[a] (Roseburg BLM), 1979-1985.

	Percent of Total Prey	Percent of Biomass
	(79)	(12,490 g)
MAMMALS		
N. flying squirrel	12.7	9.2
Woodrat spp.	36.7	62.5
Red tree vole	24.1	4.1
W. red-backed vole	6.3	0.9
Deer mouse	2.5	0.4
Lagomorph spp.	10.1	21.1
Other mammals	3.8	0.9
BIRDS	2.5	0.8
INSECTS AND ARACHNIDS	1.3	tr.

a/ Specific sites within the South Umpqua Resource area were Mitchell Creek, O'Shea Creek, Turkey Creek, and Wood Creek.

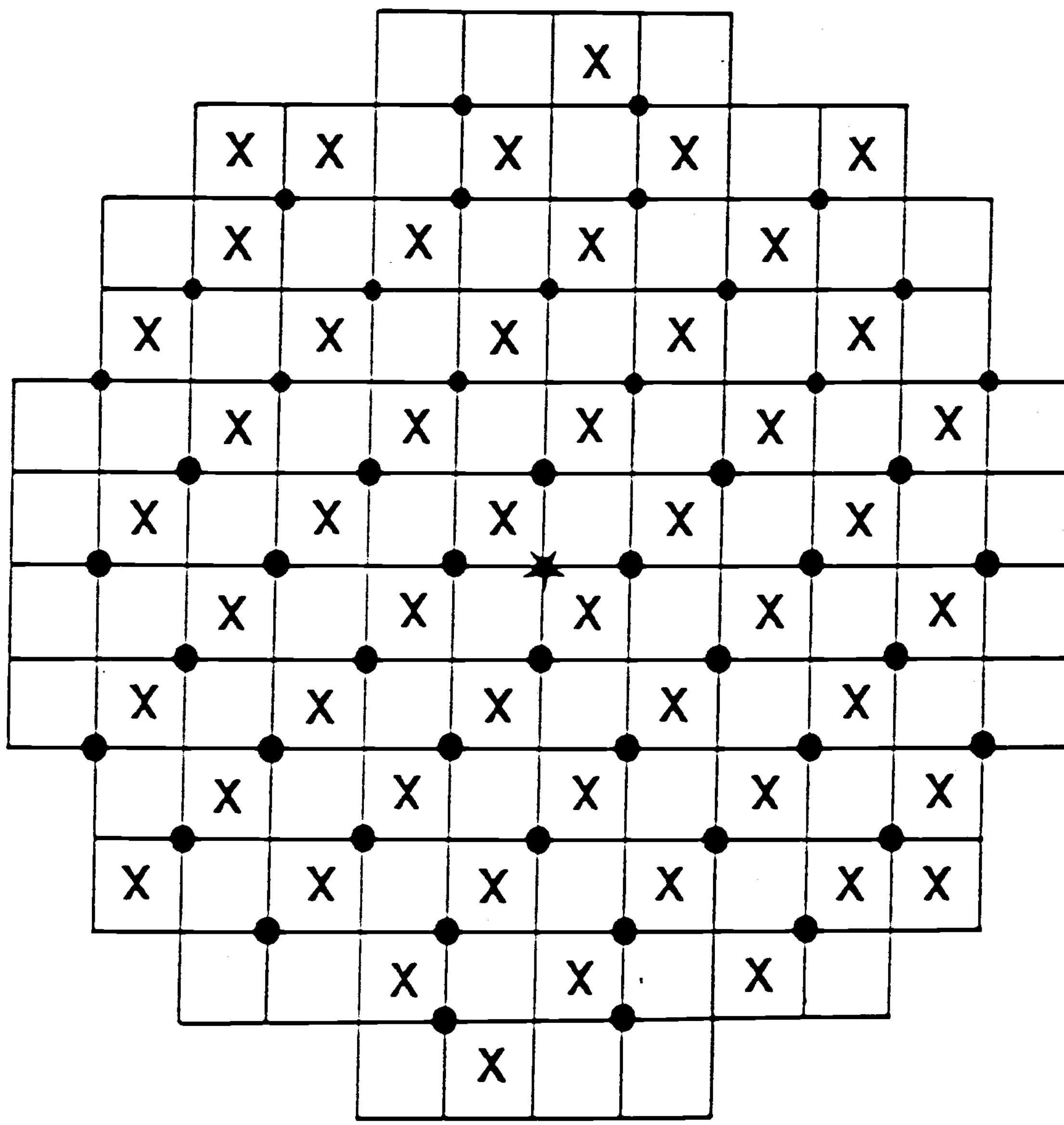
Appendix 2 (VIII). Diet of spotted owls in the Dillard Resource area[a] (Roseburg District BLM) in western Oregon.

	Percent of Total Prey				Percent of Biomass
	1978 (31)	1984 (44)	1985 (35)	(T) (110)	All Years (13,681 g)
MAMMALS					
N. flying squirrel	22.6	25.0	22.9	23.6	21.9
Woodrat spp.	16.1	36.4	17.1	24.5	53.1
Red tree vole	19.4	9.1	11.4	12.7	2.8
W. red-backed vole	22.6	6.8	11.4	12.7	2.4
Deer mouse	----	4.5	----	1.8	0.3
Lagomorph spp.	6.5	6.8	5.7	6.4	16.1
Other mammals	3.2	9.1	8.6	7.3	2.3
BIRDS	9.7	----	2.9	2.7	1.3
INSECTS & ARACHNIDS	----	----	20.0	6.4	tr.

a/ Specific sites within the Dillard Resource area were Upper Middle Creek, Iron Mountain, Cattle Creek, and Buck Creek.

Appendix 3 (Figure 16). Example of grid used for determining fragmentation and habitat availability around the dispersal roost locations. X's represent cells where homogeneity was measured, ●'s represent grid cell intersections where habitat (age class) was recorded.

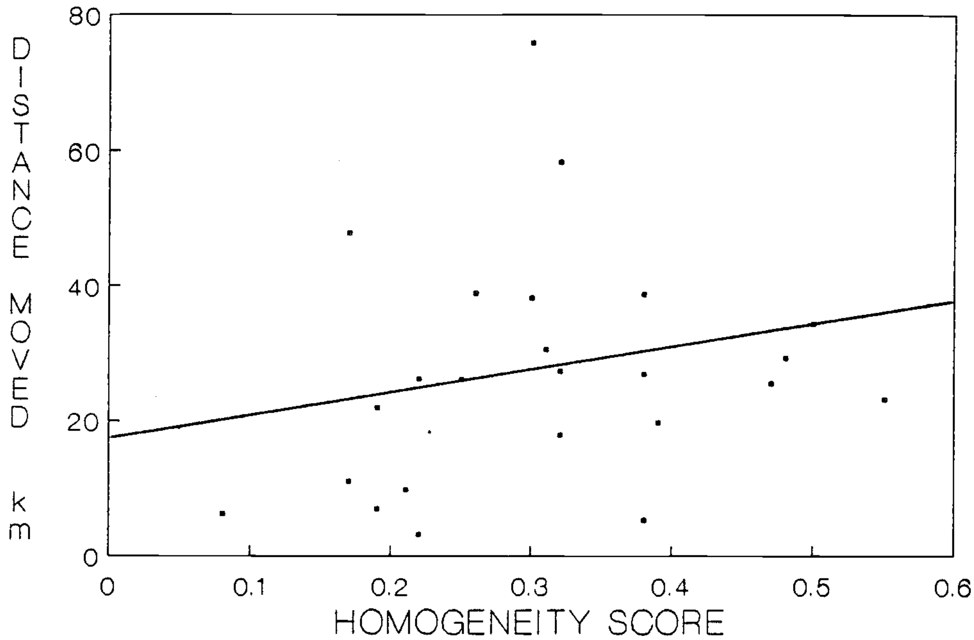
Figure 16



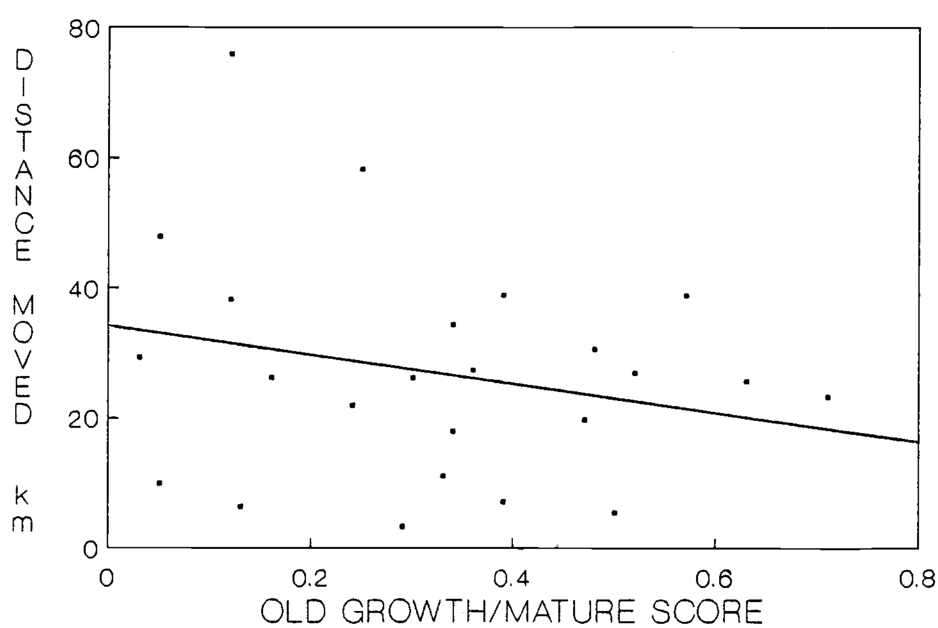
Appendix 4 (Figure 17). (A) Regression of final distance dispersed by juvenile spotted owls on a homogeneity index around the roost sites in western Oregon (r^2=0.041; n=24). (B) Regression of final distance dispersed by juvenile spotted owls on an old-growth/mature index around the roost sites in western Oregon (r^2=0.04; n=24).

Figure 17

A.


80
60
40
20
0
DISTANCE MOVED km
0
0.1
0.2
0.3
0.4
0.5
0.6
HOMOGENEITY SCORE

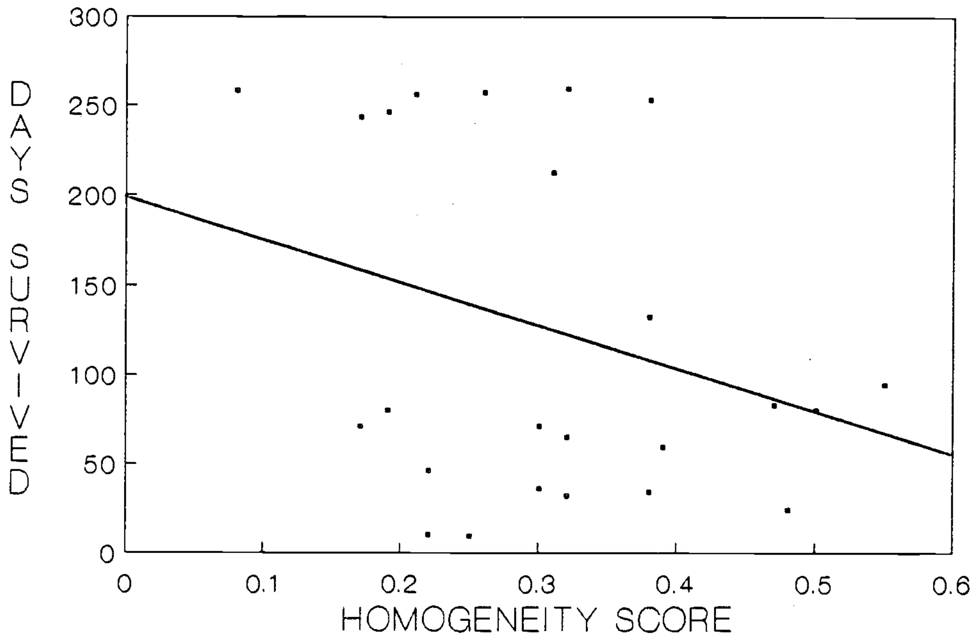
B.


80
60
40
20
0
DISTANCE MOVED km
0
0.2
0.4
0.6
0.8
OLD GROWTH/MATURE SCORE

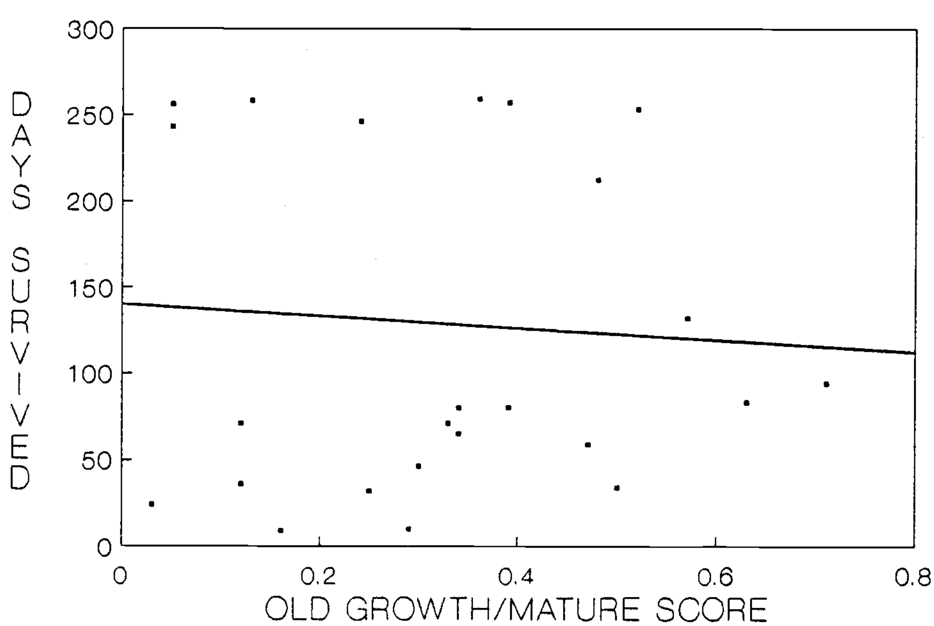
Appendix 5 (Figure 18). **(A)** Regression of days survived by dispersing juvenile spotted owls on a homogeneity index around roost sites in western Oregon (r^2=0.105; n=24). **(B)** Regression of days survived by dispersing juvenile spotted owls on an old-growth/mature forest index around roost sites in western Oregon (r^2=0.003; n=24).

Figure 18

A.


300
250
200
150
100
50
0
DAYS SURVIVED
0
0.1
0.2
0.3
0.4
0.5
0.6
HOMOGENEITY SCORE

B.


300
250
200
150
100
50
0
DAYS SURVIVED
0
0.2
0.4
0.6
0.8
OLD GROWTH/MATURE SCORE

Appendix 6. Habitat use by dispersing juvenile spotted owls in western Oregon, 1982-1985 (roost locations only).

Habitat Type	Proportion of total acreage	Proportion observed in each area (p)	C.I. on proportion of occurence ($P \leq 0.05$)
(LC71; n=38)			
OLDMATCOMB	0.48	0.92	0.807< p <1 [a]
CLOSED S/P	0.13	0.05	0< p <0.141
OPEN S/P	0.11	0.00	NOT USED
GRAFORSHR	0.26	0.00	NOT USED
OTHER HAB	0.03	0.03	0< p <0.101
(LC62; n=53)			
OLDMATCOMB	0.34	0.49	0.347< p <0.666
CLOSED S/P	0.41	0.47	0.294< p <0.646
OPEN S/P	0.11	0.04	0< p <0.109
GRAFORSHR	0.10	0.00	NOT USED
OTHER HAB	0.03	0.00	NOT USED
(BRR72; n=35)			
OLDMATCOMB	0.30	0.36	0.120< p <0.600
CLOSED S/P	0.32	0.60	0.355< p <0.845[a]
OPEN S/P	0.18	0.04	0< p <0.138[b]
GRAFORSHR	0.20	0.00	NOT USED
OTHER HAB	0.00	0.00	NOT AVAILABLE
(OBM73; n=129)			
OLDMATCOMB	0.05	0.18	0.093< p <0.267[a]
CLOSED S/P	0.37	0.80	0.709< p <0.891[a]
OPEN S/P	0.13	0.02	0< p <0.052[b]
GRAFORSHR	0.05	0.00	NOT USED
OTHER HAB	0.40	0.00	NOT USED
(SRN95; n=27)			
OLDMATCOMB	0.12	0.22	0.015< p <0.425
CLOSED S/P	0.33	0.41	0.167< p <0.653
OPEN S/P	0.17	0.33	0.097< p <0.563
GRAFORSHR	0.05	0.04	0< p <0.137
OTHER HAB	0.33	0.00	NOT USED

Appendix 6 (cont.).

Habitat Type	Proportion of total acreage	Proportion observed in each area (p)	C.I. on proportion of occurence ($P \leq 0.05$)
(EC69; n=92)			
OLDMATCOMB	0.05	0.21	0.101< p <0.319[a]
CLOSED S/P	0.38	0.71	0.588< p <0.832[a]
OPEN S/P	0.19	0.09	0.013< p <0.167[b]
GRAFORSHR	0.20	0.04	NOT USED
OTHER HAB	0.18	0.00	NOT USED
(DC05; n=25)			
OLDMATCOMB	0.71	0.96	0.862< p <1 [a]
CLOSED S/P	0.08	0.00	NOT USED
OPEN S/P	0.07	0.00	NOT USED
GRAFORSHR	0.14	0.00	NOT USED
OTHER HAB	0.00	0.04	0< p <0.098
(BJ91; n=20)			
OLDMATCOMB	0.33	0.90	0.732< p <1 [a]
CLOSED S/P	0.08	0.00	NOT USED
OPEN S/P	0.14	0.10	0< p <0.268
GRAFORSHR	0.45	0.00	NOT USED
OTHER HAB	0.00	0.00	NOT AVAILABLE
(EF80; n=73)			
OLDMATCOMB	0.52	1.00	0.971< p <1 [a]
CLOSED S/P	0.06	0.00	NOT USED
OPEN S/P	0.08	0.00	NOT USED
GRAFORSHR	0.33	0.00	NOT USED
OTHER HAB	0.00	0.00	NOT AVAILABLE
(EF93; n=46)			
OLDMATCOMB	0.39	0.93	0.836< p <1 [a]
CLOSED S/P	0.07	0.04	0< p <0.112
OPEN S/P	0.24	0.00	NOT USED
GRAFORSHR	0.31	0.02	0< p <0.072[b]
OTHER HAB	0.00	0.00	NOT AVAILABLE

Appendix 6 (cont.).

Habitat Type	Proportion of total acreage	Proportion observed in each area (p)	C.I. on proportion of occurence ($P \leq 0.05$)
(WC80; n=43)			
OLDMATCOMB	0.34	0.56	0.365< p <0.775[a]
CLOSED S/P	0.28	0.26	0.088< p <0.432
OPEN S/P	0.22	0.07	0< p <0.170[b]
GRAFORSHR	0.16	0.05	0< p <0.135[b]
OTHER HAB	0.01	0.07	0< p <0.170
(KC88; n=33)			
OLDMATCOMB	0.47	0.82	0.648< p <1 [a]
CLOSED S/P	0.28	0.12	0< p <0.265
OPEN S/P	0.13	0.00	NOT USED
GRAFORSHR	0.09	0.06	0< p <0.166
OTHER HAB	0.03	0.00	NOT USED
(LOC92; n=98)			
OLDMATCOMB	0.12	0.19	0.088< p <0.292
CLOSED S/P	0.24	0.39	0.263< p <0.517[a]
OPEN S/P	0.44	0.40	0.273< p <0.527
GRAFORSHR	0.19	0.00	NOT USED
OTHER HAB	0.01	0.02	0< p <0.056
(CC94; n=24)			
OLDMATCOMB	0.22	0.13	0< p <0.306
CLOSED S/P	0.35	0.75	0.523< p <0.977[a]
OPEN S/P	0.16	0.13	0< p <0.306
GRAFORSHR	0.06	0.00	NOT USED
OTHER HAB	0.20	0.00	NOT USED
(LLW93; n=30)			
OLDMATCOMB	0.57	0.93	0.810< p <1 [a]
CLOSED S/P	0.01	0.00	NOT USED
OPEN S/P	0.13	0.07	0< p <0.190
GRAFORSHR	0.21	0.00	NOT USED
OTHER HAB	0.05	0.00	NOT USED

Appendix 6 (cont.).

Habitat Type	Proportion of total acreage	Proportion observed in each area (p)	C.I. on proportion of occurence ($P \leq 0.05$)
(OS58; n=72)			
OLDMATCOMB	0.24	0.81	0.691< p <0.929[a]
CLOSED S/P	0.18	0.13	0.028< p <0.232
OPEN S/P	0.43	0.05	0< p <0.116[b]
GRAFORSHR	0.12	0.00	NOT USED
OTHER HAB	0.03	0.00	NOT USED
(OS59; n=71)			
OLDMATCOMB	0.39	0.93	0.852< p <1 [a]
CLOSED S/P	0.19	0.03	0< p <0.082[b]
OPEN S/P	0.28	0.01	0< p <0.040[b]
GRAFORSHR	0.07	0.00	NOT USED
OTHER HAB	0.08	0.03	0< p <0.082
(TC55; n=32)			
OLDMATCOMB	0.36	0.47	0.243< p <0.697
CLOSED S/P	0.27	0.41	0.187< p <0.633
OPEN S/P	0.23	0.13	0< p <0.283
GRAFORSHR	0.08	0.00	NOT USED
OTHER HAB	0.05	0.00	NOT USED

a/ Used significantly more ($P \leq 0.05$) than expected based on availability.

b/ Used significantly less ($P \leq 0.05$) than expected based on availability.