North Central Forest Experiment Station
USDA Forest Service
Folwell Avenue
St. Paul, Minnesota 55101

COO-1332-67

MASTER

July 19, 1971

BARRED OWL HABITAT USE

AS DETERMINED BY RADIOTELEMETRY

1

THOMAS H. NICHOLLS, Department of Ecology and Behavioral Biology,
University of Minnesota, Minneapolis¹

DWAIN W. WARNER, Bell Museum of Natural History, University of
Minnesota, Minneapolis

Abstract: Radio transmitters were successfully placed on 10 barred owls (Strix varia) during 1965-66 and the movements of the owls were followed with an automatic radio-tracking system for a total of 1,182 days. More than 28,000 owl locations were sampled from some two million locations recorded. These locations, along with habitat availability information, were programmed for computer analysis to determine intensity of habitat use. Barred owls showed consistent and highly significant preference or avoidance for different habitats despite changing seasons, phenology, weather conditions, and years. The order of habitat preference in decreasing intensity of use was oak (Quercus spp.) woods, mixed hardwoods and conifers, white-cedar (Thuja occidentalis) swamps, oak-savannas, alder (Alnus spp.) swamps, marshes, and open fields.

¹Present address: North Central Forest Experiment Station,
USDA Forest Service, Folwell Avenue, St. Paul, Minnesota.

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Dec 1

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

This paper reports the use of radiotelemetry to determine the intensity of use of various habitat types by barred owls. The recently accelerated interest in predatory animals and the difficulties involved in the study of generally nocturnal and little known avian predators presented a dual challenge to the technique of radio-tracking.

Radio-tracking techniques have been used most extensively in studies of mammals, which generally have a greater capacity for carrying radio transmitters than do birds. Several investigators have tried to equip birds with miniature radio transmitters for field studies, but few have done so successfully (Southern 1965, Graber & Wunderle 1966, Cochran et al. 1967).

Habitat use by birds has been studied by visual observation, by recapture of marked birds, and by appearance in study areas of species intermittently captured by various sampling methods. In addition to determining habitat use, data from these types of studies have been the basis for major interpretations of response to environmental change, home range, territory, migration, dispersal, and population structure.

Traditional marking methods seldom produce the continuous, minute-to-minute data necessary for evaluating short-duration movements and activities of wild birds that will accurately provide information on intensity of habitat use. In this study, radio transmitters were developed for and placed on 10 barred owls, which were captured with Japanese mist nets. Movements of the owls were monitored by the

University of Minnesota's Cedar Creek Automatic Radio-tracking Station (Cochran et al. 1965). Of some two million owl locations (fixes) recorded, more than 28,000 were used in data analysis. These locations were used to determine the intensity of use of seven different habitat types during all seasons.

The authors thank Dr. D. B. Siniff, who wrote the computer programs used in data analysis; L. B. Kuechle and C. Ransom, who built the radio transmitters used in this study; D. B. Lawrence for the aerial photographs; and Marie A. Gravdahl, who prepared the line drawings. Appreciation is extended to Dr. W. H. Marshall, Director of the University of Minnesota Cedar Creek Natural History Area; to A. Peterson, Resident Manager of Cedar Creek; P. Rice, our technician; and to the many personnel of Cedar Creek who gave freely of their help. The authors acknowledge the support of the National Institutes of Health Training Grant 5 T1 AI 188 to Dr. D. W. Warner and U.S. Atomic Energy Commission Grant COO-1332-67 to Dr. J. R. Tester.

STUDY AREA

This investigation was carried out on the Cedar Creek Natural History Area, 30 miles north of Minneapolis, Minnesota, in Anoka and Isanti counties. It is an area of some 5,000 acres owned and administered by the University of Minnesota. Habitat within the study area has been described in detail by Pierce (1954), Bray et al. (1959), and others. The topography is flat to gently rolling with sandy upland

areas interspersed with bogs, cattail (Typha latifolia) marshes, swamps, four small lakes, a creek, and a drainage ditch. Upland areas typically have sandy soil and were classified by Bray et al. (1959) as tall grass prairie, deciduous-angiosperm savanna and forest, and mixed conifer-angiosperm forest. The predominant upland trees are oaks (Quercus macrocarpa, Q. ellipsoidalis, Q. alba, Q. rubra) and pines (Pinus strobus, P. resinosa, P. banksiana), with scattered sugar maple (Acer saccharum), white birch (Betula papyrifera), and basswood (Tilia americana) often with a dense hazel (Corylus cornuta, C. americana) understory. Small farms and marginal crop land surround the area. Some of this land had cultivated fields of rye (Secale cereale), alfalfa (Medicago sativa), corn (Zea mays), and soybeans (Glycine max). Many fields were not cultivated and most fields were separated by rows of trees with understories of wild grape (Vitis spp.), Rubus species, and choke cherry (Prunus virginia).

The lowland areas have muck or peat soils usually poorly drained. These are normally dominated by white-cedar, tamarack (Larix laricina), and alder (Alnus rugosa) with such associated species as red osier dogwood (Cornus stolonifera), willow (Salix spp.), white birch (Betula papyrifera), and aspen (Populus tremuloides).

The general climatological characteristics of the Cedar Creek Natural History area have been recorded in Baker and Strub (1965) and Pierce (1954). The general seasonal and phenological characteristics occurring during this study are illustrated in Fig. 1.

Phenology

Early Spring--Owls are nesting, occasional snow storms occur, killing frost is common, the ice and snow are melting, the ground is bare, grasses are beginning to grow, the tree buds expand and leaves grow to about one-half size, the frogs start calling, and the migratory birds return during this season.

Late Spring--Young owls are about to leave or have left nests, tree leaves are fully grown, herbs and shrubs are fully developed, and mosquitoes and wood ticks are numerous during this season.

Summer--Owls are in family groups, adult owls start molting near the end of summer, mosquitoes are present, wood ticks disappear about mid-July, deer flies are active, grasshoppers are numerous, tadpoles hatch, some birds start migration in August and September, berries and nuts mature in late summer, and July temperatures range from 43 to 88 F.

Early Fall--Adult owls complete molt, killing frosts begin, mosquitoes and deer flies disappear, leaves start to turn color with most leaves fallen by mid-October except for some dead leaves that persist on oaks, and most of the Passerine birds leave the area.

Late Fall--Waterfowl migrate through the area, waters begin to freeze, snow storms start, and saw-whet owls migrate through the area during this season.

Winter--Owls increase their daytime hunting activity, owls begin courtship activities in February and March, most of the water areas are frozen, snow storms are common, snowcover is normally continuous during this period, and sub-zero temperatures are common in January and February.

MATERIAL AND METHODS

Owl Transmitter

A successful transmitter-harness was developed (Nicholls and Warner 1968) from a solid strand of #12 or #14 copper electrical wire formed into a harness with a neck loop and body loop to which transmitter parts were attached (Fig. 2). Transmitter parts and battery were encapsulated in a waterproof, cold-resistant, durable acrylic that was hard enough to withstand biting and clawing. The transmitter was located near the front of the owl's sternum with the back strap on the midline of the back between the wings. The harness and transmitter on all birds were completely covered by feathers, an advantage in cold weather because transmitters were kept warm.

Automatic Radio-tracking System

The University of Minnesota's Cedar Creek Radio-tracking System (Cochran et al. 1965) utilizes two rotating, directional, receiving antennas. Each radio transmitted at a different frequency. When the radio antennas pointed in the direction of an owl with a transmitter, the radio frequency energy emitted from the transmitter was detected by receivers at a central laboratory. Permanent records of received signals, as displayed by indicator lights on receivers, were made by photography. The data on the film were read and tabulated to conform to a sampling interval that normally was one fix

every 15 minutes during darkness and one fix every 30 minutes during daytime, or as nearly as possible to this interval. Degree bearings obtained from the antennas permitted owls to be located on maps by triangulation. The date, identification code for each owl, time, and degree bearing from each tower were punched on computer cards and analyzed by a digital computer that calculated movement and location parameters and drew a map of movements for each animal (Siniff and Tester 1965, Siniff 1966).

In any animal tracking system using triangulation, there may be discrepancies between the true location and those found by triangulation. Important sources of errors and limitations of the automatic radio-tracking system have been discussed by Heezen and Tester (1967) and Sargeant et al. (1965). Cochran et al. (1965) determined that combined system and reading errors were no greater than $\pm 0.3^\circ$ with strong signals on a calm day, and $\pm 0.5^\circ$ with strong signals on a windy day.

Habitat Analysis

The Cedar Creek area was gridded into a system consisting of 2,080, 1.6-acre (.0025 square mile) squares. Squares were numbered from 1 to 2,080 for computer identification. Choice of square size was arbitrary, but 1.6-acre squares were convenient in terms of accuracy of the radio-tracking system and also permitted detailed classification of habitat types. Square size was large enough so that each square contained at least one possible degree bearing intersection.

Each square was assigned a habitat type which was determined from aerial photographs, vegetation maps, and field observations. Occasionally, more than one habitat type was present in a 1.6-acre square. To determine which habitat type was used by the owl in such cases, a computer drawn map was made of all locations for each owl and placed over a vegetation map of Cedar Creek that also had the 1.6-acre grid. The square was coded for the most important habitat in terms of the owl's preference as indicated by the computer map of locations. For example, if both an open field and an oak woods appeared in the same 1.6-acre square and the computer location map showed most locations occurring in the oak woods, the square was coded as an oak woods habitat. The habitat information for each square, along with all locations occurring in each square for each barred owl, were programmed for computer analysis. The output from the program was presented as the number and percentage of locations occurring in each habitat type for any desired unit of time.

Habitats were categorized into seven types--four upland types (oak woods, oak-savanna, open field, and mixed hardwoods and conifers) and three lowland types (white-cedar swamp, alder swamp, and marsh). Brief descriptions of these types follow.

The oak woods type usually consisted of a mixture of two or three species of oak in moderate to high densities. Trees varied in height from 20 to 65 feet. Few shrubs and herbaceous plants grew under these dense stands. The oak-savanna habitat consisted of scattered oak trees

where densities were low enough so that grasses and other herbaceous vegetation were the actual dominants of the community. The mixed hardwood and conifer type, depending upon the area, had various combinations of sugar maple, basswood, red oak, white birch, northern pin oak, white, red, and jack pine. Few shrub and herbaceous plants grew under the mixed hardwood and conifer canopy. Open-field habitats consisted of pastures, cultivated fields, and prairies with occasional clumps of trees. Most open fields were bordered by wooded areas.

White-cedar was the dominant lowland forest tree. In some areas white-cedar overlapped and mixed with tamarack. White-cedar replaces tamarack in late successional stages at Cedar Creek. The more dense stands of white-cedar were effective in reducing the amount of light reaching the forest floor and only a few shrubs and herbs tolerated these low light conditions. The alder swamp habitat consisted of dense stands of alder in moist lowland areas. Some alder stands were so dense that it was difficult to walk through them. An occasional tamarack was found in this habitat type. Marsh areas were characterized by open wetlands with cattails, sedges and grasses, generally without trees, but sometimes having scattered clumps of red osier dogwood, alder, and willow species.

A determination of home range was necessary in evaluating habitat use. The term home range, as used in this study, was defined as that area used, traversed, or regularly surrounded by an owl during its normal activities of food gathering, mating, nesting, caring for young, and seeking shelter.

The area of each owl's home range was determined by multiplying by 1.6 (acres) the number of squares in which one or more locations were obtained. Home range boundaries were determined by drawing lines around the outermost 1.6-acre squares with fixes in them. Those few squares without fixes, but inside the home range boundary, were considered part of the home range because they were regularly surrounded by squares with fixes.

After determining the acreage of each owl's home range, the total number of acres of each of the seven habitat types present within the home range was determined. Habitat preference and intensity of use were determined by comparing the observed number of fixes occurring in each habitat type and the expected number of fixes that would have occurred if owls had entered the different habitat types by chance alone. The expected number of fixes was obtained by multiplying the percentage of the total acreage present for each habitat type by the total number of observed fixes obtained for each owl.

Data on the distribution of owl fixes with respect to different types of available habitat were tested for significant differences by chi-square methods of analysis. The 0.05 percent or less probability level was used to indicate significance. The hypothesis for the chi-square test was stated as follows: if an owl entered different habitats by chance alone, the number of radio fixes in each habitat type will be proportional to availability of the habitat types within the home range of the individual owl.

To reduce errors in location, fixes were taken only when owls were not flying because the two antennas seldom received signals at exactly the same time. When the sampling interval could not be maintained because of random uncontrollable data gaps, we considered that the percentage of time unknown was unbiased toward any specific habitat type.

RESULTS AND DISCUSSION

Barred owls adapted quickly to the transmitter-harness and it did not appear to influence their natural activities or cause injuries even after prolonged use. Only one barred owl died during the study and that was believed to be due to natural causes. Several owls carried transmitters as long as 180 days before the transmitters failed.

Ten barred owls were successfully radio-tracked for a total of 1,182 days during which 28,338 locations (fixes) were sampled from some two million owl locations automatically recorded by the radio-tracking system (Table 1). Sufficient data for habitat analysis were obtained from 9 of the 10 owls and comprised some 26,841 radio locations. The average home range size for the nine owls was 565 acres. Home range size varied from 213 to 912 acres.

Computer maps of owl locations and movements were made for all owls. Fig. 3 is an example of such a map for a 45-day period from August 24 to September 20, 1965, for barred owl 703. Each plus

mark on the map denotes one or more radio fixes obtained for the owl in that particular location. Lines between plus marks indicate movements between successive locations.

Computer maps, when placed over vegetation maps of the study area, as in Fig. 3, illustrate how intensively the owl used different areas within its home range. The wooded areas were almost completely outlined with radio fixes while the open fields and marsh on either side of Cedar Creek had few fixes. In some cases the map areas representing deciduous woods were completely covered with overlapping plus symbols denoting owl locations. The lines crossing the open areas showed that owls frequently flew back and forth between different woodlots within the home range. By knowing the characteristic outline of each woods, it was often easy to determine what particular woods the owl was using from the computer map pattern of fixes. For example, the heavily used oak woods in the northwest corner of Fig. 3 was filled in with fixes. A picture of that woodlot can be seen at the top of Fig. 4 for comparison. The open fields north and south of this oak woods received little use. The large oak woods to the south of the small open field in the middle of Fig. 4 was intensively used, as can be seen by the numerous plus marks on the computer map in Fig. 3.

Comparison of maps in Figs. 3 and 5 can be made by keeping in mind the reference points of the radio-tracking towers, Cedar Creek, Cedar Bog Lake, and the various characteristic patterns of the deciduous woodlots. Fig. 5 shows the 258-acre home range of barred owl 703 for a

65-day period between July 15 and September 20, 1965. Each square is 1.6 acres in size and numbers indicate the total radio fixes falling within each square. Note in Fig. 5 the large number of radio fixes occurring in the deciduous woods compared to the few fixes in the white areas that denote open fields and marshes. Numerous radio fixes were obtained in some edge squares. For example, the largest deciduous woods (woodlot E, Fig. 5) in the home range had both field and oak woods habitats in some of the same squares on its northern edge. The question that had to be answered was whether the fixes in those squares were located in the open field or in the oak woods. Computer maps made at 10-day intervals during each owl's tracking period answered this question for they showed exactly where the owl was. In the example cited, more than 98 percent of the fixes in the edge squares occurred in the oak woods. This explained the straight border outlined by fixes along the open field and the northern edge of woodlot E seen in Fig. 3. An aerial view of the same woods-field edge is seen in Fig. 4.

Less use was made of the white-cedar swamp in the northeastern part of the home range. A mixed hardwood and conifer habitat (woodlot C, Fig. 5) in the middle of a lowland cedar swamp received intensive use. Squares having only white-cedar in them had few fixes by comparison. Computer maps showed that most fixes occurred in the mixed hardwood and conifer habitat in those edge squares also having

the white-cedar habitat. The same relationship was true for the deciduous woods (woodlot F, Fig. 5) to the south of the white-cedar swamp. Few or no fixes were obtained in the open marsh area located on either side of Cedar Creek.

Fig. 6 illustrates how a different barred owl intensively used a mixed hardwood and conifer habitat. It shows a 10-day computer map of the movements of barred owl 709 from April 9 to April 19, 1966. The numerous fixes to the west of Cedar Bog Lake outlined an almost circular island of mixed hardwoods and conifers that was completely surrounded by a lowland white-cedar swamp. Fig. 7 is an aerial photograph of the same area showing that circular island to the upper left of the lake surrounded by the cedar swamp that received little use.

Barred owls showed definite and significant ($P < 0.05$) preference or avoidance of different habitat types. Table 2 is an example of how habitat preference was obtained for each individual owl by using the chi-square test to determine significant differences between observed and expected number of radio fixes for each habitat type. The results of these tests, summarized in Table 3, showed which habitats were significantly selected for or against by individual owls based upon habitat availability. The results were consistent for all owls with the exception of owl 707. This owl made intensive use of the oak-savanna habitat in contrast to five other owls who had this habitat in their home ranges but who did not make intensive use of it.

A total of 52 habitat comparisons were made using the chi-square test to determine which habitats were intensively used by individual owls and which ones were not. Forty-nine of these comparisons showed significant ($P < 0.05$) differences between observed and expected number of radio fixes and three showed no significant differences. Of the 49 showing significance, 12 showed that the observed number of radio fixes was more than the expected number of radio fixes with respect to habitat availability. All except one of these 12 occurred in the oak woods or mixed hardwood and conifer habitats. The one exception occurred in the oak-savanna habitat. Thirty-seven of the 49 showed that the observed number of radio fixes was less than expected. All of these occurred in either the oak-savanna, white-alder swamp, cedar swamp, marsh, or open-field habitats. Of the three showing non-significance, one each occurred in the mixed hardwood and conifer, white-cedar swamp, and marsh habitats.

The general order of preference in decreasing intensity of use was oak woods, mixed hardwoods and conifers, white-cedar swamps, oak-savannas, alder swamps, marshes, and open fields. The order of preference was similar among all nine owls. Where differences among the owls occurred, differences in habitat preference usually consisted of a one-or two-place shift in the order of preference.

Seasonal differences or shifts in habitat use were not apparent. Barred owls radio-tracked during spring (owls 702 and 712), summer (owls 701 and 703), winter-spring-summer (owls 707, 709, and 710), spring-summer-fall (owl 714), and winter (owl 704) periods all used the available habitats with similar intensity. This was true despite changing weather and phenological conditions--the general characteristics of which are outlined in Fig. 1.

There were no major differences in habitat use by different owls in different years. Owls 701 and 703 were radio-tracked during 1965 and owls 702, 707, 709, 710, 712, and 714 were tracked in 1966. Owl 704 was tracked in both 1965 and 1966. There were no major differences in the relative intensity of habitat use when male owls were compared with female owls. Sex determination is difficult in barred owls and the sex of only four owls was determined. Owls 704 and 714 were males and owls 701 and 702 were females.

Table 3 also gives the percentage of the total fixes occurring in each habitat type present in each owl's home range during the entire period in which each owl was radio-tracked. These results again emphasize the importance of the oak woods and the mixed hardwood and conifer habitats where owls spent the highest percentage of their time. Less time was spent in the white-cedar swamp and oak-savanna habitats and considerably less time was spent in the alder swamp, marsh, and open-field habitats.

Our results raise some interesting questions for further study on the reasons why such consistent habitat use patterns were found. We can only suggest some possible explanations why barred owls selected certain habitat types over others.

Two of the seven habitats were preferred over the other five. The preferred habitats were the oak woods and, if present in the home range of an individual owl, the mixed hardwood and conifer types. These upland wooded areas were normally free of a dense understory and there were few herbaceous plants growing on the forest floor. The physical characteristics of these two habitats appeared to be ideal for hunting prey. The lack of brush made it easy for owls to see, fly, and attack terrestrial prey without hitting branches or leaves enroute and giving the intended prey warning of an impending attack. The oak woods had many dead or dying trees that probably provided numerous homes for prey species such as mice and squirrels. The barred owls preferred to nest and seek shelter in hollow trees and these were plentiful in the oak woods and mixed hardwoods and conifer habitats. Barred owls were observed hunting prey from perches and these were numerous. These two upland habitats appeared to have all the items necessary for survival of the barred owl. Preferences for these two habitats may have played an important role in causing the owls to favor hunting grounds where the available prey were of characteristic types.

Owls have extraordinary visual adaptations (Conrader 1965). The forward-directed eyes are limited to a total visual field of only about 110 degrees, but the mobility of the head enables the owl to see around it. There is an overlap of the visual fields from the two eyes, giving the owl a central angle of binocular vision of about 70 degrees, compared with only about 6 degrees for song birds. Because of this wide stereoscopic vision, the owl has excellent depth perception, a necessary factor in its survival. The physical arrangement of the habitat must be of a proper structure to enable the owls to use their eyes to best advantage while hunting prey. Such was the case in the intensively used oak woods and mixed hardwood and conifer habitats.

Like their eyes, owls' ears are well-developed and efficient organs (Conrader 1965). The ear openings are large and the openings as well as the ear folds differ in size, shape, and position on opposite sides of the head. These asymmetries cause the sound to be a little louder in one ear than in the other. Because the ear openings are widely separated by the broad head, sound waves reach the two ears at minutely different intervals. These slight differences of intensity and interval enable some owls to locate prey in almost total darkness. Drier conditions generally existed in the upland deciduous woods as compared to the white-cedar, marsh, and alder habitats, and prey species probably made more noise while

moving through dried leaves and dead branches scattered on the ground. This characteristic of the habitat may have been important to barred owls whose survival depends largely upon locating prey by sounds.

The white-cedar swamp habitat had few nesting and shelter cavities even in older trees, probably because the trees were more resistant to decay fungi than were the deciduous trees in the hardwood types. For the same reason, cedar trees probably provided relatively few homes for prey species. The characteristics of this habitat for hunting prey did not seem to be as ideal as those in the deciduous woods. The dense foliage would make flying and seeing more difficult and sounds were probably muffled by damp or wet vegetation on the forest floor.

The oak-savanna habitat was not utilized as intensively as expected except by owl 707. The oak-savanna was a relatively open habitat and most trees were smaller in height and diameter so few hollow trees were present. Abundant prey appeared to be present in this habitat, but other factors of the area apparently did not favor its use by most of the barred owls studied.

Alder swamps were avoided by barred owls. The physical arrangement of this habitat was such that large owls would have had a difficult time flying or attacking prey because of the high density of alder stems and branches. Some alder swamps were so dense that a man would have extreme difficulty penetrating them. There were also no suitable nesting trees in this habitat.

The marsh habitat was also avoided by the owls. There were few or no suitable perches in this habitat, nor were there adequate shady retreats where owls could perch and conceal themselves during usually inactive daylight periods. Nesting or shelter cavities were virtually non-existent.

The open-field habitat was the least used. This habitat generally lacked cover for concealment, suitable nesting trees, and hunting perches. Prey species appeared to be abundant, but were probably not utilized to any extent because of other unfavorable factors.

Although barred owls intensively used certain habitats more than others, little-used habitats might also be important to the owls. Habitats generally avoided by owls may be a source of prey that eventually disperse into habitats used more intensively by owls. For example, terrestrial prey living in white-cedar swamps, alder swamps, and marshes when they are relatively dry may, during periods when these habitats become too wet for prey to survive, migrate to adjoining drier upland areas where they may be utilized as food by barred owls.

Habitat selection must be complementary to the biological requirements of the individual species. It seems most logical for animals to use a habitat or a combination of habitats that most nearly contains all the items necessary to their survival. The survival of the barred owl appears to depend upon the availability of suitable food, areas for courtship and mating, shelter for nesting and concealment, and perches

for hunting and resting--all of which must be in accordance with the owl's biological requirements and abilities. This study indicated that barred owls favored habitats which appeared to be most suitable for the successful completion of its life cycle.

CONCLUSIONS

Radiotelemetry was a useful technique for studying the movements of barred owls. They carried radio transmitters well and there was no indication that transmitters caused injuries or influenced the owls' natural activities. Accurate determinations of home range size were possible using radio-tracking. Habitat preference and intensity of use were determined with confidence. Those habitats (oak woods and mixed hardwoods and conifers) having all or most of the requirements necessary for survival of the barred owl were also the same habitats most preferred and most intensively used with no significant variations with regard to sex, different individuals, phenological changes, changing weather conditions, or years. The method of habitat analysis presented in this study may be useful in studies of habitat use of other species of animals.

LITERATURE CITED

- BAKER, D. G., and J. H. STRUB, JR. 1965. Climate of Minnesota.
Part 3. Temperature and its application. University of Minnesota
Agricultural Experiment Station. 62pp.
- BRAY, J. F., D. B. LAWRENCE, and L. C. PEARSON. 1959. Primary
production in some Minnesota terrestrial communities for 1957.
Oikos 10(1):38-49.
- COCHRAN, W. W., D. W. WARNER, J. F. TESTER, and V. B. KUECHLE. 1965.
Automatic radio-tracking system for monitoring animal movements.
BioScience 15(2):98-100.
- _____, G. G. MONTGOMERY, and R. R. GRABER. 1967. Migratory flights
of *Hylocichla* thrushes in spring: a radiotelemetry study.
The Living Bird 6:213-225.
- CONRADER, J., and C. CONRADER. 1965. Owls. Wisconsin Tales and
Trails 6(4):26-29.
- GRABER, R. R., and S. L. WUNDERLE. 1966. Telemetric observations
of a robin (*Turdus migratorius*). Auk 83(4):674-677.
- HEEZEN, K. L., and J. R. TESTER. 1967. Evaluation of radio-tracking
by triangulation with special reference to deer movements.
J. Wildl. Mgmt. 31(1):124-141.
- NICHOLLS, T. H., and D. W. WARNER. 1968. A harness for attaching
radio transmitters to large owls. Bird Banding 39(3): 209-214.

- PIERCE, R. L. 1954. Vegetation cover types and land use history of the Cedar Creek Natural History Reservation, Anoka and Isanti Counties, Minnesota. M.S. Thesis. Univ. of Minnesota. 137pp.
- SARGEANT, A. B., J. E. FORBES, and D. W. WARNER. 1965. Accuracy of data obtained through the Cedar Creek Automatic Radio Tracking System. Minnesota Museum Natural History. Tech. Report 10. 20pp. Mimeo.
- SINIFF, D. B. 1966. Computer programs for analyzing radio-tracking data. Minnesota Museum Nat. Hist. Tech. Report 12. 22pp. Mimeo.
- _____, and J. R. Tester. 1965. Computer analysis of animal-movement data obtained by telemetry. BioScience 15(2):104-108.
- SOUTHERN, W. W. 1965. Biotelemetry: a new technique for wildlife research. The Living Bird 4:45-58.

Table 1. Summary of transmitter days, data days, and number of fixes obtained from barred owls during 1965-66 on the Cedar Creek Natural History Area.

Barred Owl	Date Released with Transmitter	End of Tracking Period	Transmitter Days ^a	Data Days ^b	Approximate number of fixes sampled	Notes
701	5-19-65	8-9-65	84	77	2,251	Stopped transmitting
702	3-22-66	5-19-66	58	56	1,027	Stopped transmitting
703	7-15-65	9-20-65	67	65	2,479	Stopped transmitting
704	11-12-65	2-13-66	94	92	4,653	Owl died
707	2-15-66	8-15-66	181	65	2,122	Stopped transmitting
709	2-23-66	9-11-66	200	197	6,431	Stopped transmitting
710	3-8-66	9-11-66	186	185	5,043	Stopped transmitting
711	3-14-66	5-17-66	64	14	400	Owl often out of receiver range
712	3-14-66	5-5-66	52	51	2,587	Owl left area
714	3-22-66	10-4-66	196	99	1,345	Stopped transmitting
Total			1,182	901	28,338	

^aTransmitter days = the number of days the transmitter was functional.

^bData days = the number of days in which usable locations were obtained.

Table 2. Order of habitat preference as indicated by the chi-square test for significant differences between observed number of radio fixes and expected number of radio fixes in each habitat type for barred owl 709 (sex unknown) from February 23 to September 11, 1966.

Habitat Type	Acreage Available	Percentage of Total Acres Available	Number of Radio Fixes		X ² Value
			Observed ^a	Expected ^b	
Mixed hard-woods and conifers	126	14	2,081	903	1,786.90***
Oak woods	279	30	2,869	1,935	644.03***
White-cedar swamp	238	26	1,296	1,677	116.96***
Alder swamp	42	5	4	323	331.64***
Marsh	97	11	52	709	683.99***
Open field	130	14	148	903	734.01***
Total	912	100	6,450	6,450	

*** P. < 0.005 (1 df).

^a-Fixes were normally taken every 15 minutes during darkness and every 30 minutes during daylight.

^b-The expected number of radio fixes was obtained by multiplying the percentage of the total acreage available for each habitat type by the total number of observed radio fixes.

1 3. Percentage of total fixes occurring in each habitat type and habitat selection as indicated by the chi-square test for significant differences between observed and expected number of radio fixes in each habitat type during the period in which each owl was radio-tracked.

BARRED OWL NUMBER, SEX, AND DATES									
Number of fixes and Habitat Type	701♀ (5-19-65 to 8-9-65)	702♀ (3-22-66 to 5-19-66)	703 (7-15-65 to 9-20-65)	704♂ ^a (11-12-65 to 2-13-66)	707 (2-15-66 to 8-15-66)	709 (2-23-66 to 9-11-66)	710 (3-10-66 to 9-11-66)	712 (3-14-66 to 5-5-66)	714♂ ^a (3-22-66 to 11-4-66)
Number of fixes	1,990 ^a	942	2,478	4,653	1,705	6,450	5,031	2,264	1,328
Oak woods	94 ^b (54) ^c	81 ^b (38)	53 ^b (27)	84 ^b (43)	49 ^b (23)	45 ^b (30)	81 ^b (37)	73 ^b (35)	84 ^b (36)
Mixed hardwoods and conifers	NP ^d	NP	37 ^b (17)	NP	21 ^e (15)	32 ^b (14)	NP	NP	NP
White-cedar swamp	< 1 ^f (1)	3 ^e (2)	5 ^f (20)	NP	10 ^f (21)	20 ^f (26)	< 1 ^f (1)	< 1 ^f (2)	< 1 ^f (2)
Oak-savanna	NP	9 ^f (18)	NP	14 ^f (18)	12 ^b (6)	NP	7 ^f (16)	15 ^f (22)	12 ^f (24)
Alder swamp	3 ^f (13)	< 1 ^f (2)	NP	< 1 ^f (10)	1 ^f (4)	< 1 ^f (5)	3 ^f (11)	4 ^f (12)	1 ^f (8)
Marsh	2 ^f (17)	5 ^f (19)	2 ^f (15)	1 ^f (10)	3 ^f (11)	1 ^f (11)	7 ^f (14)	6 ^f (14)	2 ^e (14)
Open field	1 ^f (15)	2 ^f (21)	3 ^f (21)	1 ^f (19)	4 ^f (20)	2 ^f (14)	2 ^f (21)	2 ^f (15)	1 ^f (16)
Total	100 (100)	100 (100)	100 (100)	100 (100)	100 (100)	100 (100)	100 (100)	100 (100)	100 (100)

^a Fixes were normally taken every 15 minutes during darkness and every 30 minutes during daylight.

^b Habitat selected for; significant ($P < 0.05$).

^c Percentage of total acres of each habitat available in home range.

^d Habitat not present in home range.

^e $P > 0.05$.

^f Habitat selected against; significant ($P < 0.05$).

FIGURE CAPTIONS

Fig. 1. Occurrence of Seasons--Cedar Creek Natural History Area, 93° 15' East Longitude, 45° 24' North Latitude.

Fig. 2. Left: owl transmitter as it appeared before back strap was attached and acrylic applied. Right: the 70-gram transmitter-harness used on barred owls. The transmitter operated 175 to 200 days with a continuous signal and had a range of up to 3 miles when a Mallory ZM12 battery was used for power.

Fig. 3. A computer drawn map of locations and movements of barred owl 703 from August 24 to September 20, 1965. A total of 1,055 fixes were used in compiling the map. White areas on map are wooded, and shaded areas are open fields or marshes. Note heavy use of wooded areas and little use of open areas and marshes.

Fig. 4. Aerial view of open-field and oak woods habitats. Objects in center of open field are experimental duck pens.

Fig. 5. Home range of barred owl 703 from July 15 to September 20, 1965, was 258 acres. Each square is 1.6 acres in size and numbers in squares indicate the total number of radio fixes falling within each square. White areas on map indicate open fields or marshes. Note how little use was made of these areas compared to the intensively used deciduous woods.

Fig. 6. Computer map of the fixes and movements of barred owl 709 from April 9 to April 19, 1966, based on 480 fixes. The intensively used area to the west of the lake is a mixed hardwood and conifer habitat that is surrounded by a little-used white-cedar swamp habitat.

Fig. 7. Aerial photograph of Cedar Bog Lake showing the circular mixed hardwood and conifer island adjacent to the lake that was completely outlined by fixes as seen in Fig. 6.

OCCURRENCE OF SEASONS CEDAR CREEK NATURAL HISTORY AREA MINNESOTA

93° 15' E
45° 24' N

FIGURE 1.

FIGURE 2.

FIGURE 3.

FIGURE 4.

FIGURE 5.

FIGURE 6.

FIGURE 7.