Radio Telemetry Methods for Studying Spotted Owls in the Pacific Northwest

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Abstract


The paper is a practical guide to field methodology for conducting a radio telemetry study of spotted owls (*Strix occidentalis*) in mountainous terrain. It begins with a synopsis of spotted owl biology and basic telemetry. The criteria used to select which owls will carry transmitters are discussed as are location and capture methods. Instructions for attaching transmitters and recommendations for general, night, and aerial telemetry are presented. Suggestions are given for controlling data quality, for researcher training and safety, and for field interpretation of radio signals. Equipment needs and license and permit requirements are also discussed.

Keywords: Radio telemetry, *Strix occidentalis*, spotted owl, Pacific Northwest, methods.

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Introduction

The development of radio telemetry equipment in the early 1960s enabled biologists to study the behavior of secretive animals. Cochran and Lord (1963) describe an early telemetry system. Radio telemetry was rapidly adopted as a technique for studying home range and habitat use. Storm (1965), for example, used radio telemetry to study red foxes (Vulpes vulpes). Advances in miniaturization of electronic components allow biologists to study even small animals with minimal effects on the animals.

The spotted owl (Strix occidentalis) has been successfully studied with radio transmitters (Alien and Brewer 1985; Carey and others 1988, 1989, in press; Forsman and others 1984; Forsman and Meslow 1985; Gutierrez and others 1985; Miller and Meslow 1985). Researchers are using radio telemetry to estimate the total area over which an owl roams, how the owls use the habitat types, the relation between the mix of habitat types and total home range size, regional variation in home range size, breeding behavior, and intraspecific and interspecific interactions. In addition, radio telemetry is being used to determine temporal and spatial movements of owls.

The first step in designing a radio telemetry study is to formulate a well-defined, specific set of objectives reflecting a careful review of the literature and specific questions about the biology of the organism to be studied. The objectives dictate the experimental design and sampling plan. We are currently involved in a study of the home range and habitat use of about 50 spotted owls in five landscapes (Carey and others 1988). The experimental design reflects objectives of estimating population parameters for home-range size and habitat selection and determining how these parameters change with landscape type and composition. The sampling plan we follow was based on a pilot study that provided an optimal sampling schedule for our specific objectives (Carey and others 1989). Additional advice on experimental design and sampling is provided by Dunn and Gipson (1977), Johnson (1980), MacDonald and others (1980), Neu and others (1974), Swihart and Slade (1985, 1986), and White and Garrott (1986).

The authors have combined experience in radio telemetry of 15 years. Most of us have been tracking spotted owls for 2.5 years, and one of us, for 6 years. We have studied spotted owls across much of their geographic range from southern California to Washington. Some of us have tracked other species as well. Our extensive experience with radio telemetry and spotted owls has prompted us to document our knowledge of radio telemetry in rugged terrain for other professionals researching spotted owls or other wide-ranging vertebrates.

Spotted Owl Biology

Essential sources of information on spotted owl biology are Carey and others (1990), Forsman (1981), Forsman and others (1984), and Gutierrez and Carey (1985).

Size

Body size determines how large a transmitter may be used; the U.S. Fish and Wildlife Service (1980) recommends not exceeding 3 percent of the body weight. The spotted owl is a medium sized owl. Males weigh 500 to 705 grams (x = 593 grams for 49 males), and females weigh 550 to 855 grams (x = 686 grams for 54 females). Although the female is larger than the male, sex of individuals is most accurately determined by their vocalizations (Forsman and others 1984). Calls of the male are
lower in pitch than those of the female. Barrows and others (1982) report the sexes can be distinguished by the pattern of bars on rectrices (tail feathers), but this method is not reliable in Oregon or northern California.  

Age Classes

Because owl behavior varies markedly with age, age must be included in a study design. Three age classes are distinguishable (based on plumage) in the spotted owl: juvenile, subadult, and adult. Owls are referred to as juveniles during their first year. Owls are considered subadults from 12 months of age until 26 months, when their white-pointed rectrices are replaced with the mottled buff rectrices with rounded tips indicative of adults (Forsman 1981).

Molts

 Feather replacement is an important consideration in choosing the method for attaching the transmitter—mounted on the tail or as a backpack. Adult spotted owls molt every year between April and mid-October. Body feathers are replaced annually. Tail and wing feathers are usually molted every 2 years. Rectrices are molted from 15 June to 11 August (Forsman 1981).

Vocalizations

Spotted owls can be located by their vocalizations. Adult spotted owls are long lived, are usually monogamous, and may occupy the same site for many years. They are territorial and tend to defend their home range through vocalizations. They can be located by inciting them to respond to imitated calls and are most responsive between March and September, the period for breeding, nesting, and raising young (Forsman and others 1984).

The vocal repertoire of spotted owls consists of several hoots, barks, and whistles. A four-note hoot that is a location call is the most common vocalization. Another common call is a location call consisting of a series of 7 to 15 hoots. Both these calls are commonly given by males and females. Females, and uncommonly males, also give a contact call of a hollow whistle with an upward inflection at the end. Spotted owls produce many other less commonly used calls (Forsman and others 1984).

Movements

The extent of the species' range is important in planning the logistics of a study. The northern spotted owl (S. o. caurina) is associated with old-growth forests in western Washington, Oregon, and northern California (Carey 1985; Carey and others 1989, 1990; Forsman and Meslow 1985; Foreman and others 1977,1984; Gutierrez 1985; Gutierrez and others 1984). Home range sizes differ greatly. Forsman and others (1984) found home range sizes for 14 radio-marked owls in Oregon ranged from 549 hectares to 3380 hectares. Mean home ranges for about 25 pairs of owls in five different landscapes in southwest Oregon range from 668 hectares to 4168 hectares (Carey and others 1988).  

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Roost Selection

Knowing where owls roost assists in visually locating an owl in the forest. The locations of roost sites differ seasonally. Owls select summer roost sites that protect them from extreme summer temperatures; for example north-facing slopes with a closed forest canopy (Barrows 1981; Foster and others, in press). Foreman and others (1984) and Barrows and Barrows (1978) found that the owls roost high in the canopy on cold, wet days but roost lower on hot, dry days. Owls may be difficult to locate visually in winter during the day when they are perched high in the canopy. In summer, owls are likely to be roosting near or on the ground.

Pellets

Spotted owls, like other owls, regurgitate indigestible material. The pellet contents can be analyzed to learn food habits (Errington 1930). Information gained on prey selection can be a valuable adjunct to telemetry studies. Biologists should wait until the afternoon if they want to have the greatest success in searching for fresh pellets. Even then, we have had low success in finding pellets of nonnesting owls. Pellets are usually abundant near nesting owls and owlets.

Telemetry Procedures

Essential sources of information on radio telemetry are Carey and others (1989), Kenward (1987), and Mech (1983).
Basic Telemetry

There are three basic components to a radio telemetry system: transmitter, receiver, and antenna. The transmitter uses a lithium or mercury battery or solar cell to generate a radio signal via a transmitting antenna. The receiver picks up the radio signal through a receiving antenna; a speaker (or headphones) then produces a "beep." When several transmitters are in one area, the receiver is often fitted with a scanner that can be programmed to continuously monitor or autoscan each frequency for a short time.

There are two types of receiving antennas. Omnidirectional antennas are usually mounted to a vehicle and are used to determine presence or absence of a signal and to enable the researcher to efficiently approach the transmitter. Directional antennas are used to estimate the direction of the transmitter. See "Telemetry Equipment" for a more detailed description of equipment.

To estimate the transmitter's location, three to five bearings are taken from different stations and plotted on a map or aerial photograph. Bearings can be measured with a handheld compass adjusted for declination. Because ferrous metal and electrical currents attract the compass needle, bearings should be taken at least 5 meters away from vehicles and no heavy metal objects (receiving system, pocket knife, heavy buckles) should be near the compass. Ideally, all bearings will cross at a point, thereby indicating the transmitter's location; in practice, however, the plot of the triangulation usually produces a polygon rather than a point because bearings are seldom precise. The polygon is sometimes referred to as the triangulation polygon (Cochran 1980, Heezen and Tester 1967, Mech 1983), and its size indicates the degree of error in the bearings. There are many sources of uncertainty in bearings: error in determining bearings, error in measuring bearings, bias in equipment, error in plotting, and extrinsic factors (for example, signal reflection off rocks or trees). Because the recorded bearings are point estimates of the direction to the transmitter, they also have a variance. When the variance associated with bearings is added to the triangulation polygon, an error polygon is the result. Error polygons are always larger than triangulation polygons and, if properly constructed, can be assigned a probability of containing the transmitter. See "General Telemetry" for a more detailed discussion of telemetry procedures.

Selecting Owls

Study objectives should be the primary concern when selecting owls to attach radios to. In designing any study, biologists must ensure that the specific study objectives will be met and that all sampling will contribute to meeting these objectives.

A major concern when owls are selected is whether or not quality locations can be consistently obtained. Spotted owls are commonly found in low-elevation commercial forests. Because the management of these forests includes timber harvest, much of the forest is fragmented into various age classes. Determining habitat use, or forest type use, requires a road or trail system sufficient to allow the researcher to work close (<1000 meters) to the owl and to be able to determine which habitat type or forest patch the owl is using. The road system may not be important in areas where the forests have not been fragmented. The less accurate, longer distance locations (>500 meters from researcher to transmitter) can still be used to determine habitat use as long as the forest type is homogenous throughout much of the study area and the owl is not near an edge. Estimates of home range will be imprecise, however, and
precise measurement of distances moved are impossible. Topography renders some roads useless for telemetry (see "Signal Influences and Interpretation"), and some roads will be seasonally blocked by snow or wet conditions. Any of these factors (road access, topography, and seasonal access) can limit a researcher's ability to consistently obtain high-quality, accurate data on the location of an owl. If roads or trails are unavailable, reflective tape may be used to mark the route to carefully located telemetry stations. Surveying of new trails may be necessary, and it may not be possible to conduct a study with sufficient precision to meet certain objectives.

How close owls are to each other should be considered when owls are selected to carry transmitters. Selecting owls in proximity to each other will increase efficiency. From owls with nearly adjacent home ranges in easily accessible areas, a researcher experienced in radio telemetry techniques can usually get a quality location on six to eight owls per 8-hour night.

The essential reference is Forsman (1983).

Locating and Capturing Owls

To locate and capture spotted owls, some guidelines should be followed:

Locating

• Be persistent; search repeatedly.
• Be thorough; took everywhere.
• Begin with a four-note location call; later try the series location call and a contact call.

Capturing

• Be patient; it may take a while.
• Be imaginative; try different bait, bait placement, and lures.
• Be confident, sure, and quick when actually noosing the owl.
• Be gentle when handling the owl.
• Be calm throughout.

The first step in implementing a telemetry study is to locate the owls. It is helpful to have several years of survey data for spotted owls to facilitate the planning of a telemetry study. If information on previous occupancy is not available, the task of finding owls becomes more difficult and could involve extensive surveys. We have found, though, that even resident pairs may change their center of activity or be replaced by a new pair with a different center of activity (Peeler and others, in press).
Spotted owls will usually respond to an imitation of their call and, depending on topography, can be heard up to 0.75 kilometers away. It is often possible to use a road system to call for owls. Vocal imitations or a portable tape player with a prerecorded tape of spotted owl calls are effective in prompting owls to call. The researcher should be familiar with the entire vocal repertoire of the spotted owl. Spring is the best time to call for spotted owls, but they continue to respond late into the summer as well. If the population has been studied previously, calling near the historical nest groves is nearly always effective in locating the owls; however, additional surveys will be necessary to determine if other owls are present before a sampling plan can be implemented. For sites where owls do not respond or access is poor, it may be necessary to hike into the area or continue calling within a 1.5-kilometer radius of the historic area. Owls are most vocal during the late evening and early morning hours. Call at these times to locate owls that are not vocal during the day. For more information on calling surveys, see Forsman (1983).

Capturing spotted owls is best done during daylight hours because it is nearly impossible and always dangerous to try to catch owls in the woods at night. If the owl is located during a night survey, it is best to wait until daylight or return later the next day to try to relocate the owl at its daytime roost. Once the owl responds, it should be approached quickly before it stops calling. As the researcher approaches the owl, the owl may move towards the researcher and perch nearby without making a sound. Whitewash and pellets indicate high-use areas. Two people are needed to catch and place transmitters on owls. Take all necessary materials to the site. See appendix 1 for a list of equipment needed to locate, capture, and place transmitters on owls.

When the owl is located visually, the researcher determines if the owl can be captured at the initial perch location by using a noose pole. (See appendix 2 for a description of the noose pole.) If the owl can be noosed, the person without the pole should divert the attention of the owl away from the person with the pole. Owls that have not been captured previously are easily approached, and their attention is easily diverted with live bait such as a mouse or rat tethered to a stake (see fig. 1) or noises imitating distress calls of small mammals. A lure (usually a rodent skin) on a string can also be used to create movement similar to that of a small mammal and hold the owl's attention while it is approached and noosed. The person approaching the owl should pay special attention to the behavior of the owl so that it is not flushed.

Figure 1—Mouse pin used to tether live bait for owls. The heavy wire is pushed into the soil to prevent the escape of the bait.
The noose should be lowered over the owl's head and drawn closed around its neck. The owl can then be lowered gently to the ground. The owl should be kept under control and close to the rod. The second person should be prepared to quickly secure the wings and talons of the owl to prevent injury to both the owl and the researchers. After the owl is under control, remove the noose from around the owl's neck.

For owls that are difficult to catch (such as those previously captured), capture methods or strategies will need to be changed. Extra time and effort may be needed to attract the owl from a high perch to within reach of the noose pole. Mice may have to be supplanted with rats or even wild prey. Placing mice on logs, branches, and tree trunks may work better than tethering them to the ground.

Varying the capture technique has worked successfully in our project. We found that owls that have been captured before become nervous when approached by a person looking directly at the owl. Looking away from the owl lets researchers more easily approach the owl: a second, distant researcher can watch and describe the behavior of the owl to the person with the noose pole. An owl that will no longer tolerate the direct approach, as naive owls do, may be noosed by using stealth. Camouflaging the noose rod may help, but owls key on movement and may be wary of an approaching noose rod. CRT traps, Bal-chatri traps, mist nets, and hand captures are other options for capturing wary owls. The CRT trap is a spring-loaded, baited trap that cinches around the bird's legs when the bird hits the bait and trips the trap. The Bal-chatri trap consists of a wire mesh or Plexiglas cage covered with small nooses and placed over bait (Bull 1987, Smith and Walsh 1981). The nooses entangle the bird's legs when the bird hits the trap. Forsman and others (1984) used mist nets to capture owls. Both Bal-chatri traps and mist nets require a relatively long setup time. "Handgrabs" has been used successfully; the researcher simply grabs the owl's legs when it stoops over the bait. Bull (1987) provides a review of techniques for capturing owls.

Once the owl is captured, one researcher holds the owl while the other attaches bands and the transmitter. The owl's talons are held securely while the owl is lying on its back on the top of the thighs of the holder. The head of the owl can either be toward or away from the holder's abdomen (most commonly it is toward the abdomen). In this position the forearms of the holder also secure the wings of the owl against the thighs and forearms of the holder. This is the least stressful and most comfortable way to hold the owl for both the researcher and the owl. In this position the owl often will close its eyes and remain calm during the entire process. Rustling leaves or other noises may cause the owl to struggle. Owls may become heat stressed on warm days (>27 °C); work should be completed as quickly as possible to avoid this condition.

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Attaching Radio Transmitters

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Once the owl is under control, a U.S. Fish and Wildlife Service (USFWS) band is placed on the owl's tarsus and the band number and leg recorded. A colored band can be placed on the other leg if necessary to meet research objectives. It is illegal to place auxiliary markers on birds, such as color bands or transmitters, without banding the birds with a USFWS band.

After the owl has been banded, the feet are wrapped with an elastic, self-sticking material called Vetwrap or Coband (made by 3M). One foot should be wrapped first, then the two feet wrapped together. Owls should be weighed and examined to determine general health. Each owl should be weighed in a disposable bag and the bag discarded after use to prevent transmission of disease or parasites among owls. Keel prominence can be used to assess the condition of the owl. A sharp, prominent keel is usually an indication of thin breast muscles and therefore poor condition. Condition when the transmitter is attached may be important in interpreting study results.

Both backpack and tail-mounted transmitters can be used on spotted owls. Light-weight transmitters can be mounted on the tail; heavy transmitters must be mounted on the body. The potential for adverse effects on the owl is related to transmitter weight; however, transmitter weight is also directly related to transmitter performance (signal strength, signal duration, and pulse rate). Tail-mounted transmitters fall off when the owl molts its tail in the summer or fall every 2 years. Owls must be recaptured to remove backpacks.

The frequency of the transmitter should differ by at least 0.010 megahertz from the frequency of transmitters on other owls within 20 kilometers, especially if the transmitter is being placed on a subadult. Each transmitter should be marked with the frequency so that the mark will not easily rub or fall off. Turn on and test the transmitter to ensure proper operation. A faulty transmitter will often fail within the first 24 hours of operation, so transmitters should be tested by turning them on for a day before they are placed on an owl. Store transmitters having reed switches about 5 centimeters from other transmitters to prevent the magnets from canceling out each other and thereby activating the transmitter.

Transmitters are prepared with harnessing materials before they are taken to the field. Backpack transmitters need to be fitted with a harness of Teflon ribbon. The harness is cut to form two straps; one strap fits behind the wings of the bird and the other fits around the neck. The straps are passed through transverse holes in the transmitter package and are secured with acrylic (see fig 2). The acrylic keeps the transmitter from moving on the harness, thereby reducing the possibility of abrasions. Test to be sure that the acrylic will prevent the straps from moving. Tail-mounted transmitters are prepared by securing the center of two strands of unwaxed dental floss to the ends of the transmitter with acrylic, which allows each of the four corners to be tied tight against the rachis in preparation for gluing.
Backpack transmitters—Before attempting to attach a transmitter to a wild bird, the researcher should practice on captive owls or watch a transmitter being attached to an owl by an experienced biologist. It is essential that the harness and transmitter be positioned and fit properly. Failure to attach the transmitter correctly will result in undue stress to the owl and possibly death. The transmitter must be positioned so that it and the harness do not interfere with the owl's movements. The harness must be tight enough so that the transmitter does not bounce around the back of a moving owl but not be so tight that the transmitter or harness restrict the owl's movements or cause abrasion. The harness cannot be too loose either, or the owl may get its foot or beak caught underneath it. Care must be taken to position the transmitter and lower (belly) strap of the harness so that the lower strap does not cut into the wing when the owl flies. The transmitter itself must be inspected to make sure it is free of burrs and bumps and that the straps are securely anchored. If transmitters are to be placed on juveniles, the process should be undertaken in July or later when the young are at or near adult weight.
Changes in weight can occur that may cause the transmitter to tighten or loosen. We feel it is more important to attach the transmitter properly for the weight of the owl at the time the transmitter is being attached than to attempt to anticipate a weight change. In our study, weight change for individual adult owls between successive years ranged from -195 grams to +170 grams, with a mean maximum weight change for 42 individuals of 54 grams. In the spring, just before eggs are laid, females may weigh considerably (>150 grams) more than normal.

The backpack transmitter is attached with a Teflon harness and rides between the scapulae on the back of the owl with the antenna running down the back (see fig. 2). If the owl has been carrying a transmitter that needs replacing, all areas of contact between the owl and the transmitter and harness should be examined for chafing and sores. Any anomalies should be recorded.

To attain the transmitter, place the neck loop of the transmitter over one side of the head first then lower it over the other side. The facial disk feathers must be free of the transmitter harness. The researcher should ensure that no damage is done to the owl’s ears as the neck loop is gently lowered over the head and positioned around the neck. Wiggling the transmitter from side to side while pulling down slightly will ensure that the straps are riding below the facial disk feathers. Bring the lower two straps on the transmitter under each wing. The wing of the owl must be gently pulled away from the owl's body at the elbow. Position the straps behind each wing. It is important to ensure that the straps rest between the body and the wing feathers. The axillary feathers tend to rest more closely to the body than do other wing feathers. The straps should be placed between the axillars and the body of the owl. The straps must be flat and not twisted.

A small piece of denim (8 by 8 centimeters) placed on the breast of the owl will prevent feathers from getting in the way while the transmitter straps are fastened together. The two lower straps should be pulled together snugly across the keel. The tightness can be assessed while the straps are held together temporarily with hemostats or similar device. With the transmitter in a good position, sew or crimp the Teflon straps together until they feel secure (about 10 complete stitches).

The neck loop is then pulled down and under the lower straps and temporarily fastened to the body loop with hemostats. Sew the neck loop to the body straps. The junction of the straps should be just below the anterior end of the keel. Cut off the excess strap material and remove the denim. The tightness of the harness should be checked by feeling all the way around the straps. The owl should be allowed to flap its wings a couple of times to permit the transmitter to settle and shift. If the transmitter is too tight, remove and refit it. If the transmitter is too loose, tucks can be sewn flat into the straps. After the transmitter has been properly attached, remove the vet wrap and release the owl. See appendix 3 for a summary of radio-marking procedures. Snyder and others (1989) discuss a similar method for attaching transmitters to snail kites (Rostrhamus sociabilis).
A variety of metal clips can be used to fasten the harness straps together instead of sewing them. We used an electrician’s crimping sleeve for ground wires, and Hamer used a fence clip and stainless steel wire. The tendency with clips and crimping sleeves is to get the harness too tight. Position the clips carefully to prevent abrasion to the owl’s flesh. Although this method is faster than sewing and has been used successfully, we prefer sewing.

It is difficult to objectively assess the fit of a backpack harness. The most accurate way to test the fit is from the back of the owl. While the straps are being sewn, the owl will probably have its head tilted back. This causes the top straps to be too long. Before the straps are actually sewn or crimped, the bird should be held upright so the head is in the natural, upright position. Then the backpack can be assessed for proper fit. The bottom or antenna end of the transmitter should be snug, but not so tight that it cannot be pulled clear of the body. The top of the transmitter should be looser than the lower straps to allow free movement of the head and wings. One finger (8-10 millimeters in diameter) should be able to fit between the harness and the neck with ease. The transmitter should ride squarely between the scapulae with the top of the transmitter level with the bottom of the neck. The harness should have enough slack to allow the transmitter to move slightly.

Dunstan (1972) suggests that a properly fitted harness should be loose enough so that a rod 4 millimeters in diameter can fit between the owl and harness. We feel that using a probe 4 millimeters in diameter to assess maximum tightness could result in the harness being too tight and that checking the position of the transmitter on the back of the owl is a better guide in evaluating harness tightness.

Tall-mounted transmitters—The tail-mounted transmitter is tied and glued to the underside of the base of the owl’s two central rectrices (see fig. 3). To mount the transmitter, the two central rectrices must first be isolated. Alcohol can be used to dampen the undertail coverts. Baby powder sprinkled around the tail region will prevent the epoxy from sticking to feathers; use alcohol and cotton swabs to clean the powder from the rachis where the transmitter will be placed. The transmitter is mounted on the underside of the tail so the owl cannot easily pull on the antenna or transmitter. Excessive bending or spreading of the rectrices may bruise the feather bases and lead to premature molt of the bruised rectrices (Kenward 1985). The mounting strings from each corner of the transmitter are tied around the shafts of the two central rectrices (without puncturing the rachis), as close to the owl as possible, with the antenna running down one rachis. Do not tie the strings so tightly that the rachises are crushed, spread apart, or otherwise stressed. Tie the antenna to the rachis every 3.8 centimeters. After the transmitter and antenna have been tied on, use epoxy to seal the gap between the transmitter and rachis and also on the knots and strings of the transmitter and antenna. If the knots are not covered with epoxy, the owl may tug at the knots and rip the feather. After the epoxy has dried and the transmitter mount has been inspected, remove the vet wrap and release the owl. See appendix 3 for a checklist of procedures. These tail-mount procedures were adapted from Kenward (1987).

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General Telemetry

The following guidelines show some basic telemetry principles:

**Choosing listening points**
- Ensure line-of-sight reception of radio signals.
- Work close (<1 kilometer) to the owl.
- Stay above the owl; avoid being below the owl.
- Separate bearings by at least 10 degrees, preferably 60 degrees.
- Recognize and use the topographic influences on radio signals.

**Listening**
- Use headphones.
- Reduce the gain.
- Adjust the pitch.
- Move around to evaluate the signal.
- Find the peak signal.
- Find the signal nulls.
Once a transmitter has been attached, telemetry should begin as soon as possible to minimize the chances of losing contact with the owl. Owls can be wide ranging; learning where their high-use areas are makes subsequent relocation easier. To find a radio-marked owl, researchers drive to the area the bird is known to frequent or to the place it was last located and listen for the transmitter's signal with the omnidirectional antenna. If more than one bird is present in the area, the researcher uses a scanner to monitor the frequencies of all birds potentially present. Slight differences in frequencies (± 0.002 megahertz) are possible between receivers. Also, each observer detects signal peaks at different pitches. Tune the receiver to adjust the pitch so that the true signal direction is easily ascertained. Scanning should begin well before reaching the area (>5 kilometers) in case the bird moved farther than usual. Such a practice eliminates much of the searching usually required when the bird moves a long way (>2 kilometers) or to an unusual area.

When searching for a bird, the researcher can stop occasionally and take bearings to help estimate the general location of the bird. If only a weak signal is audible with the omnidirectional antenna, and no signal is heard with the H-antenna in the normal horizontal position, holding the H-antenna vertically can help determine the general direction of the transmitter. Experience and familiarity with the topography can help the radio telemetry researcher choose good stations to take bearings from. An experienced researcher may be able to tell the general location of the owl by using signal strength from the omnidirectional antenna and knowledge of the topography (see "Signal Influences and Interpretation"). The researcher should frequently consult a map or aerial photograph to make best use of the road system. Once the researcher has driven to a good telemetry station close to the bird, bearings can be taken to estimate the bird's location.

To estimate the location of an owl, the researcher's triangulation should consist of a minimum of three bearings taken from stations that can be precisely and accurately located on an aerial photograph or map. Bearings should be plotted on photocopies of large-scale aerial photographs or topographic maps. Having predetermined stations marked along frequently used roads and corresponding marks on the aerial photos or maps can greatly assist researchers in determining their location. Experience with signal behavior will enable the researcher to select the best stations to take bearings from and to determine the most trustworthy bearings (see "Signal Influences and Interpretation"). The most trustworthy bearings are not always the strongest signals or the bearings taken closest to the owl. The best bearings are those taken along the line of sight. Each recorded bearing should be evaluated by the signal strength, consistency, and directionality; record this evaluation. Bearings should not be plotted as they are taken because they influence the researcher's subsequent bearings. After three or four good bearings have been taken, they are plotted on a photocopy of the appropriate aerial photograph or map. The owl's estimated location is the center of the resulting polygon (Mech 1983). When more than three bearings are taken, the best three, based on the evaluations, are used for the location. Attach the data sheet to the photocopy showing the owl's plotted position. Use different color pens to record and plot each triangulation to reduce later confusion, especially if several triangulations are plotted on the same photocopy.
Figure 4—When the change in the angle between bearings is small (A), a 5-degree error in one of the bearings moves the polygon center a great distance. When the change in the angle between bearings is large (B), a 5-degree error in one bearing has less effect on the resulting polygon.

Differences between successive bearings ideally should be 60 degrees (Springer 1979), but this degree of separation is seldom achieved in practice because of limited access and interfering topography. The potential for error increases with decreasing angle change between successive bearings (fig. 4). The greater the distance between the researcher and owl, the greater the distance must be between telemetry stations so that the angle between successive bearings changes sufficiently. In our study area, if the owl is less than 500 meters from the stations, stations as close together as 161 meters are used with no sacrifice in accuracy. We used 10 degrees as the minimum angle change in extreme situations. Chu and others (1989) recommend a minimum of 20 degrees of angle separation between successive stations.

To check the accuracy of triangulations and obtain characteristics of day roosts, researchers must walk into the forest and visually locate owls. First, the researcher examines the triangulation and decides on the best route. If the researcher approaches from higher on the hillside than the owl is located, the signal will usually remain strong in the true direction. Approaching from lower on the hillside than the owl is located will necessitate more interpretation of the signal because of the effect of the hillside on the signal. If the owl is on the same hillside as the researcher, the signal will not necessarily be strongest in the true direction of the owl. Signals can be reflected from the hillside opposite the researcher. If the signal is consistently pointing at the opposite hillside, as the researcher proceeds, the owl is on the opposite hillside. Walking up drainages should be avoided unless it is strongly suspected that an owl is in the bottom of the drainage. Steep drainages cause much signal bounce.
and, hence, confusion when tracking. Even small topographic features can block or reflect signals. Tracking experience and practice in the area will help the researcher to correctly interpret signals.

As the researcher nears an owl, the signal strength will increase rapidly with decreasing distance to the owl. As the signal strength increases rapidly, changes in the direction of the strongest signal will also be evident, and the researcher should start looking for the owl in nearby trees. Sometimes the signal will weaken as the researcher passes under the owl. In this case, the signal will strengthen when the antenna is pointed up. To maintain a signal in the true direction of the owl, it is helpful to walk higher on the hill or to the side of the location where the owl is suspected of being.

If the owl is roosting high in a tree, the signal will start strong and gradually become stronger as the researcher gets close. If the owl is roosting low, the signal strength will start weak and quickly become strong as the researcher gets close (Kenward 1987). As signal strength increases, it sometimes floods the receiver and directional- ity may be reduced or lost. Reducing the gain and tuning the receiver helps in discerning the signal peak. Experience will teach the researcher about how far away the bird is for a given signal strength.

Sometimes it is difficult to locate the owl even though the bird is very close. Disconnecting the antenna from the receiver will help determine if the researcher is close to the owl. A signal audible without the headphones and antenna usually indicates the owl is within 50 meters and probably closer. The exact distance that a signal is audible without headphones and antenna depends on the topography and the particular equipment being used. Researchers should experiment with their own equipment to learn the relation between the distance to the transmitter and the signal strength with the antenna disconnected at the receiver, with and without headphones. Sometimes a general direction can be established without headphones and antenna by keeping the receiver close to the body and slowly turning in a circle. The signal may weaken when the researcher’s body is between the owl and receiver. If the bird is high in a tree and next to the trunk, it may be difficult to locate visually. A researcher can often narrow the location of a bird down to a single tree by circling it with the antenna to determine if the peak signal always points to that tree. The signal strength may be best on one side of the tree suggesting that the owl is perched on that side of the tree. The researcher can also scan up and down the tree with the H-antenna and using the peak signal to find the approximate height of the owl in the tree (Kenward 1987). The elimination of other perches or the presence of fresh whitewash may also help indicate the location of the owl. Thus it may be possible to determine the location of an owl without actually seeing it.

**Night Telemetry**

The basics of night telemetry are the same as general telemetry with two exceptions: the researcher is unable to see a great distance, and owls are active at night and more likely to move before a satisfactory triangulation is obtained. Because vision is limited, the researcher must know the area quite well from day reconnaissance to determine the exact location of the stations the bearings are taken from. The use of topography for orientation is not possible at night, which makes interpreting signal variations and their effect on the bearings more difficult. Limited vision can be an advantage because the researcher is less likely to prejudge the location of the owl.
and therefore bias the bearings. At night, the researcher must choose a close object or sight down the boom of the antenna to obtain the compass bearings; during the day, a distant landmark can be used.

Fortunately, spotted owls are a "sit-and-wait" predator and frequently stay in the same place for several hours. To avoid problems associated with movement, bearings should be obtained simultaneously or as quickly as possible. We take a maximum of 20 minutes to complete a triangulation. This seems to be sufficient, because we have detected very few movements when triangulations were completed in less than 20 minutes. If the signal suddenly starts fluctuating in strength and changing direction, the owl may be moving. The researchers should wait a few minutes and start over. If the signal strength remains constant, then the owl has probably stopped moving. If it is not possible to get to the necessary stations to take bearings within 20 minutes, then two observers can be used and simultaneous bearings taken.

**Mortality**—If the researcher is not using a mortality sensing transmitter, there must be a system for checking on suspected mortalities. If the owl is located in the same place for three nights or more, the night researcher should contact a day researcher to investigate. The day researcher should triangulate on the owl and, if there is no obvious movement since the last time the owl was located at night, walk to the owl to determine if the bird is alive.

**Lost owls**—If a night researcher is unable to locate an owl, a day search should be implemented. If an owl disappears and is not quickly found, its home range and habitat use cannot be determined accurately. The day researcher should drive to the last known location or commonly used areas for that owl while scanning for the frequency assigned to that owl. Sometimes a transmitter's frequency will shift slightly, so several hertz above and below the normal frequency must be scanned. Search the entire home range of the owl from elevated sites (signal reception is best from high stations). When a weak signal is obtained, the directional antenna should be used to determine the general direction to the owl. Maps should be consulted to determine the best road system to obtain a quality location on the owl. If the owl is not found during the initial ground search, the transmitter may have malfunctioned and calling surveys may be used to determine if the owl is present in its normal range. If the searcher fails to hear any signal for the bird and calling surveys do not find the owl, then an aerial search should be started.

**Aerial Telemetry**

Aircraft can be used to supplement tracking of spotted owls when ground searches fail, when road conditions (for example, snow) prevent thorough ground searches, or when limited access precludes triangulations on the ground. Aerial tracking can be expensive. Researchers must weigh the costs and efficiencies of thorough ground searches versus aerial searches when deciding how to search for missing birds. If more than 1 week elapses after the ground searches are begun, then an aerial search should begin (weather permitting).

Flights are infrequently needed on studies of resident adult spotted owls, because the owls do not usually move more than 4 kilometers from their high-use area. Some subadults that seemingly pair with resident adults, later exhibit the behavior typical of subadults—dispersing 3.2 to 78.0 kilometers from their capture site (Miller 1989).
Aerial telemetry generally is done from a Cessna 172 or 182 because telemetry gear can be mounted on the wing struts and because these planes are capable of low-speed, low-altitude flying and are highly maneuverable.

The pilot should be briefed before the flight about the nature of the flight and be given instructions on the destination(s), flight patterns, and altitude for flying. Show the pilot a flight map of the search location. Begin the search at the last known location of the transmitter. Initial altitude should be just above the ridge tops so that the researcher can detect any audible signals from malfunctioning transmitters. This low-altitude search should include an area 3 kilometers in radius around the last known location of the owl. If the researcher detects no signal at low altitude, a search pattern at 1800 to 2400 meters should be initiated. The search pattern should be circular with each subsequent circular path 3 to 5 kilometers from the last search path representing twice the minimum transmitting distance (Mech 1983). This pattern ensures that a transmitter signal will be detected because most spotted owl transmitters easily transmit 1.5 to 2.5 kilometers from ground to air, provided they are still transmitting at near-normal power. The pilot will consider safety first and may opt to fly at a different altitude for short periods.

The equipment needed for the flight is listed in appendix 1. Figure 5 shows one way to mount antennas on the airplane. Mounting methods for aerial telemetry must be approved by the Federal Aviation Administration (FAA) but can differ locally. Check with your agency for additional regulations.

Our mounting technique consisted of two H-antennas mounted midway on each wing strut and pointed about 45 degrees down and away from the plane. The elements of the antennas should be taped to prevent them from vibrating off during the flight. The antennas are attached with wing nuts and lock washers to the end of a hollow aluminum rod 5 centimeters in diameter. The rod is attached with two U-bolts to a sheet of aluminum preformed to fit around the struts of the plane. Holes must be drilled in the proper place to accommodate the U-bolts. Wing nuts and lock washers are used to secure the mount to the strut of the plane. A piece of rubber must be placed between each strut and strut mount (fig. 5) to prevent excessive noise and signal interference. The plane's strobe light may also introduce noise at the same pulse rate as the transmitters on the owls, which will result in false detection of a signal. See Hegdal and Colvin (1986), Mech (1983), and Whitehouse and Steven (1977) for other variations and details of antenna mounting.

Monitoring begins as soon as the plane is airborne. If there are other radio-marked birds in the area, monitor the frequency of one bird for a short time to ensure that all equipment is working properly. A switchbox is used to switch on one or both antennas until a signal is heard. Once a signal is heard, the direction of the signal can be determined by switching off one of the antennas and flying a circular path. See Mech (1983) for a detailed description of aerial telemetry methods.

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4Personal communication, Gary Miller, research assistant, Oregon State University, Department of Fisheries and Wildlife, 104 Nash Hall, Corvallis, OR 97331.
Familiarity with the area is essential; the researcher must know the location of the plane at all times so that the location of the owl can be estimated. The configuration of the land and the road system can help estimate the owl's location. Some planes are equipped with loran, which helps in determining the approximate area. Because locations estimated from the air may be imprecise, a triangulation or visual sighting from the ground should be used to precisely locate the bird.

In the field, researchers encounter many problems that prevent them from getting accurate, precise locations for a bird. Our accuracy averages 100 to 125 meters; 95 percent of our triangulation polygons are less than 2 hectares. Two main problems are access and topography. If roads or trails do not exist near an owl, a single researcher cannot get close to the bird and still complete a triangulation quickly enough to reasonably eliminate the possibility of movement by the bird between bearings. When access is poor, many triangulations will be long and triangulation polygons quite large.

The most significant factor influencing the quality and reliability of a radio signal is topography. Topography influences the signal by reflecting it from hillsides and cliffs (Kenward 1987, Mech 1983), thus giving the researcher a false impression of the transmitter's location. Signals affected by bounce may lose their directionality; in other words, the signal will be strong in a wide arc. Signal bounces can often be detected by taking several bearings from different stations, plotting the bearings, and eliminating those inconsistent with the majority (Mech 1983).
An important factor affecting the transmission of radio signals is vegetation. Vegetation can attenuate a radio signal (Chu and others 1989, Mech 1983), distort it by creating interference (Kenward 1987), or reflect it. Bearings taken from stations overlooking nonforested areas are often less distorted than those taken in forested areas. Vegetation that is dense and wet (the type often associated with old-growth forests in the Pacific Northwest) attenuates radio signals more than sparse, dry vegetation (Mech 1983).

The best place to take a bearing from may not be the road closest to the owl. As long as distances are reasonable (<1 kilometer), bearings unobstructed by dense vegetation or topography (line-of-sight bearings) are always best, even if they are taken from a little farther away than a bearing blocked by heavy vegetation or a ridge. Appendix 4 illustrates some examples of poor telemetry situations and suggests improvements. The researcher usually should be within 500 meters of the owl in mountainous terrain for accurate telemetry. Otherwise, bearings should be taken from stations high and opposite the owl when the owl is high on a ridge or midslope, or from low stations in the same drainage if the owl is low.

If the path between the transmitter and receiver is unobstructed by dense vegetation or topographic features, signal strength follows a standard bell curve when plotted against antenna direction; signal strength uniformly decreases as the antenna is pointed away from the transmitter. Variations from this indicate interference and distortion caused by surrounding vegetation and topography. The closer the behavior of a signal is to the "ideal," the more reliable it is.

Beginning researchers often have trouble determining where to start taking bearings and where the optimal telemetry stations are for a given telemetry situation. Researchers experienced in radio telemetry techniques save much time by using signal strength and topography to estimate a bird’s location (for example, within 50 hectares) with the omnidirectional antenna and not wasting valuable time stopping to take bearings when the bird is still too far away. Such efficiency can come only through experience and familiarity with the topography, road system, and habits of individual owls.

The following list of practical tips can help a novice researcher decide where to start taking bearings:

- When a signal is heard and bearings taken, the researcher should think about direction, approximate distance (indicated by signal strength), and which side of a ridge the bird may be on (strong signal if the bird and researcher are on the same side, weak if on opposite sides).

- Bearings taken from stations overlooking nonforested areas are less distorted by vegetation and therefore often more accurate and precise.

- Signal strength is a function of the square of the distance, so halving the distance quadruples the signal strength; the closer a person gets to a bird, the faster its signal strength increases.
If the researcher is driving along the bottom of the drainage, signals can remain relatively constant and fairly strong because the signal is tunneled by the valley; bearings will often point straight up or down the drainage.

When the bird and the researcher are on different ridge tops, signals can be quite strong even though distances are long.

Topography and its effect on signal strength can give clues to the location of a bird. If a person drives by a small hill on the right and the signal weakens (because it is blocked by the hill), the bird is probably to the right side of the road behind the hill.

If a signal becomes stronger as the researcher drives by the mouth of a drainage, the bird is probably up that drainage.

Once familiar with topography and roads, the experienced researcher can continue driving until the signal gets weaker and then backtrack to determine the best stations for triangulation.

The following list gives suggestions for evaluating the reliability of bearings:

- Bearings can be taken from different stations until a good signal, relatively unaffected by bounce, is obtained. This signal indicates the general location or direction of a bird and helps in evaluating the reliability of other, lesser quality bearings.

- Signals affected by bounce are usually inconsistent in strength and direction. Weak signals indicate that a ridge or other topographic feature is blocking the radio signal or that the bird is far away. In either case, walking around a few meters or moving the antenna up or down can help the researcher find the best signal.

- Bearings taken from hilltops are usually reliable for direction but not distance (bird can be far away and still have strong signals).

- Bearings taken from low stations are often distorted by signal bounce; thus signal strength and direction may not indicate the bird’s actual location. Strong signals usually mean the bird is close unless the bird is low or the topography is flat.

- Assuming bounce is not a problem, the direction of the strongest signal usually indicates the actual direction of the bird within 3-10 degrees.\(^5\) Other, weaker signal peaks heard when the researcher stands a few meters away are probably bounce.

\(^5\) Personal communication, Bill Burger, Telonics, 932 East Impala Avenue, Mesa, AZ 85204-6699.
Sources of Error

Drainages can funnel signals and produce consistent but inaccurate bearings.

Signals can often be improved by using high stations (knolls or ridges).

Signals affected by bounce often become polarized and inconsistent in strength. Signals can be improved by turning the directional antenna slightly from horizontal to find the best signal. The directionality of H-antennas decreases rapidly as the antenna deviates from the horizontal position and approaches vertical. Only a general direction can be estimated when the H-antenna is held vertically.

Signals fluctuating in strength when the antenna is stationary suggest that the bird may be moving and that the researcher should wait for the bird to stop before triangulating again.

Interference between two radio waves reaching the antenna from different paths may cause strong signals to disappear and then reappear when the researcher takes a few more steps (Mech 1983). This phenomenon most often occurs when the distance between researcher and transmitter is small.

Two factors affecting the size and shape of the error polygon and the accuracy of the location are the system precision and the location of the transmitter relative to the receiving system (Lee and others 1985, Springer 1979). The system precision is affected by the equipment, observers, and telemetry techniques. Antennas have an inherent imprecision of two to three degrees (Mech 1983). Springer (1979) found no significant differences in bearings among receivers. The type of compass used can be a source of error, because some models are more precise than others. We use a hand-held compass with declination adjustment. Declination settings should be checked periodically to ensure accuracy.

Receiving antennas become more precise with increasing numbers of elements (Kenward 1987); however, antennas with three or more elements are cumbersome and impractical to carry in steep, vegetated terrain. Fixed tower stations are not practical for wide-ranging species in rugged terrain. The portable H-antenna allows the researcher to choose among numerous telemetry stations and, at any particular station, to move around to detect bounce or signal distortion caused by vegetation or topography.

Reliability of estimates of location reflects the number of bearings taken. Three bearings have a greater probability of accurately locating an owl than do two bearings (Springer 1979). The scale of the photo affects the precision with which bearings can be plotted. The scale should not be so small that the width of the pencil induces error or that the detail of the road stations are difficult to determine (>1:24000 [1 unit = 24000 unit]), but it should not be so large that the photos or maps are impractical to carry or store (<1:1000). Photo distortion is another source of error. If photos with distortion are used, errors will occur in the accuracy of the location when the outer third of the photo is used for any part of the triangulation. We use 1:12000 ortho-photos corrected for distortion, but corrected photos are not always available.
Animal movements may account for errors in locations. Animals that move frequently or continuously will require two or three observers to take simultaneous bearings (Storm 1965).

The source of most errors is the location of the transmitter relative to the receiving system (Chu and others 1989, Lee and others 1985, Springer 1979). Storm (1965) found that locations on flat ground up to 400 meters away are accurate to within 16 meters, but when the receiver and the transmitter are separated by ridges, the error increases to 96 meters. The closer the transmitter is to the ground, the more effect topography has on signal transmission and quality.

Signals can be absorbed or reflected by surrounding vegetation. The error increases with greater distance between transmitter and receiver. By working as close to the transmitter as possible and using bearings providing great angle separation (20-55 degrees), Chu and others (1989) found that much of the error associated with the telemetry system can be eliminated.

As with all scientific research, quality control is essential. The research findings will be only as accurate as the data used to draw the conclusions. It is very important for researchers to constantly check the accuracy of their triangulations and accompanying data. There are three major steps to follow to maintain quality telemetry locations: (1) check the accuracy of individual telemeters and their equipment under controlled conditions, (2) check the accuracy of locations in the field, and (3) check for errors after the data are recorded.

The ultimate responsibility for the quality of the telemetry locations lies with the researcher in the field. Telemetry depends heavily on the judgment of the researcher. In determining a location, the researcher must consider all possible influencing factors. Once a location has been recorded, there can be no questioning the location that was determined in the field because owls may indeed occur in unlikely habitat or in ecotones (see "Sources of Error").

The best opportunity to check the accuracy of triangulations is during daylight. Because the owls do not move much when on day roosts (see "Spotted Owl Biology"), researchers can complete a triangulation and then walk into the forest to ascertain the owl’s actual location. Researchers can also triangulate on transmitters placed in known locations in the field. If a researcher is having difficulty with a triangulation or is unsure about the location, other roads or access points should be checked and additional bearings taken to verify or refute the original triangulation. Researchers must check a variety of their triangulations—long, short, large, and small triangulation polygons, and so forth. More of the long-range triangulations should be checked because they have the greatest chance for being in error.

Checking the accuracy of triangulations is more difficult at night than during the day; the researcher cannot walk into the forest to ascertain the location. Occasionally the researcher may hear a vocalization from an owl, but unless the owl is very close, it is difficult to pinpoint the location. The best way to verify night triangulations is to drive additional roads and take more bearings as mentioned above. Because of the time necessary to check a triangulation and the possibility of a bird moving before the check is made, verification of night triangulations is difficult.
Data sheets should be filled out completely and legibly in the field. If data are incorrect or illegible, then erroneous information will be entered in the data set. Plotting should be done in the field so that a triangulation polygon of acceptable size is obtained. Taking a few extra minutes to obtain a good telemetry location and record it accurately and clearly is well worth the time.

After returning to the office, the researcher should once again look over the data sheet to make sure everything is complete and accurate. Another researcher, preferably one familiar with the area, should then check the data sheet. When the data are entered into the computer, they can be rechecked for errors before final analysis.

Supervisors must also check the dedication and accuracy of their employees. Supervisors should go out in the field with the researchers and observe them at work. They should also regularly check data sheets for obvious errors or problems. Quality should be emphasized over quantity.

Because spotted owl researchers often work alone, at night, in inclement weather, in remote areas, and on poor roads, a four-wheel-drive vehicle is a necessity. Vehicles used in the field should be designed for rugged off-road use with ample room for the occupants and their equipment. Power, road clearance, maneuverability, simplicity of operation and care, and durability should all be considered in selecting a vehicle.

For safety and efficiency, all vehicles should be equipped with a two-way radio tuned to either agency frequencies or the citizens bands (CB). The radio should be of sufficient power to be useful in remote areas, and researchers should know proper radio communication procedures and repeater locations. The telemetry receiver should be turned off and disconnected from the receiving antenna before any transmissions are made from a short-wave radio; the power surge from a short-wave communication radio could damage the telemetry receiver. Because researchers drive all night, vehicles should have a range of at least 400 kilometers with a full tank of gasoline. Extra-large tanks or dual fuel tanks may be necessary. All off-road vehicles should be equipped with skid and belly plates and tires with a deep, lugged tread designed for off-road use.

Telemetry vehicles should generate little electrical interference. Electrical interference from the engine (engine noise) blocks faint signals and can be very irritating to the researcher, thereby affecting concentration. Engine noise differs with vehicle and manufacturer. Noise filters can be installed on vehicles, but this does not always solve the problem. Suppression of electrical interference on a noisy vehicle can be difficult or costly, and it may be more efficient to replace the vehicle if it is leased.

During adverse weather, roads may become impassable to or easily damaged by four-wheel-drive vehicles. In these instances, a four-wheel all-terrain vehicle or snowmobile may be applicable. Snowmobiles and all-terrain vehicles require trailers for long-distance transport, and drivers need to wear helmets and carry proper safety equipment. Whether researchers are using a four-wheel-drive truck, all-terrain vehicle, or snowmobile, they should know the proper use and the limitations of the vehicles and accessory equipment.
Maps and Photographs

Maps are available that have as much information as desired: topography, habitat type, roads, streams, coordinate grids, and cultural information. Aerial photographs, by their nature, contain all the physical features mentioned above; boundaries, coordinate grids, and obscured roads can be added to the photographs in the lab. In most cases, aerial photographs are preferred over maps because they contain more useful information; wide spots in roads and clearings are evident on photographs but not on maps. The aerial photographs are also a base for obtaining cover-type maps. A trained interpreter can discern cover type, size class, and crown density from aerial photographs. One advantage a map without cover types has over aerial photographs is the lack of bias associated with a researcher's preconceptions of suitable habitat when determining a location.

Recent aerial photographs and maps for the entire study area should be obtained. Areas the birds may use and nearby areas a bird may venture to should be included. Aerial photographs are available in several sizes and scales. A good scale is 1:12000, which allows researchers to discern most landmarks without additional equipment and also allows enough area to be covered by one 21.6- by 27.9-centimeter page so that plotting a triangulation does not require more than one page. There are problems with standard 22.9- by 22.9-centimeter aerial photographs because 60 to 70 percent of the photograph is subject to radial distortion (see "Sources of Error"). Corrected aerial photographs and orthophotoquads are not distorted and are usually available in the 45.7- by 61.0-centimeter size. They can encompass a large area depending on the scale. Orthophotoquads can be ordered with Universal Transverse Mercator grid lines superimposed. If this service is not available, coordinate grids can be overlain on the photograph and permanently drawn in ink, but this can be time-consuming and expensive. Photocopies can be made from the master photograph or map to carry into the field for plotting triangulations and can accompany the data sheet back to the office for analysis.

Each researcher should carry a complete set of photocopied aerial photographs or maps covering their study area as well as road maps covering any place likely to be included in travel. It is sometimes hard to find a particular location on large-scale photographs; but using the photograph in conjunction with a small-scale road map is easy.

Aerial photographs become outdated when new roads are built and logging operations are completed, but roads and clearcuts can be permanently marked on the photographs or maps. Aerial photographs are easily marked with ink, grease pencil, or white paint used to correct typing errors. Updates should be made as soon as they are discovered so that data on habitat use remains accurate. Changes on the base maps should be dated and incorporated into the geographic information system, if one is being used for habitat analysis.

Licenses

The assignment and use of radio frequencies are controlled by the Federal Government. The National Telecommunication and Information Administration (NTIA) administers the use of radio frequencies by Federal agencies. The Federal Communications Commission (FCC) regulates non-Federal users. Use of the radio frequencies and the coordination of frequency assignments is overseen by the Interdependent Radio Advisory Committee (IRAC). This committee, composed of representatives of all the
groups using the frequencies delegated for wildlife telemetry, attempts to coordinate the assignments of frequencies so studies do not interfere with one another. Wildlife telemetry is defined as a secondary radio service and is not afforded protection from interference by other radio sources. Transmissions emanating from telemetric sources are not to interfere with primary services.

Three separate frequency assignments are available for wildlife telemetry:

1. Wildlife and Ocean Buoy Frequency Assignment. Two spectral bands have been allocated to this assignment: 40.66 to 40.70 megahertz and 216 to 220 megahertz. Licenses for using these frequencies are good for 2 years. There are several restrictions governing the power of transmitters and these should be considered before applications for these assignments are completed. This assignment is available to both Federal and non-Federal users.

2. Department of Interior Frequency Assignments. This assignment controls the 164 megahertz frequency band and is available solely to Federal users. Licenses for these frequencies are available for 5 years.

3. Experimental Service Assignments. This classification is available to non-Federal users wishing to use frequencies not otherwise available to them for radio telemetry. A detailed statement of reasons for requesting these frequencies must be presented, and researchers must be willing to submit detailed results of their research. Use of these frequencies is subject to periodic review and should not be considered for long-term studies. Non-Federal users may apply for use of Federal frequencies under this assignment.

Applications to use radio frequencies are directed to the appropriate agency, either the NTIA or the FCC, depending on the status of the user. The licensee is the group or agency the radio transmitters belong to. Federal users, or licensees, use standard request forms (that is, Form DI-800, Request for Radio Frequency Assignment). Most Federal agencies have developed a standard procedure for handling and coordinating requests for radio frequency assignments. Many agencies use their radio frequency assignments for two-way radio communication, which will interfere with radio telemetry.

Non-Federal groups apply to the FCC and will be required to complete FCC Form 442, "Application for New or Modified Radio Station Authorization Under Part 5 of FCC Rules, Experimental Radio Services" and possibly Form 440-A, "Supplemental Information for Application in the Experimental Radio Service Involving Government Contracts." The local FCC offices may be unfamiliar with the procedures for obtaining licenses for radio telemetry. For more information on the procedures and help in applying for frequency assignments, write the Federal Communication Commission, Frequency Liaison Branch, 2025 M Street, Washington, DC 20554.
Permits

Federal agencies are required to await licensing before ordering radio equipment. Non-Federal groups should also wait for the arrival of their license before ordering equipment, because the equipment necessary will differ based on the frequencies assigned. Researchers should coordinate with the wildlife agency of the state the work is done in. That agency may keep a roster of frequencies being used by wildlife researchers to avoid interference among studies, and it may be possible to obtain permission to use frequencies under the state's license. See Kolz (1983) for more information on the assignments of radio frequencies.

Spotted owls, like other raptors, are protected under the Migratory Bird Treaty Act (U.S. Laws, Statutes, etc. 1918). A permit therefore is required to take, possess, transport, sell, purchase, band, and mark the birds and their parts including feathers, eggs, and nest (Code of Federal Regulations 1988). Applications for banding and marking permits must be made to the Bird Banding Laboratory, Office of Migratory Bird Management, U.S. Fish and Wildlife Service. Laurel, MD 20707 and to the Endangered Species Office, USFWS. Banding permits do not authorize the killing, removal from the wild, or holding of birds in captivity. Salvage permits for dead birds or bird parts must be requested from the regional offices of the USFWS.

Each application asks for general and certification information plus specific information on species and numbers involved, location of collecting, statement of purpose, name and address of collecting person and their institution, and permit number and expiration date of any state or local permits.

The banding and marking permit allows specified migratory birds to be banded. They may be banded only with USFWS numbered leg bands. Other bands, dyes, and markers must be specifically authorized by the permit. Radio transmitters must be included as an auxiliary marker. Birds found dead or killed as a result of the normal banding operation may be salvaged and donated to scientific or educational institutions. Permit holders are required to maintain accurate records of their activities and file reports with the USFWS as outlined in North American Bird Banding Techniques (U.S. Fish and Wildlife Service 1980). Marking or banding permits are valid for 2 years from the date of issue, unless otherwise stated on the permit.

In addition to a Federal banding permit, a state permit is required. Oregon and Washington require a "Scientific Taking Permit" to trap and release spotted owls. Permits are required to trap and mark, salvage, and take specimens of most species of wildlife. The need for permits should be investigated and the appropriate permits obtained before any field work is begun.

Telemetry Equipment

Different frequencies behave quite differently under otherwise constant conditions, and researchers must let the specific research situation and FCC regulations guide the choice of a frequency band for the telemetry study. The frequency use must also be coordinated with other researchers in the area who are using radio telemetry so that frequencies on adjacent studies do not overlap. Topography and vegetation tend to reflect and attenuate less with lower frequencies (32 to 49 megahertz) than with higher frequencies (150 to 164 megahertz); however, low frequencies require large receiving antennas that are less practical than the relatively small antennas used for higher frequencies (Mech 1983).
It is usually safe to assume that anything attached to an owl can be expected to have some form of impact on the bird. The radio transmitter might encumber its movements or modify its behavior. These factors must be considered when the transmitter size and method of attachment are selected. The USFWS (1980) recommends that the transmitter and harness weigh <3 percent of the body weight of the bird; Cochran (1980) recommends 4 percent or less.

We use two types of transmitters on owls: backpacks and tail mounts. The backpack transmitters weigh about 20 grams, are powered by lithium batteries, and have an estimated life of 10-13 months. The life expectancy and weight of a transmitter depend on its efficiency, signal strength, pulse rate, and pulse width. The tail-mounted transmitters weigh about 6 grams and have an estimated life of 12 months. The lighter weight of these transmitters is possible because of the slower pulse rate (about 38 beats per minute versus 70 beats per minute on backpacks) reduced signal strength, shorter pulse widths, and different transmitter design. Although we have only limited experience with tail-mounted transmitters, we feel that they have the least impact on owls because of their smaller size and weight and the method and location of attachment.

Because the tail-mounted transmitters are attached to the owl's rectrices and are not in contact with the bird's flesh, there is little opportunity for abrasion and proper fit of the transmitter is not a problem. The rectrices are molted every other year (Foreman 1981) so there is no need to recapture the owl to remove the transmitter. Should the tail-mounted transmitter malfunction, however, replacement of the transmitter is difficult if not impossible. The slower pulse rate and weaker signal on the tail-mounts make determining the location of the owl more difficult. The weaker signal may not be audible when the bird is far from the road (>800 meters) or in steep drainages. Backpack transmitters, with their more powerful signals, can lessen these problems. Care must be taken not to attach tail-mounted transmitters immediately before the owl's tail molt. If molt history is unknown, attaching transmitters after mid-August will ensure at least 1 year (roughly) of tracking before the tail feathers are replaced.

Receivers should be selected based on the transmitter and type of telemetry to be done. Attach a scanner to the receiver if several birds are followed in one area. A scanner allows the researcher to scan for several (programmable) frequencies. The scanner can be removed to reduce weight when the researcher is walking in the forest to the owl. Most receivers are susceptible to moisture, so take care to protect them from the elements. Plexiglas, waterproof covers are available, or the researchers can keep the receivers under their rain gear or in clear plastic bags.

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6 Personal communication, Fred Anderka, Holohil Systems, Ltd., R.R. 2, Woodlawn, ON, KOA 3MO, Canada
Receiving antennas are constructed specifically for the frequencies they are intended to receive and the desired accuracy. At the higher frequencies (>140 megahertz), those most commonly used in wildlife telemetry, the antennas are small enough to be carried easily through the woods. The most frequently used directional antenna is the three-element Yagi. Another smaller, directional antenna is the H-adcock antenna. One problem with the H-adcock, that the three-element Yagi does not have, is its inability to discern between the front and back signals. The H-adcock antenna has signal peaks of equal strength 180 degrees apart (fig. 6a). If the front elements on the H-adcock antenna are slightly shorter than those on the rear, then the front peaks are noticeably stronger than the rear signal peaks (Kenward 1987). The Yagi and modified H-antenna have signal peaks 180 degrees apart, but because of the antenna construction, the front peak is stronger than the rear (fig. 6b).

The H-antenna has two advantages over the three-element Yagi: it is smaller in size and weight and it has a slightly better angular accuracy (Kenward 1987). Loop antennas are preferred for work in the lower frequencies (Kenward 1987); however, they do not differentiate between front and back signals.

Omnidirectional, or whip, antennas have no discernible signal peaks and receive signals equally well from all directions in a plane perpendicular to the antenna element. These antennas are attached to the roof of a truck and are used to scan for several birds at the same time. With the omnidirectional antenna, researchers are able to judge signal strength and pick the best stations to take directional readings from.

Several other antenna systems could be used. Fixed tower stations are an option if the terrain is flat or if the towers can be mounted on ridgetops, and roof-mounted directional antennas can be used if roads are clear of brush and overhanging limbs. Null-peak systems, which are very accurate, can be used if antenna size is not important. Many other antennas have been designed for use with other animals and in other localities, but omnidirectional, roof-mounted antennas and modified H-antennas are commonly used for telemetry of spotted owls in rugged, heavily forested terrain. The H-antennas are easily portable through steep forested areas and areas with thick brush.
Headphones are necessary in radio telemetry to block out exterior noises and to make subtle changes in signal strength more apparent. It is against the law in some states to drive a vehicle while wearing headphones; even when legal, extra caution should be exercised while driving. Appendix 5 contains a list of manufacturers of radio-tracking equipment. See Cochran (1980), Hegdal and Colvin (1986), Kenward (1987), and Mech (1983) for more information on equipment.

Radio telemetry is a technical process, but the ability to perform it effectively is an art. Researchers must account for many factors when interpreting signals to obtain high-quality bearings. Because the location of telemetry stations relative to transmitter location and the surrounding topography and vegetation influence signal strength, quality, and direction, researchers must be aware of the interrelation among these factors. The quality and quantity of data collected are dependent on well-trained radio telemetry researchers. All radio telemetry projects need a training program to help new personnel gain proficiency in the technique and the terrain they will be working with. As part of their training, they should collect the types of information called for in the study. The cost to a project of insufficient training can be great in lost data (when birds move beyond their normal range and return before they are relocated), money (increased cost for staff hours and vehicle operations when birds have to be relocated), and morale due to the frustration of chasing lost birds without success. Research conclusions are only as good as the data they are derived from; therefore, researchers should provide each team member with the capabilities to perform their job adequately. This section contains exercises to assist the novice researcher in interpreting signal quality so they can use signal characteristics as clues in locating the transmitter rather than as impediments resulting from misunderstandings.

As an introduction to telemetry, take a receiver and transmitter to a large flat field and become comfortable with its use. Stand at various distances from the transmitter and move the antenna through 360 degrees by simply extending an arm and spinning the body around. Note how the signal strength increases as the antenna approaches the direction of the transmitter, peaks when it is pointed directly at the transmitter, and decreases as it is moved away. Become familiar with line-of-sight signals as the first step in interpreting the variations typical of the mountainous country the spotted owl lives in. Try homing techniques by locating transmitters hidden in tall grass or brush. Note that when approaching the transmitter, the signal becomes remarkably stronger. Reduce the gain to reduce the signal noise on either side of the true direction of the transmitter; you will be able to pinpoint the true location. Move several meters in various directions to separate good signals from bad. Pinpoint the true direction when signals come from several directions by adjusting the tuning knob while readjusting the gain. This eliminates problems associated with strong signals received when the transmitter is 180 degrees from the direction the antenna is pointed. Familiarize yourself with the relation between the distance from transmitter and signal strength with and without the antenna, antenna cord, and headphones.

Once familiar with radio signals unaffected by bounce, attempt to locate transmitters in areas representative of the study site. Have several transmitters placed along a road at various distances, and elevations and among various topographic features. Accompanied by a researcher experienced with radio telemetry, drive the road, scan for each frequency, choose the appropriate station for each bearing, and record signal strength, quality, and direction for each. Use a Y-adapter so that two headphones
can be linked to the same tracking equipment; discuss the various types of signals and problems and solutions with an experienced researcher. Radio-marked owls may be substituted for hidden transmitters if the exact location of the owl is known and the telemetry nuances of the area are understood. This exercise is designed to enable new researchers to quickly appreciate the effects of topography on signal strength and direction.

Another exercise is to take bearings on an owl as you return to the vehicle from the owl’s roosting site. Note how the signal changes as you get farther away and as various topographic features act on the signal. This is a rewarding exercise because it offers explanations on trouble areas encountered during the walk into the area. Practice and patience are the keys to developing an expertise in radio telemetry.

After gaining some familiarity with the behavior of radio signals in various types of topography, familiarize yourself with all roads in the area. Drive along each road and note the topography and any effect it could have on signals, road condition, seasonal access, potential telemetry stations, and orientation to timber stand (can good angle separation be obtained from this road alone, or if not, what other roads can be used to gain telemetry access to an area within the shortest time?). Large-scale aerial photos are invaluable in putting various roads and timber stands into perspective. Consult the photos while driving the area so you can associate photo locations with actual field locations.

Safety

Safety should be foremost in the minds of people involved with owl telemetry. The researcher spends a lot of time driving in adverse conditions; poor roads, heavy logging traffic, fog, snow, and rain are just a few of the hazards encountered. Walking into an area during daylight presents its own set of safety hazards with steep terrain, fallen trees, slick rocks, and falling branches. Most owl researchers work alone and at night, which complicates and amplifies hazards.

Spotted owl researchers should always practice safe driving habits. Before leaving for the field, do a general vehicle inspection. Drive at a reasonable speed and keep to the right side of the road. Be especially alert for oncoming vehicles and other road hazards (for example, fallen trees or slides), look ahead for the eye shine of deer, and go slowly. When stopping to take bearings on a well-traveled road, turn on hazard lights or leave the parking lights on. Be especially cautious when backing up or turning around. Drowsiness presents an additional hazard when driving at night. If you feel you are getting sleepy, DO SOMETHING ABOUT IT! Take a nap, walk around, or drink coffee, but do not drive when fighting sleep. Regular, predictable work schedules can help promote good sleep patterns.

All researchers should carry safety equipment in their vehicle at all times. This equipment includes jack, spare tire and tire change tools, tire chains, tow chain or winch, jumper cables, shovel, ax, basic tools, fire extinguisher, flashlight (with good batteries), first aid kit, sleeping bag, and two-way radio. In addition, researchers should carry other emergency equipment when hiking towards owls that includes first aid kit, hard hat, extra clothes, food, water, rain gear, matches, whistle, map and compass (and be able to use them), and flashlight. Layer clothing so it can be removed and added to prevent sweating.
A few basic safety procedures can temper the hazards of owl telemetry work. Researchers should always use a sign-out sheet and indicate specific destination, time out, expected return time, and always sign in upon return. Someone should regularly check the sign-out sheet to see if a researcher is out unusually late. In the daytime, it is a good practice to leave a note with the vehicle indicating direction and time of departure. Researchers should use four-wheel-drive vehicles and have a full gas tank before leaving. Know the limitations of the vehicles and do not exceed them. Each vehicle should be equipped with a good two-way radio so researchers can coordinate their efforts, call for help, let someone know if they will be out late, or simply talk to ward off sleep. With the proper emergency equipment, a few basic safety procedures, and good driving habits, researchers can do their jobs in relative safety.

**Acknowledgments**

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**Literature Cited**


Appendix 1

Telemetry Equipment—

Basic—

receiver
scanner
omnidirectional roof-mount antenna
directional handheld antenna
headphones
compass
colored pens
data sheets
write-in-rain data sheets
stapler (to staple data sheets)
photocopies of aerial photographs or maps to draw triangulations on road maps
list of frequencies
clipboard
watch
headlamp
personal first aid kit

**Additional for roost visits**—

clinometer
plant key
rangefinder
d.b.h. (diameter at breast height) tape
pellet bags and data sheets
flagging (to flag roads and day roosts)
permanent marker (to write on flagging)
binoculars
cruiser’s vest to carry equipment

**Additional for aerial telemetry**—

switchbox
two directional antennas
two wing strut mounts
two pieces of insulating material, to be placed between the struts and strutmounts
two 3-meter flight cords
one 1.5-meter coaxial cable (to use between receiver and switchbox)
duct tape for taping the flight cords to the wing struts
road maps of the entire area to be searched (50-kilometer radius)
flight map for the pilot (available from the airport)
sunglasses
aerial photographs (optional)
camera (optional)
binoculars (optional)

**Capturing Equipment**—

**Basic**—

equipment on basic telemetry equipment list
owl calling tape and tape player
noose pole
extension rod
scale
weighing bag
lure
live mice and rats
tether to hold mice and rats
leather gloves
tape measure
backpack to carry equipment

Additional for attaching backpack transmitters-

radio transmitters and harness
hemostat
needle and rug thread
scissors
vet wrap
bib for owl
crimping tool and crimp sleeves (if using crimp method)

Additional for attaching tall-mounted transmitters—

transmitters
epoxy
toothpicks
something to mix epoxy on
unwaxed dental floss
cards to isolate feathers
paper clips or clamps to hold cards
baby powder
cotton swabs
cotton balls
alcohol
needle
thread
scissors
vet wrap

Additional for banding—

U.S. Fish and Wildlife Service bands
permit or subpermit
pliers
color bands
pop rivet gun
list of color-banded birds in the area
color band assignments

Appendix 2

Noose pole

The noose pole is the most efficient method for capturing spotted owls. A surf casting rod is used to maneuver the loop over the head of the owl. Figure 7 illustrates the loop detail. The split ring or knot placed 9.5 centimeters from the small loop that forms the lasso acts as a stop preventing the loop from choking the owl.
Materials

Materials needed to build a noose pole—

- Stiff surf casting rod (approximately 3.4 meters)
- Spool of string trimmer line (0.040 millimeter), monofilament
- Fly fishing reel (used to hold 8 meters) of excess line, line anchored to reel
- Surgical tubing (9.5 millimeters outside diameter)
- Soft wire to support loop

Appendix 3

Checklist of Procedures for Attaching a Radio Transmitter to a Spotted Owl

**Backpack transmitter—**

1. Record band number and which leg it is on.
2. Vet wrap the feet.
3. Remove the old transmitter and check and record abnormalities.
4. Weigh owl and record weight.
5. Remove magnet from the new transmitter and check whether it is working (note: this is also done prior to departure for the field).
6. Put the neck loop of the transmitter harness over the head of the owl.
7. Lay lower straps out so that they are flat and even.
8. Put each lower strap under the appropriate wing and be sure that all the flight feathers are clear. Be careful of a few straggler feathers.
9. Pull lower straps up high and over the keel.
10. With denim on the breast, tighten the straps over the keel and use the hemostats to hold them in place.
11. Readjust if necessary to be sure the harness is properly fitted.
12. Sew the breast straps securely.
13. Pull the neck loop straps under the breast straps and sew securely.
14. Make sure that the fit is correct. Take tucks if necessary or cut the transmitter off and start from step 5.
15. Remove denim.
16. Remove vet wrap and release owl in an open flight path.

**Tail-mounted transmitter—**

1. Record band number and the leg it is on.
2. Vet wrap the feet.
3. Remove the old transmitter and record any abnormalities.
4. Weigh owl and record weight.
5. Remove magnet from the new transmitter and check whether it is working (this is also done before departure to the field).
6. Isolate central rectrices (12 rectrices total).
7. Dampen undertail coverts with alcohol.
8. Put baby powder around tail region; use alcohol and cotton swab to clean powder from rachis where transmitter and antenna will mount.
9. Mount transmitter on underside of tail as close to bird as possible.
10. Tie antenna side of transmitter first. Tie around shaft (do not puncture or crimp shaft).
11. Tie antenna to rachis every 2.5 to 3.8 centimeters.
12. Epoxy in the gap between transmitter and shaft.
13. Epoxy over knots and strings.
14. Use baby powder to prevent epoxy from sticking to feathers.
15. Allow glue to dry.
16. Remove vet wrap.

Appendix 4
Examples of Poor Telemetry Situations

The following diagrams illustrate topographical features (such as ridges and drainages) that affect radio signal reception and suggest telemetry stations best suited to minimize these affects.

A steep road cut blocks radio signals from below. Moving above the transmitter and close to the edge allows for a line-of-sight bearing.
A small hill blocks and distorts a radio signal even though the distance to the trans-
mitter is short. Moving across the drainage to the opposite hill facing the transmitter
allows for a line-of-sight bearing and much improved radio signals (stronger and
more directional), even though the distance between the researcher and transmitter
is greater.

Radio signals are generally poor when the researcher is in the bottom of a valley
because the signal bounces off the opposite hillside. Better locations can generally
be obtained from above the transmitter and, ideally, from the hilltop opposite the
hillside where the transmitter is.

Strength and directionality of radio signals can often be greatly improved by moving
to the edge of the hill; this creates almost a line-of-sight bearing as opposed to the
bearing taken from further back.

When the transmitter is low on the side of a ridge, signals will greatly improve if the
researcher moves to the same side of the ridge as the transmitter.
Appendix 5

Source of Supplies

Radio telemetry equipment—

Advanced Telemetry Systems, Inc.
Box 398
Isanti, MN 55040
(612)444-9267

Austec Electronics, Ltd.
#1006, 11025-82 Avenue
Edmonton, AB T6G OT1
Canada
(403)432-1878

AVM Instrument Company, Ltd.
2368 Research Drive
Livermore, CA 94550
(415)449-2286

Beacon Products Company
360 East 4500 South
Salt Lake City, UT 84107
(801)265-1383

Biotrack
Stoborough Croft
Grange Rd., Stoborough
Wareham, Dorset BH20 5AJ
England
Wareham (09295) 2992

B- & R Ingenieurgesellschaft mbH
Johann-Schill-Str. 22
7806 March-Buchheim
West Germany

Cedar Creek Bioelectronics Laboratory
University of Minnesota
Bethel, MN 55005
(612)434-7361

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The list of radio telemetry equipment suppliers is taken from Hegdal and Colvin (1986, p. 680-681) and Fuller (1987, p. 127).
CompuCap
8437 Yates Avenue North
Brooklyn Park, MN 55443
(612)424-2373

Custom Electronics
2009 Silver Court West
Urbana, IL 61801
(217)344-3460

Custom Telemetry and Consulting
185 Longview Drive
Athens, GA 30605
(404)548-1024

Holohil Systems Ltd.
RR2
Woodlawn, ON KOA3MO
Canada
(613)832-3649

L.L. Electronics
P.O. Box 247
Mahomet, IL 61853
(217)586-2132

Lotek Engineering, Inc.
11 Younge St. S
Aurora, ON L4G1L8
Canada
(416)727-0181

Microwave Telemetry
610 Chestnut Ave.
Townson, MD21204

Midwest Telemetry
Attn: Judy Montgomery
P.O. Box 773
Urbana, IL 61801
(217)367-1904

Narco Scientific
7651 Airport Blvd.
P.O. Box 12511
Houston, TX 77017
(713)644-7521
Remote Monitoring Systems
P.O. Box 2155
Walla Walla, WA 99362
(509)529-1060

Scien-0-Tech Consultants, Ltd.
Nox 14426
Nairobi, Kenya
or
Box 87054
Mambasa, Kenya

Smith-Root, Inc.
14014 N.E. Salmon Creek Avenue
Vancouver, WA 98665
(206)573-0202

Telemetry Systems, Inc.
Box 187
Mequon, WI 53092
(414)241-8335

Telenics
932 East Impala Avenue
Mesa, AZ 85204-6699
(602)892-4444

Wildlife Materials, Inc.
R.R. 1, Grant City Road
Carbondale, IL 62901
(618)549-6330

**Teflon tubing for transmitter harness—**

Bally Ribbon Mills
23 North Seventh Street
Bally, PA 19503
(215)845-2211

The paper is a practical guide to field methodology for conducting a radio telemetry study of spotted owls (*Strix occidentalis*) in mountainous terrain. It begins with a synopsis of spotted owl biology and basic telemetry. The criteria used to select which owls will carry transmitters are discussed as are location and capture methods. Instructions for attaching transmitters and recommendations for general, night, and aerial telemetry are presented. Suggestions are given for controlling data quality, for researcher training and safety, and for field interpretation of radio signals. Equipment needs and license and permit requirements are also discussed.

Keywords: Radio telemetry, *Strix occidentalis*, spotted owl, Pacific Northwest, methods.

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