Wildlife Radio-telemetry

Standards for Components of British Columbia's Biodiversity No. 5

Prepared by
Ministry of Environment, Lands and Parks
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Resources Inventory Committee

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Preface

This manual presents standards for the use of wildlife radio-telemetry in British Columbia. It was compiled by the Elements Working Group of the Terrestrial Ecosystems Task Force, under the auspices of the Resources Inventory Committee (RIC). The objectives of the working group are to develop inventory methods that will lead to the collection of comparable, defensible, and useful inventory and monitoring data for the species component of biodiversity.

This manual is one of the Standards for Components of British Columbia's Biodiversity (CBCB) series which present standard protocols designed specifically for groups of species with similar inventory requirements. The series includes an introductory manual (Species Inventory Fundamentals, No. 1) which describes the history and objectives of RIC, and outlines the general process of conducting a wildlife inventory according to RIC standards, including selection of inventory intensity, sampling design, sampling techniques, and statistical analysis. The Species Inventory Fundamentals manual provides important background information and should be thoroughly reviewed before commencing with a RIC wildlife inventory. RIC standards are also available for vertebrate taxonomy (No. 2) and animal capture and handling (No. 3). Field personnel involved in the telemetry should ensure they are thoroughly familiar with the latter of these standards before engaging in any restraint or handling of wild animals.

Standard data forms are required for all RIC wildlife inventory. Survey-specific data forms accompany most manuals while general wildlife inventory forms are available in the Species Inventory Fundamentals No. 1 [Forms] (previously referred to as the Dataform Appendix). This is important to ensure compatibility with provincial data systems, as all information must eventually be included in the Species Inventory Datasystem (SPI). For more information about SPI and data forms, visit the Species Inventory Homepage at:
http://www.env.gov.bc.ca/wld/spi/ric_manuals/

It is recognized that development of standard methods is necessarily an ongoing process. The CBCB manuals are expected to evolve and improve very quickly over their initial years of use. Field testing is a vital component of this process and feedback is essential. Comments and suggestions can be forwarded to the Elements Working Group by contacting:

Species Inventory Unit
Wildlife Inventory Section, Resource Inventory Branch
Ministry of Environment, Lands & Parks
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The Resources Inventory Committee consists of representatives from various ministries and agencies of the Canadian and the British Columbia governments as well as from First Nations peoples. RIC objectives are to develop a common set of standards and procedures for the provincial resources inventories, as recommended by the Forest Resources Commission in its report “The Future of our Forests”.

For further information about the Resources Inventory Committee and its various Task Forces, please contact:

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Terrestrial Ecosystems Task Force

The background information and protocols presented in this document are based on the unpublished draft manual, Standards Manual for Wildlife Radio Telemetry, prepared for the Resources Inventory Committee by Lorraine Andrusiak, Eric Walters, Eliot Terry and Keith Simpson of Keystone Wildlife Research. The draft manual was edited to its present form by James Quayle with earlier assistance from Ann Eriksson. Helpful review comments were provided by Myke Chutter, Helen Schwantje, D.V.M, and Malcolm McAdie, D.V.M. All decisions regarding protocols are the responsibility of the Resources Inventory Committee.

The Components of British Columbia’s Biodiversity series is currently edited by James Quayle with data form development by Leah Westereng.

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1. INTRODUCTION

Wildlife radio-telemetry may be defined as the transmission of information from a transmitter on a free-ranging wild animal to a receiver. Wildlife-related telemetry is also known as radio tagging, radio-tracking or simply ‘tagging’ or ‘tracking’. Advances in the field of wildlife telemetry have made it possible to acquire detailed data on many aspects of wildlife biology, including habitat use, home range size, mortality and survivorship, and migration timing and routes. Since many wildlife species are secretive and difficult to observe, radio-telemetry has provided a valuable tool to learn more about their respective life-histories. As a result, radio-telemetry studies are very common throughout the current wildlife literature (see Bibliography).

Despite its popularity, radio-telemetry is inappropriate under many circumstances. It is an expensive and time-consuming technique which has proven to be unsuitable for use in some species (due to the animal’s size or life-history traits). Despite the frequency with which radio collars and other transmitters are attached to research animals, surprisingly little is known about their effects on the behaviour and survivorship of the species in question. Certain First Nations groups strongly believe that collars and even ear tags influence behaviour and therefore actively oppose the use of these devices on game animals. The potential for modified behaviour and differential survival of radio tagged animals may introduce additional bias and error which could be reflected in study results. Quite clearly it can also be detrimental to the animal wearing the tag. The placement of a radio tag on an animal represents a commitment by the researcher, and there is the possibility that it is done at the expense of the animal it is placed on. Thus, transmitters should only be attached when project funding guarantees the ability to monitor a tagged animal for the life-span of the transmitter.

Given these realities, this manual is intended to provide biologists with some guidance for using the technique of wildlife telemetry in British Columbia. It is not intended to be used as a comprehensive ‘how-to’ manual covering all of the wildlife species in the province, but rather as a general guide covering basic telemetry equipment, principles of the technique and experimental design, while providing some general recommendations for the major species groups. It is the philosophy of the authors that a successful telemetry study is one that adheres to the principles of experimental design in conjunction with a thorough literary review, discussion with other biologists and telemetry suppliers, and a strong familiarity with the focal species. No manual can take the place of thorough preparation and users are encouraged to utilize all the resources at their disposal in order to obtain more specific information.

This manual is organized into 7 major sections which reflect the normal scope of decisions required to plan and initiate a radio-telemetry study.

1. In the first section, discussion focuses on considerations relating to the licensing required to initiate a telemetry study and the humane treatment of study animals.

2. The second and third sections deal with radio transmission. Fundamental information is presented about the mechanics of radio transmitters, and protocols and key considerations are provided to ensure their safe attachment.
3. The fourth and fifth sections focus on signal reception. Information is presented about options for receivers and antennas, as well, as recommendations for successful relocation.
4. In the sixth section, the design of radio-telemetry studies is discussed in relation to specific objectives. General considerations are presented as are more specific ones for five common objectives (habitat use, home range, movement pattern, and demographic studies).
5. Finally, the seventh section provides examples from representative species groups to illustrate equipment and methods used by other researchers as well as the results obtained. These examples should not be confused with recommendations.

It is recommended that experienced researchers be consulted for advice, particularly for first time studies in new areas or with unfamiliar equipment. Many important technical problems which can be critical to a telemetry project are often not recorded in the literature. Consultation with knowledgeable peers and other experts should be a standard procedure, particularly if the use of new or “unproven” technologies is proposed. The Internet provides several interlinked telemetry user contacts. An extensive list of product manufacturers, Internet addresses and published reports is provided in sections 9 and 10 to facilitate networking and contacts.

1.1 Ethical Considerations

In British Columbia, it is strongly recommended that all studies involving radio-telemetry of terrestrial wildlife undergo peer and veterinary review prior to commencement. This review should include examination of inventory objectives and methods, evaluation of expected ecological impacts, and provision of permits by the proponent (e.g., telemetry amendment to banding permit). In addition, experienced reviewers can provide valuable guidance regarding transmitter weight, attachment method and capture protocol, helping to avoid problems which have already been solved by other professionals. Because of the invasive nature of telemetry projects, researchers should be particularly diligent that proper field procedures are followed. Apart from the obvious humane considerations, animals which are unduly stressed or influenced by the capture technique and/or radio tag will not be representative of normal behaviour for the species. In extreme cases, injury and mortality may be the end result.

Researchers planning a radio-telemetry study should strive to ensure that study animals are affected as little as possible by the transmitter, and are handled humanely and effectively during capture and transmitter attachment procedures. Capture techniques should be designed to minimize stress to the animal at all times, and their selection should be based upon an understanding of the behavioural and physical characteristics of the species to be restrained, the field

conditions under which the procedure will occur, the knowledge and skill of the persons handling the animals, the goals of the investigation, and the availability of appropriate equipment and facilities. Capture sessions should be timed to avoid disturbing animals during their most sensitive periods, such as when they are breeding or tending young. If chemical restraint is required, it should only be performed by trained personnel who have successfully completed the Ministry Chemical Immobilization Training Course. In addition to administering an immobilizing drug, personnel involved in chemical immobilization should be capable of monitoring the anaesthetized animal and providing appropriate support measures should an anaesthesia emergency occur. As well, any animal which is subjected to general anaesthesia should not be released or left unattended until it has fully recovered. Specific guidelines for collection and trapping, restraint and handling, and investigator impact, are outlined in manual No. 3, Live Animal Capture and Handling Guidelines for Wild Mammals, Birds, Amphibians and Reptiles. Researchers should be thoroughly familiar with the content of this manual before commencing any telemetry work.

Transmitters must be attached in a manner which will minimize any effects on the study animal. Researchers should take extreme care when fitting harnesses and collars to ensure that they allow freedom of movement so that an animal's movements are not hampered, but are not so loose-fitting as to increase the danger of entanglement. Additionally, they should exercise caution if using a new method of transmitter attachment and generally avoid any method which has been reported to cause adverse effects in the study species or similar species. Ideally, researchers should test attachment methods on captive animals before using them in the field. This also allows inexperienced researchers to become familiar with animal handling and transmitter attachment under controllable conditions. Zoos, game farms, falconers and wildlife rehabilitators are possible sources of captive animals on which to test transmitter attachments. (Note that permission should be obtained from the appropriate government agency before testing transmitters on releasable rehabilitation animals). More specifics of transmitter attachment are presented later in this manual.

Public perceptions should also be considered during design of a telemetry study, as, in some cases, members of the public may be more sensitive to marking methods and radio-tags than the animals themselves. In some areas, such as parks, people may be disturbed by the sight of wildlife with fluorescent collars and ear-tags. Small ear tag transmitters may be more suitable for this type of location. As a minimum requirement, drop-off collars/ harnesses are to be used if possible so that tag attachment is not permanent. Implanted transmitters with external antennas may also cause adverse public reactions. Researchers should make every effort to educate and reassure the public regarding the effects and benefits of telemetry equipment on wildlife.

Finally, it cannot be overstated that although this manual provides useful guidance for the use of radio-telemetry, it is by no means a replacement for appropriate training and practical experience.

1.2 Permits and Licenses

Both the federal and provincial governments have responsibilities for wildlife in British Columbia. It is useful to have an understanding of the jurisdictions of these different agencies to appreciate the licensing requirements for telemetry projects of different species.

The Department of Fisheries and Oceans is responsible for all marine mammals in British Columbia. These will not be covered in this manual.

The B.C. Ministry of Environment, Lands and Parks has sole jurisdiction over all reptiles, amphibians, and terrestrial mammals in the province. The Ministry issues sundry permits to biologists who will be capturing, handling and/or collecting wildlife in the province.

The Ministry also protects the province's birds, and has sole jurisdiction for a portion of these, including all raptorial birds, cormorants and pelicans, upland game birds, kingfishers, corvids, blackbirds, grackles and cowbirds. The Ministry is responsible for issuing sundry permits for activities involving these bird groups.

Environment Canada has superseding authority over the remaining portion of the province's bird fauna: those birds which are listed in the Migratory Bird Convention Act (including most migratory songbirds, woodpeckers, waterfowl, shorebirds, and seabirds). Provincial sundry permits are not required to work with these; however, it is a good idea to inform local BC Environment offices of your intended activities to avoid any confusion, particularly as regional offices tend to receive inquiries from the curious members of the public.

It is generally recommended that birds be banded at the same time as they are radio-tagged. All birds, other than upland gamebirds (for which the province issues separate bands), must be banded with a United States Fish and Wildlife Service (USFWS) band, dispensed through the Bird Banding Office of Environment Canada, in Hull, PQ. Any researchers attaching transmitters to birds banded with USFWS bands will need to meet with requirements for permitting set by the Bird Banding Office. These include letters of approval of an animal care committee and authorization of Industry Canada (see below).

A federal banding permit is required before any banding of birds is allowed. Permits may be obtained through the Canadian Wildlife Service in Delta or directly from the Bird Banding Office in Hull, PQ. Ministry of Environment biologists may obtain subpermits under the Ministry's master permit by contacting the provincial Bird Specialist, Wildlife Branch. Applicants should allow three months to process applications.

Generally speaking, all terrestrial wildlife radio-telemetry studies in the province should undergo both peer and veterinary review. Although it is the intention of the provincial government to establish its own Animal Care Committee review process, this may not be in place for several years. Formal Animal Care Committee reviews are currently limited to those provided by the province's universities. Where sufficient need is present, formal reviews may be arranged in advance for external researchers. In the majority of cases, where this

review process is not available, proponents are strongly recommended to organize their own peer and veterinary review to the satisfaction of the permitting agencies.

In addition to animal handling permits, licensing is also required to operate a radio transmitter. Industry Canada (formerly Communications Canada) requires that each transmitter and receiver be licensed, and assigns the frequencies to be used (A. Thompson, Industry Canada, pers. comm.). This is necessary to avoid potential conflicts with air traffic and other frequencies. Industry Canada recommends that researchers receive confirmation of assigned frequencies before ordering transmitters. As well, any equipment not manufactured in Canada must be certified for approval by the Department of Communications.

In cases where the province is funding the project and is consequently purchasing the equipment, the radio-transmitters should be included under the provincial government licensing agreement with Industry Canada and thus the project may not require its own individual license. To ensure this, researchers must contact:

> Telecommunications, Central Services Section, Corporate Services Division, Ministry of Environment, Lands, and Parks

Applicants for inclusion under the provincial license will be required to provide details of the number of transmitters, supplier, model number, power, range, antenna type, location of any non-mobile receiving stations, and the geographic area of operation. They are also strongly urged to check with other radio-tracking projects in the study area in order to avoid duplication of frequencies. In some cases, it is also recommended to enquire about local frequencies to see if they are commonly used by paging companies or other annoying sources of interference.

For projects which require a separate radio license, application should be made to the closest district office of Industry Canada (Appendix 1). Applicants must provide the same information as they would for the province. Licenses are valid for one year, and a fee is charged for each license.

Researchers who wish to build there own transmitters rather than purchasing commercial ones will likely be subject to additional licensing requirements. Transmitters must be certified to operate in Canada and this will likely require extensive testing by an Industry Canada laboratory. Before development of custom transmitters begins, researchers should contact Industry Canada for details.

Regulatory requirements for all terrestrial species are summarized in Table 1.

Table 1. Regulatory requirements for radio-tagging a wild animal in British Columbia.

MELP=Ministry of Environment, Lands, and Parks; BBO=Bird Banding Office, Environment Canada.

Species	Regulatory requirements
Terrestrial mammals, reptiles, and amphibians	• Peer & Veterinary Review for MELP • BC Sundry permit from MELP • Radio transmission license from Industry Canada
Raptors, cormorants, pelicans, corvids, upland gamebirds, cowbirds, grackles, blackbirds, kingfisher	• Peer & Veterinary Review for MELP & BBO • BC Sundry permit from MELP • Banding permit or subpermit from BBO • Radio transmission license from Industry Canada
Migratory birds as listed under Migratory Bird Convention Act	• Peer & Veterinary Review for BBO • Contact local regional MELP office • Banding permit or subpermit from BBO • Radio transmission license from Industry Canada

2. TRANSMITTERS

Conventional transmitters consist of an antenna, a power source and a transmitter unit. Although this combination is fairly fundamental, the specific components chosen may vary between projects. In light of this, rather than attempt to recommend a particular type of transmitter, it is likely more useful to the researcher to describe the basic equipment options which are currently available for transmitters.

2.1 Antennas

2.1.1 Types of Transmitting Antennas

The two most common transmitting antenna are whip antennas and loop antennas:

1. **Whip antennas**

   Characteristics: Most frequently used. Omni-directional. Usually stainless steel with a Teflon coating. Must be light, strong, and generally withstand a tremendous amount of flexing.

   Pros/Cons: Produce more uniform signal over a greater distance than do loop antennas. Potentially subject to breakage through metal fatigue or corrosion; however, whip antennas may be sandwiched between layers of a collar for protection when attached to rough species (e.g., bears).

2. **Loop antennas**

   Use: With collars, tuned to radiate maximum signal at the exact neck circumference for which they are constructed (±5%).

   Pros/Cons: Signal does not travel as far as whip antenna.

   - Useful for species which would chew/pull whip antenna.
   - Wire loop may serve as both collar and antenna.

2.2 Power Sources

2.2.1 Common Power Sources

1. **Lithium and silver batteries**

   Use: Most commonly used for wildlife transmitters.

   Pros/Cons: Potentially cumbersome.

   Duration and nature of study must complement characteristics of battery life which is directly proportional to pulse period and inversely proportional to pulse width and signal strength (Lessard 1989).

2. **Solar Cell**

   Use: Renewable energy source powered by sunlight.

   Pros/Cons: Low weight, long-lived transmitter package.

   Not recommended for:

   i. Nocturnal species

   ii. Species active under heavy cover.

   iii. Species which occupy burrows or caves.

   iv. Aquatic species which frequently dive (e.g., turtles)

2.2.2 General Considerations

The battery capacity, operational life and duty cycle requirements determine the radio frequency energy the transmitter circuitry can generate and deliver to the antenna (Beaty 1990). The theoretical relationship between battery capacity, current drain and operational life is expressed by the equation:

$$\frac{Battery\_Capacity(milliampdays)}{Avg\_Current\_Drain\_of\_Transmitter(milliamps)} = PackageLife(days)$$

Discussion of transmitter range tends to focus on “Line of sight” (LOS) range. This is the maximum unobstructed distance between transmitter and receiver which produces an adequate signal. Range may be influenced by environmental conditions and geographic factors. High humidity, heavy fog, heavy rain, wet snow, and intervening vegetation will absorb energy from the signal. Radio waves reflecting from rock outcrops or water bodies will also reduce the signal’s energy due to phase cancellation (Beaty 1990). Increasing the transmitter power output by four times results in a doubling in LOS range, and a subsequent fourfold decline in battery life.

In general, larger batteries equate to increased weight, increased life, and increased range. The relationship between battery life and signal range is an inverse one. A transmitter which emits a signal which can be received at long distances will not last as long as one which puts out a shorter-range signal. For wide-ranging species it may be preferable to use long-range, short-life tags, whereas for a study of species with small home ranges, long-lasting tags with shorter ranges may be more appropriate. The range and life of a transmitter is dependent on the size of the battery, which in its turn depends on the size of the study animal and the method of transmitter attachment. The best trade-off between weight, life and range of a transmitter will depend on the particulars of each study.

2.3 Transmitters

Transmitters (tags) are available as complete units (including attachment options such as collars) or as components which are assembled and finished by the researcher. (Note: transmitters which are not assembled commercially may be subject to additional testing and certification requirements through Industry Canada.) Manufacturers generally package transmitter units in a metal can and/or cover them in an acrylic or epoxy resin coating to protect them from the elements (e.g., salt water) and from being damaged by the teeth, beak or claws of the animal.

2.3.1 One-stage and Two-stage Transmitters

Transmitters are available as one- or two-stage circuits. One-stage transmitters are useful for many applications due to their simple design and consequent low weight (as low as 0.5 g or less). Two-stage transmitters consist of a basic oscillator plus an amplifier, and must be powered by a minimum of 2.4 volts. Two-stage transmitters are larger, more complex and often more powerful than single-stage units. Functionally speaking, choosing between a one- or two-stage transmitter has several implications (Table 2).

Table 2. A comparison of one-stage and two-stage transmitters (adapted from Kenward 1987).

One-stage transmitter	Two-stage transmitter
• Relatively inexpensive	• Relatively expensive
• Tend to weigh less.	• Tend to weigh more.
• Less range for a given weight of tag.	• Greater range for a given weight of tag.(1-2 x).
• Longer life for a given weight of tag (3-4 x).	• Shorter life for a given weight of tag.

Generally speaking, two-stage radio transmitters are best suited for wide-ranging animals, including birds, which are large enough to carry them. Animals which are too small to carry a two-stage transmitter, or have localized, relatively short movement patterns, can carry one-stage transmitters.

2.3.2 Types of Transmitter Activation

1. **Positive Magnetic Shut-off Switches**

   Characteristics: A magnet is taped to the outside of the transmitter to prevent it from activating. The magnet is removed when the transmitter is deployed and transmission begins.

   Pros/Cons: Simple activation. Not suitable for very small transmitters. More expensive than an unfused connection.

2. **Unfused Battery Connection**

   Use: Unfused connection must be soldered closed to activate transmitter. Connection should then be covered with a protective epoxy.

   Pros/Cons: Light weight - often used with very small transmitters (e.g., 0.5 g) to keep weight down. Requires practice to activate quickly. Connection leads may break if worried (i.e. if transmitters are exercised during storage). Increased time required for activation; soldering and epoxying can be difficult in the field. Cannot be deactivated if research animals are not successfully captured.

2.3.3 General Protocols

Ideally, transmitters should be stored on a wooden shelf with at least 2.5 cm distance between magnets on different collars to ensure that the magnets do not cancel one another out and activate the transmitters (Decker 1988). A stored transmitter should also be exercised 2 to 3 days/month in order to prevent the build-up of a ‘passivation layer’ on the battery electrodes. A receiver should be used to check that all magnets are in place and all transmitters are turned off. Small transmitter tester units are also available from several suppliers.

A detailed log should be kept of each transmitter unit (including those in storage) giving receipt dates, storage times, testing and results, deployment date, number of relocations and any notes on unusual signal characteristics or animal behaviour (see Appendix for sample). If the transmitter fails, the log is invaluable when the failure is analysed by the manufacturer.

Transmitters may be refurbished (replacing the battery, canister, antenna and attachment and testing all components) or retrofitted by re-working a transmitter to new specifications, (e.g., changing a deer tag to a moose tag; Decker 1988b). Both of these procedures are best done by the company from which the transmitter was originally ordered.

Proper care and maintenance of transmitters is critical to justify the often expensive costs of field studies. There is little point in wasting opportunities to

place radio tags on animals because the tag has failed to work for the desired time period.

2.3.4 Specialized Transmitters

Platform Terminal Transmitters (PTTs)

ARGOS Platform Terminal Transmitters (PTTs) differ from conventional VHF transmitters in that they emit a much more complex and larger transmission which is repeated at longer intervals and received by an ARGOS satellite (Burger 1989b). PTTs can transmit diverse data such as temperature, activity count, dive count, length of last dive, time spent out of water, etc. Transmitters may be programmed to collect and compile data and then transmit it at specified times when the satellite's orbit takes it overhead. PTTs do not transmit the animal's location; this is calculated by the satellite or an Earth station from two or more transmissions. ARGOS satellite systems offer up to 20 locations per day (dependent on the transmitter's geographical position, Shaw 1991) with accuracies from 150 to 1000 m. Some researchers have reported that marked variations in accuracy and sampling frequency may occur within and among studies (Keating *et al.* 1991). Users may obtain data collected by the satellite either electronically (via modem or telex) or in the form of computer disks or tapes or hard copies. At present, PTT transmitters are available in weights as low as 25 g (from Toyocom, see Suppliers List).

Global Positioning System Transmitters

A GPS (Global Positioning System) transmitter locates itself by receiving and triangulating signals from at least 3 of 26 possible satellites, then transmits its position (the animal's position) to the user. The accuracy of GPS location systems may vary with the density of the forest canopy (Rempel *et al.* 1995). GPS transmitters can also be programmed to compile location data for a specified length of time, then transmit all of the data at once when contacted by a special receiver operated by the user. In this way, several weeks of location data can be recovered during a single relocation flight. GPS transmitters can also be combined with the ARGOS system to download their data via satellite. At present, the size of GPS transmitters (1800g) limits their use to larger animals such as wolves and moose.

Wildlink

Wildlink radio transmitters store activity data in a computer within the radio collar (Kunkel *et al.* 1991). The user can communicate with the collar's computer by transmitting signals to a collar-mounted receiver, and can control the transmission of stored data to a standard wildlife telemetry receiver. These collars may also be equipped with remotely-controlled tranquilizer darts to allow recapture of animals (Mech *et al.* 1990). Limitations include failure of immobilization due to frozen drugs during excessively cold periods.

2.3.5 Special Options

Radio-telemetry may also be used to provide information other than the animal's location. Virtually any information which can be expressed as a variable voltage can be transmitted (Osgood, no date). However, each additional component will add to the weight of the package and decrease its operational life.

Activity sensors

Activity sensors vary the transmitter pulse rate (Pulse Interval Modulation or **PIM**) according to the animal's activity. There are two types of sensors: real-time and time-delay (Burger 1988).

Real-time sensors change the pulse rate instantaneously with the animal's activity. The orientation of a tip-switch built into the transmitter determines the specific pulse rates. In this way, the researcher is able to distinguish activities such as perched versus flying or head up versus head down. Alternatively, a 'relative activity' type sensor will provide an increase in pulse rate as the animal's activity increases. The researcher must calibrate the pulse rate to specific activities or behaviours by correlating the pulse rate with visual observations of the animal's behaviour. Pulse interval timers provide accurate means of determining pulse rates. Transmitters with real-time sensors are also available with two distinct pulse rates which give an active/inactive signal.

In **time-delay sensors**, the tip-switch is incorporated with a counter. The transmitter pulse rate changes only if the switch is not triggered within a specified period of time. This type of sensor is most commonly used for mortality studies, but is also used to indicate hibernation or activity versus inactivity. Delay times for the counter may be set from seconds to several days. Researchers should keep in mind that the slower pulse rates are also more difficult to triangulate than faster rates, and that if a predator or scavenger moves the collared animal's body, the mortality switch may be delayed. Transmitters with variable pulse rates also use more power than those with steady rates.

Temperature and light sensors

VHF **temperature sensors** may be used to monitor either the animal's body temperature or the environmental temperature. Body temperature data may be useful in determining health or reproductive status, and ambient temperature may also be utilized for habitat selection or hibernation studies. Transmitters for body temperature may be placed subcutaneously, internally, within the inner ear, cloacally, or vaginally (Burger 1989). Transmitters for ambient or den temperature may be placed on a regular collar or harness. Size or weight limitations and the data precision required will also affect transmitter type and placement.

Temperature data are transmitted via PIM. The relationship between temperature and pulse rate must be carefully calibrated over the range of temperatures which the transmitter could encounter. Since this relationship may change as the transmitter ages, transmitters should be recalibrated at the end of the study. Temperature sensing transmitters may also be used to detect

mortality. However, researchers must keep in mind that a carcass in direct sunlight may not initially register a temperature appreciably cooler than a live animal.

Pulse rates of **light level indicator transmitters** are controlled by a light sensor mounted within the transmitter. This allows researchers to calculate the amount of time spent under cover or in a burrow.

Pre-programmed Duty Cycles

Transmitters are available from several manufacturers which contain programmable microcontrollers. These allow the researcher to specify on/off cycles to increase battery life. When the transmitter is deactivated, it goes into a "stand-by" mode in which its power requirements can be reduced to 10% of its normal power usage. Using this technology, a transmitter can be programmed to turn itself off in the fall, during an animals period of hibernation, and then reactivate itself again come spring. Its life can also be prolonged by alternating active and inactive days. For a long term study, two ear-tag transmitters can be programmed so that one will turn itself on after the other is expected to fail.

3. TRANSMITTER ATTACHMENT

There are many different ways to physically attach transmitters to wildlife. Some species such as grizzly bears or wolverines require very sturdily-built transmitters and attachment systems. Special consideration is also needed for transmitters fitted to prey species. While a snowshoe hare may not be particularly hard on a transmitter, a lynx which captures the hare may damage the transmitter so that the researcher may be unable to locate it. Researchers studying species which spend a lot of time in the water (e.g., beaver) must ensure that transmitters and their attachment system will stand up to frequent immersion. The best attachment option for a particular study must be chosen on the basis of the body type, shape, size and lifestyle of the study species and the type of data required by the researcher. Provincial standards for Wild Animal Capture & Handling must be consulted prior to any capture, restraint, or transmitter attachment.

3.1 General Protocols

Researchers are strongly urged to follow these recommendations with regard to attachment of radio tags (after Bertram 1980 and White & Garrott 1990):

Rules for wildlife transmitter attachment

1. Always carry a spare tag, to replace a dying tag or to test receiving equipment.
2. Routinely record the signal pulse rate of tags, to detect the slowing which precedes cell failure.
3. Tag more than one animal in a social group, in case one tag fails.
4. Treat all animals with the utmost respect.
5. Use the smallest possible transmitter package when instrumenting any animal. Although it may vary for some species, generally no tag should exceed 5% of an animal's body weight. For some animals, such as bats, 4% may be a more appropriate proportion.
6. Transmitter packages which are placed on animals which are dependent on cryptic coloration should be as inconspicuous as possible.
7. Transmitters and their attachments should be tested on captive animals before they are tested on free-ranging animals. Test animals should be the same sex and age as the intended wild animals, and researchers must anticipate potential difficulties due to changes in an animal's size, morphology, or behaviour over the course of its life.
8. Transmitters should always be tested both before and after attachment to ensure that they are working correctly and that the magnets have been removed.

9. Allow several days or up to one week for newly instrumented animals to acclimate to a transmitter before collecting data about "normal" behaviour.
10. Whenever possible, avoid instrumenting animals during their reproductive period, as many species appear to be particularly sensitive to disturbance at this time.
11. Seriously reconsider placing a transmitter on any animal that appears to be in poor body condition or impaired in some other way, unless it is particularly meaningful to the study to follow that specific individual. Recaptured animals showing adverse effects from transmitters should not be retagged. Researchers should not sacrifice the individual for the sake of a larger sample size

Once transmitter attachment is complete, the animal should be carefully observed before release. Short-term behaviours such as scratching at the collar or attempting to shake off a tag will generally cease when the animal becomes accustomed to carrying the transmitter. These behaviours should be distinguished from more serious effects such as improper balance, impeded movement or shifting harnesses which will require intervention. It is an unfortunate reality that many of these problems and behaviours will not be apparent or manifest until the animal is actually released and is difficult to recapture. This only serves to emphasize the importance of thorough research, preparation and testing beforehand.

3.2 Collars

3.2.1 Protocols - Materials

Collars are the most common form of transmitter attachment for mammals. Collars should be made of materials which :

- are durable;
- are comfortable and safe for the animal;
- can withstand extreme environmental conditions;
- do not absorb moisture; and
- maintain their flexibility in low temperatures (Burger 1989c).

Common collar materials are butyl belting, urethane belting, flat nylon webbing, tubular materials, metal ball-chains, PVC plastic, brass or copper wire and cable ties.

3.2.2 Protocols - Fitting

The transmitter package may be situated either under the animal's neck or on top of it. Collars must be properly fitted for the comfort and safety of the animal. A collar should fit snugly to prevent it coming off or chafing the animal as it moves, but it must also be sufficiently loose as to be comfortable and not interfere with swallowing or panting. To reduce the risk of chafing on the neck,

collars should generally be fastened at the side, with any metal fittings covered or smoothed on the inside surface of the collar. Neck circumference will vary according to species, age, sex and sometimes the season. Transmitter manufacturers usually have records of collar sizes previously used for various species.

Collar thickness and width are important considerations. Width of the collar will affect how the transmitter sits on the animal's neck. Some researchers prefer narrower collars because there is less surface area in contact with the animal. Others prefer wider collars for better weight distribution (Burger 1989c). One of the most important considerations should be the possibility of the collar getting caught up in vegetation. This is a particularly important consideration with small mammals (especially those that burrow).

Expandable collars and harnesses are mandatory in those cases where it is necessary to allow for growth in young animals or for species which undergo neck swelling (e.g., male ungulates in rut) (Hölzenbein 1992). Braided nylon over surgical tubing and nylon web with elastic folds are offered as expandable collars by one company. Expandable collars should not be used unless they are well tested, as poorly designed collars can be very problematic. In the past, certain collars have stretched prematurely as a result of social interactions or behaviours such as neck rubbing. As a result, there is always the possibility of transmitter loss, icing up in winter, or of the collar becoming snagged by branches or even the animal's own legs.

3.2.3 Protocols - Removal & Recovery

Breakaway or "rot-away" collars are strongly recommended in cases where the researcher does not intend to recapture the animal and remove the collar. Breakaway collars or harnesses incorporate a link of material which is designed to break away and allow the transmitter to drop off after a pre-determined interval. Breakaway links should be environmentally degradable material or electronic links controlled by timers or radio receivers. Environmentally degradable materials which have been used for this purpose include cotton thread and sections of cotton fire hose or cotton spacers on large mammal collars (Karl and Clout 1987; Hellgren *et al.* 1988). These weak links may also function to break and free the animal if the collar/harness is snagged on a branch. However, it is important to consider that the breakaway collar or harness does not impair the movement or activities of the animal during the period in which it is being shed. For example, a breakaway bird body harness could easily impair wing movement as it is lost and result in mortality. Radio and timer-controlled breakaways may be jammed by freezing or dirt, and also add to the size, weight and complexity of the transmitter package.

Where appropriate, it is recommended that collars and harnesses be marked in order to enhance their visibility. Paint or non-metallic reflective materials may be sewn or glued to collars and harnesses; however, this is likely not appropriate for cryptic species. Metallic tape or foils should not be used as they will detune the transmitting antenna. Adhesive tapes should also not be used as they are not very durable and may foul fur or feathers. For game species or urban studies it may also be helpful to mark a contact phone number on the collar. Colour-coded collars are also available from telemetry equipment manufacturers.

3.3 Other Common Methods of Attachment

As it is not possible to establish detailed protocols for all methods of attachment, this section presents a selection of commonly used methods and some key considerations surrounding successful deployment.

3.3.1 Tail Mounts

Description

Tail Mounts are attached to the tail feathers of a bird. In different studies, they have been glued (including wax) or sewn to a bird's rectrices or attached to them with cable ties or alligator clips (Bray and Corner 1972; Kenward 1987).

Key Considerations

Transmitters attached to tail feathers are lost when the bird moults. Rectrices should be handled gently while the transmitter is being attached as stresses to the base of the feather may result in its being moulted prematurely. Considerations should be made with respect to the organism's life history. Depending on how an animal uses its tail, a tail mount may be inappropriate (e.g., woodpeckers - antenna may snag in bark of a tree).

3.3.2 Implantable Transmitters

Description

Implantable transmitters are best suited for species:

- whose necks are not well-defined (e.g., snakes),
- whose heads are smaller than their necks (e.g., male polar bears),
- which might be impeded by an external transmitter (esp. burrowing animals),
- which are sensitive to external attachment (i.e. amphibians),
- which are young and expected to grow.

They are also used for certain biotelemetry applications (especially body temperature). Implants are sealed with neutral (biologically inert) epoxy, resin, or wax, and implanted into the body cavity or under the skin. The antenna may be left external to the body, implanted under the skin or it may be contained entirely within the implant unit.

Key Considerations

Despite the initially invasive nature of this technique, one of the key advantages of implants is that they may be much less irritating (if implanted correctly) to the animal than an external tag. Implanted transmitters have a fairly limited range. Those with an implanted antenna will have an even shorter range, but will be less subject to damage or infection than transmitters with external antennas. Transmitters are also expensive to implant as they generally require that researchers employ a qualified veterinarian. Animals may also need to be

held for a protracted period in order to recover from the effects of a general anaesthetic.

3.3.3 Backpack Modules

Description

Backpack modules are attached to the animal by a harness, which is often run through tubular passageways on the transmitter pack (Nicholls and Warner 1968; Jackson *et al.* 1985; Ward and Flint 1995). Harnesses may be made from soft Teflon ribbon, plastic-coated wire, metal beads, plastic beads, surgical tubing or polyester soft stretch elastic.

Key Considerations

The style of harness used depends on the study species, and it is generally necessary to test a harness style on captive specimens before using it in the field. Some manufacturers offer ready-made harnesses to fit the more common species. Elastic harnesses will eventually degrade and free the animal from the transmitter and biodegradeable sutures can be used to release harnesses from aquatic animals. Kenward (1987) states that it is best to avoid the use of harnesses for a species that can be tagged any other way, as the animal may potentially wear the harness for the duration of its life, and even the best-fitting harnesses may eventually snag.

3.3.4 Adhesive Transmitters

Description

Adhesive transmitters may be glued onto an animal's body, often its back, with cyanoacrylate glue, false eyelash cement, surgical bond (skin cement) or other glue-like substances. Titan Seabird Glue is used by one researcher to attach tags to Dunlin (P. Shepherd, Simon Fraser Univ., Burnaby, B.C., pers. comm.). In birds, the area is usually prepared by trimming feathers to 2 to 5 mm in length. Carapace mounts are typical with turtles while other reptiles have had tags taped to their tales. Mammals can have them glued directly to the fur (e.g., bats, voles) or sometimes the fur is removed before attachment. Typically the whip antenna runs dorsally and caudally to the long axis of the body.

Key Considerations

Depending on the type of adhesive used, the tag will generally detach itself. Preparation of an attachment site on the animal may require clipping/shaving which may induce additional stress and potential physiologic problems, such as interference with thermoregulation or flight. Aggressive grooming of adhesive transmitters may shorten their active life further than limits imposed by the power supply.

3.3.5 Necklace Packs

Description

Necklace packs are often used on upland game birds. These packages simply hang down on the breast of the bird, supported by light flexible cable or cord around its neck. The cord is run through a sleeve to protect the bird's neck.

Key Considerations

This system is probably the easiest and quickest to mount, resulting in shorter bird-handling time. Necklace must be long enough to allow the animal to swallow large food items without choking.

3.3.6 Eartag Transmitters

Description

Although originally designed for use on polar bears, eartag transmitters have since been used on other species of bear and ungulates (Telonics). They are particularly favoured for large animals with changing neck girth (e.g., juveniles, male cervids). A round design and foreshortened antenna allow the transmitter to rotate freely while remaining in place.

Key Considerations

This type of transmitter can range over 3 km given ideal conditions (flat landscape, open vegetation, dry environment). Long antennas should be avoided as they can annoy the animal.

3.3.7 Miscellaneous

Descriptions

Numerous other techniques have been used to attach transmitters to animals. For example, meshwork vests with transmitters attached have been used on birds (Lawson *et al.* 1976). Numerous other examples can be found in Chapter 7.

Key Considerations

If an attachment design is new, it is critical to test it adequately, preferably on animals in enclosures before conducting a study in the wild. It is important to keep in mind, however, that a captive animal may not have the same physical demands as a free-ranging one. For example, a captive raptor may tolerate a certain attachment technique, but a wild bird will have to fly and hunt with it.

4. RECEIVERS

4.1 Receivers

4.1.1 Equipment

The function of a receiver is to receive the signal picked up by the antenna (to which it is connected by a coaxial cable), amplify it, and make it audible to the user. Receivers are available in a variety of sizes, weights and prices from a number of national and international suppliers. Study needs will determine whether data collection is best done manually by field personnel or whether an automated receiving station should be set up. Receivers are powered by replaceable and/or rechargeable batteries, and may also be equipped with a cigarette-lighter adapter for connecting to a vehicle's electrical system. Some models are equipped with scanners which may be programmed to switch between a number of different frequencies; this is ideal for studies with a number of animals which tend to wander. Strip-chart recorders or data loggers may also be incorporated into a receiving system, and are particularly useful for automated receiving stations.

4.1.2 Protocols - Handling

Receivers may be damaged by static electricity from clothing or car seats and by radiated power from voice communication systems (Crow 1988). To prevent this damage:

- clothing and vehicle seats should be treated with antistatic fabric softener (especially during cold weather);
- receivers should be turned off and the antenna disconnected when getting in and out of vehicles and when using voice communication systems; and
- roof-mounted antennas should be separated from transceiver antennas.

It is also worthwhile to note that receivers are sensitive to moisture. This is an important consideration when try to locate animals in the rain.

It can be useful to adjust a receiver up or down in order to identify the best or most functional frequency for a given transmitter. It is not uncommon for a transmitter's best frequency to be slightly different from the one identified by the manufacturer. As well, a transmitter's frequencies may drift slightly.

4.2 Antennas

Receiver antennas may be hand-held or mounted on a vehicle roof, aircraft or boat. A Yagi antenna is a directional 'gain' type antenna which uses a number of parasitic directors in front of the 'driven' element (the one connected to the coaxial cable) and a reflector behind the driven element in a defined mathematical relationship (Jones 1990). Directional antennas such as Yagis or

'H' antennas concentrate the radiated energy to the front of the antenna. Minor lobes to the sides and rear are also produced.

Antenna beam width refers to the radial distance between the angles at which an antenna is held in which an audible signal is received (the 'directionality' of the antenna). The greater the number of elements, the smaller the beam width. For example, a 3-element Yagi antenna has a beam width of 60^o in the horizontal orientation, and a 2-element H antenna has a beamwidth of 100^o in the horizontal orientation. Both antennas have wider beam widths in the vertical orientation (Burger 1991).

4.2.1 Protocols

Regardless of the type of antenna, the elements must remain straight and parallel to one another to ensure maximum receiving efficiency. Antennas are tuned to a particular frequency, and antenna elements are only interchangeable if they are the same length as the original elements, and are interchanged between antennas of the same frequency range. Maintain antenna elements in perfect alignment; badly damaged elements are likely beyond repair.

4.2.2 Types of Receiving Antennas

Handheld

The most commonly used hand-held antennas are the Yagi and the 'H' antennas. Hand-held Yagis have 2 to 5 elements. Each additional director element increases the distance from which the antenna can pick up a signal. Loop antennas are small, hand-held antennas which are useful for close-in tracking of 1 km or less.

Boat or vehicle-mounted antennas

Large directional antennas with 5, 8 or 14 elements are usually used as vehicle mounted antennas or at fixed sites. Omni-directional (bipole) antennas may be mounted on a vehicle and used to determine the general vicinity of an animal. A precise location can then be determined with a directional antenna.

Aircraft-mounted Antennas

Both Yagi and H antennas have been used for relocating animals from the air. Antennas are mounted on fixed-wing aircraft with brackets designed to fit struts on commonly used types of aircraft. The operator uses a switch box to listen through the left or the right antenna or both to determine the direction of the incoming signal. The receiving system can be connected to the aircraft intercom system so everyone in the aircraft can hear the transmitter. Brackets to mount an antenna on a helicopter skid are also available (Telonics).

Brackets must be chosen carefully as strut sizes may vary within the same model of aircraft. The antennas should be centered on the struts with the tips of the antennas facing fore and aft, with the front of the antenna facing out toward the wing-tip and slightly downward (about 30^o below the horizontal axis of the wing, Jones 1988). Some researchers recommend orienting the antennae at 90^o to each other. Duct tape is often used to attach antenna coaxial cables along the

outside of the wing and through windows or vents into the cabin. Antenna / coaxial cable attachments should also be secured or taped as they can become loosened by constant vibration and jeopardize the results of the flight. All equipment attached to aircraft is governed under aviation law and requirements may vary according to ownership, use and location. Researchers must ensure that their equipment and their means of attachment comply with the appropriate aviation standards.

Fixed-Site Receiving Stations

Automatic direction finding systems incorporate a rotating antenna, a fluxgate compass and a receiver/datalogger that automatically determines and stores bearing and signal strength information on a particular animal for downloading.

Very large antennas with many elements may be installed at a fixed receiving station. Antennas at fixed sites are subject to lightning strikes and therefore should be well-grounded. Fixed receiving stations require some prior knowledge of the animal's range to ensure the best placement.

5. RELOCATING WILDLIFE

5.1 Ground versus Aerial Monitoring

Determining whether a ground survey, aerial survey or a combination of these monitoring techniques is most appropriate will depend on the objectives of the study, the specific species biology, and terrain as well as budget constraints. Aerial monitoring is most efficient for sampling animals that live in inaccessible mountainous terrain or disperse long distances and require searching over large geographic areas. Ground relocations allow more detailed observations of an animal to be made, and are less expensive than relocation flights.

Local climate and weather patterns can be also be an important factor in determining the suitability of ground versus aerial monitoring. Locating animals by aircraft may be largely restricted if seasonal weather is unsuitable for telemetry flights, as is the case in certain coastal areas. In contrast, other regions of the province may experience winter snowfall which will limit mobility to such an extent that aerial monitoring is the sole option.

Table 3 outlines some of the specific advantages and disadvantages of either method.

Table 3. General uses of and advantages/disadvantages of ground and aerial monitoring.

	Ground Monitoring	Aerial Monitoring
General Uses	• Animals which are slow-moving, sedentary, unwary, and/or characterized by relatively short movements or predictable distribution.	• Animals which are larger, carry more powerful transmitters, and move greater distances. • Studies of migration and dispersal. • Studies in rugged/inaccessible terrain.
Pros/Cons	• Inexpensive but labour and time intensive. • Particularly useful for locating a specific transmitter of known frequency • Depending on mobility of focal species, actual sighting may require harassment • Error can be minimal; often a product of the observer's ability to plot the animal on a map	• Expensive but efficient way to scan for numerous animals over a large area. • Especially efficient for locating large numbers of tagged animals quickly. • Aircraft safety considerations may render direct observation impractical under some circumstances. • Errors can be large (>.5 km) for locations without direct observation • Accuracy testing may be appropriate (depending on study objectives) • Requires weather conditions which are favorable for flying

5.2 Accuracy of Locations

The accuracy of a radio-location varies with habitat type and may result in biased estimates of observed habitat use. A common source of error is signal bounce. Signal bounce occurs most frequently in mountainous terrain where a signal is deflected by a mountain, resulting in potential errors of many kilometres. The most effective way to overcome signal bounce during ground tracking is to take many bearings from several different places. When all signals appear to be coming from the same point then there is a good chance that the animal has been located correctly. However, if the signals are coming from a number of different points then signal bounce is likely still occurring (White and Garrott 1990).

Visual observations of radio-located animals provide the best confirmation of the accuracy of the relocation data. For large animals, a reasonable proportion of locations should be confirmed by direct visual observations (some biologists use >30% as a general rule; however, this may not be practical in all cases). In new study areas or with species which cannot be observed on a regular basis, it is strongly recommended that triangulation be used with an assessment of aerial fixes made using collars placed in known locations. Such trials can test the consistency and accuracy of triangulation using various personnel and methods under various environmental conditions. Results of the trials can be used to

identify problems (e.g., signal bounce) and ensure that methods are adjusted to reliably obtain accurate radio locations.

When relocating wildlife in the field, most users judge the angle over which the signal sounds loudest, determine a bearing by mentally bisecting that angle, and follow the bearing to move closer to the signal. The process is repeated until the animal can be seen or its location can be inferred. The latter may be accomplished by circling the signal to determine a bounded area in which the focal animal must occur, tracking the animal to an obvious habitat or landscape feature, or by sandwiching the animal between the receiver and an apparent obstacle.

Alternatively, if the researcher wishes to avoid disturbing the animal, or if locations must be determined at night, the process of triangulation may be used. This requires finding the intersection of two or more bearings to determine one location. An error polygon can be calculated around the point estimate, resulting in a measure of precision equivalent to the area of the polygon. The size and shape of the error polygon is determined by:

1. the accuracy of the directional antennae;
2. the distance between the two receiving points;
3. the distance of the transmitter from the receiving points; and
4. the angle of the transmitter from the receiving points.

The most accurate estimate of an animal's location is obtained by receiving fixes that are closest to the animal and at 90^{o} from each other. To reduce the size of the error polygon, three bearings can be taken and the animal's location estimated from the centre of the intersections. The error polygon formed by three radio bearing lines should be small enough to accurately place the animal in a single habitat polygon. If the location is near an edge, additional bearings should be obtained to accurately locate the animal on the map.

Where possible, standard telemetry base points should be established, marked and numbered by personnel experienced in use of radio-telemetry equipment. New observers should be familiarized with the base points and standard triangulation procedures by an experienced person. Triangulation of animals which are moving will produce large polygons (less accurate locations). For this reason, it is difficult to accurately determine locations of fast-moving nocturnal wildlife such as owls. If triangulation is used to determine wildlife positions, error measures should be calculated and reported along with the study results (Springer 1979; Saltz and Alkon 1985; Schmutz and White 1990; Saltz 1994). White and Garrott (1990) provide a useful compilation of error calculations for telemetry.

5.3 Protocols

5.3.1 General Guidelines

The following guidelines should be adhered to when relocating animals (adapted from Page 1982):

1. Ensure that you use an antenna which is matched to the frequency transmitted.
2. As a general rule, the antenna elements should be oriented in the same direction as the transmitter antenna (i.e., when relocating a caribou wearing a radio-collar with a vertically-oriented whip antenna, the receiving elements should also be held vertically).
3. Hold antennas as high as possible or mount them on poles. Keep antennas at least 2 m away from all other objects, especially those which are large and metal objects, as these will cause detuning of the antenna.
4. Make use of null signals as well as peak signals to determine the direction to a transmitter. Using a 2-element antenna, the signal should be weakest when the tips of the elements point directly at the transmitter.
5. Make use of hills and other places of high elevation from which to receive signals.
6. Know your study area. Whenever possible take bearings through the flattest terrain with the least vegetation.
7. Take repeat bearings over a short time period, especially if the animal is active.
8. Get as close to the animal as possible. Attempt to confirm locations with direct observations.
9. Avoid sources of interference.
10. Take as many bearings as practical.

5.3.2 Aerial Surveys

The following guidelines for aerial surveys are adapted from Gilmer *et al.* 1981.

Equipment

- Safety equipment (First aid kit, survival kit, etc.)
- List of animals and frequencies to be located during flight (include notes on frequency drift)
- Clipboard, pencils, pens
- Maps and RIC data forms (or other with similar fields)
- Camera and film
- Communication radio (air to ground)
- Test signal transmitter
- Timepiece
- Receiver
- Scanner
- Auxiliary power supply
- Headphones
- Switchboxes
- Extra coaxial cable (proper length with connectors)
- Antennas and mounts
- Tool kit for mounting antennas (wrenches, screwdriver, pliers)
- Duct tape, electrical tape
- Extra bolts, washers

Procedures - Pre-flight

1. Obtain a good set of maps and air photos of the project area. It can be useful to have both large and small scales.
2. Define the area which is to be searched for animals before the flight. If the Project Area is large, it may be useful to break it down into smaller Study Areas which can be effectively searched within an allotted time.
3. Primary power sources for receivers should be fresh and fully charged at the start of the survey.
4. An up-to-date list of transmitter frequencies should be carried, including the location of each animal from the previous search (as this may be a useful starting point).
5. Set up receiving equipment (this should be done with the pilot who has the ultimate responsibility for its safety):
   - Attach mount with antennas to aircraft.
   - Run coaxial cables into cabin.
   - Hook up switch boxes and receiver.
   - Use duct/electrical tape to secure connections and cables where appropriate.
   - Test system, make sure switch box functions correctly.
   - Check programmed frequencies and dwell time.

Procedures - In Flight

1. Begin the search with the switch box set to “both” allowing the crew to listen for animals on either side of the aircraft.
2. At the outset of the flight, it may be beneficial to test equipment by making use of a test transmitter which is left at a known location on the ground.
3. Depending on the nature of the focal species and the objectives of the study, it may be useful to begin searching at the last recorded location for each animal. If this is unsuccessful, a more systematic, transect-based search design should be utilized (see item 8).
4. When a signal is detected, the control switch should be moved to “left” and then to “right” to determine from which side of the aircraft the signal is coming.
5. Once the direction has been determined, the pilot should turn the aircraft in the direction of the transmission. This will result in a temporary “null” signal until the aircraft flies close enough to the transmitter that the signal becomes audible again.
6. At this point, it should be possible to “home-in” on the transmitter position. Again, the operator changes the switch box from “left” to “right” to determine which side of the aircraft the transmitter is on. The operator will then identify an area on the appropriate side over which the pilot should begin a wide circle.
7. By moving the switch “right” and “left”, the operator should be able to determine if the transmitter is within the area being circled. The circle may then be tightened, and focused based on the strength of the signal and the knowledge of the species habitat preferences.

8. Whenever possible, flight crews should attempt to verify an animals presence through direct observation.
9. For searches of a large number of highly mobile animals over a large area, it may be more appropriate to use a systematic method, using a scanner and parallel transects. For such searches, biologists should be aware of the limitations of receiving equipment to effectively scan for animals in a fast-moving aircraft. To this end, the formula below will calculate the maximum number of animals that may be effectively scanned for on a survey flight (for more information, see Gilmer *et al.* 1981).

$$NC = MDxGSx\frac{3600}{SR}$$

where: NC=maximum number of animals which can be searched for

MD=minimum detection distance parallel to the aircraft's direction of movement

SR= receiver scan rate

GS= maximum ground speed of aircraft

6. STUDY DESIGN

6.1 General Considerations

Despite the wide range of possible research questions which a radio-telemetry study can address, the provincial wildlife inventory program requires that all telemetry work be focused on issues of species abundance and distribution. Within the context of the wildlife inventory program, radio-telemetry should be used as part of an inventory project to address at least one of the following objectives:

1. Provide information about the use and/or selection of landscape/habitat by a species (section 6.3).
2. Provide locations of key habitat elements (e.g., hibernacula, nests) which are required to facilitate conservation of a species (section 6.3).
3. Provide descriptions of home ranges, including their size, position, density, and/or composition in terms of habitat (section 6.4)
4. Provide an assessment of population size, such as through the use of bias-correcting indices for other RIC-approved surveys, or population dynamics, such as studies of mortality and survival (section 6.5).

Assuming research objectives, including hypotheses, have been declared and deemed compatible with the objectives above, a researcher should also consider a number of additional questions before embarking on a study involving radio-telemetry.

- Is radio-telemetry the best method to address the project objective or hypothesis? Are less expensive alternatives available? If so, do the differences in the type and quality of data collected using radio-telemetry warrant the associated expense?
- How many animals will need to be radio-tagged to provide a meaningful conclusion to the project hypothesis? Can the study species be captured in sufficient numbers to provide an adequate sample size? In the event of low capture success, will the decline in statistical power render the results meaningless?
- Can a radio tag provide a useful measure of the study variable(s) with levels of accuracy which are adequate for the project? Will the resulting data be in format conducive to analysis?
- Can the study species carry a radio tag without undue detrimental effects? Can the study species carry a tag of sufficient size to possess adequate range and tag life?
- Is the project's budget sufficient to cover tags and monitoring equipment? Will staffing levels be adequate to ensure proper monitoring of study animals on an adequate monitoring schedule?

If the answer is negative or unknown for any of the above, the use of radio-telemetry techniques should be reconsidered. Despite the attraction of radio-

telemetry as an inventory technique, it is very expensive, labour intensive, and potentially stressful to animals. Its application should be limited to those situations where it is most warranted.

If the use of telemetry techniques seems valid, the researcher should undertake a literature review of the subject area. S/he should be looking for previous examples of tag types and successful attachment techniques, for the taxonomic group concerned. The investigator should consult with several suppliers of telemetry equipment and researchers experienced in the area in order to determine tag type and attachment method. Much research in telemetry is experimental and many people have not published the results, thus contacting experienced researchers can be very productive.

6.2 Sampling Considerations

Radio-telemetry studies must take into account two measures of sample size 1) the number of individuals followed, and 2) the number and timing of relocations of each individual. Data points gathered for individuals are used in home range / habitat use analysis whereas the number of tagged individuals is usually used with more typical statistical testing. This distinction is very important: one cannot expect to answer many questions by obtaining large samples of relocation data for one animal. The number of animals tagged must be adequate for statistical tests since it is the animal and not the number of locations that is the true sample size. There is a compromise to be reached between numbers of animals tagged and numbers of relocations per animal. Biases to one or the other are usually not desired. However, Alldredge and Ratti (1992) stated that ‘it is doubtful that random sampling can be achieved in practice in most studies with radio-tagged individuals’.

The number of animals of each age and sex which are sampled is determined by the objective or hypothesis being tested. For example, if only data on mature animals are desired, then the researcher does not have to sample younger animals. Studies of populations which are not easily divided into meaningful sex or age classes are more reliant on assumptions of homogeneous catchability. To illustrate, some wildlife species may be very difficult to sex and/or age under field conditions. Under these circumstances, the researcher may be forced to assume that the sample of tagged individuals adequately represents the study population. All such assumptions should be explicitly stated when the study results are reported.

Seasonal considerations are also a factor in many wildlife studies. If the study objectives are to examine winter range size of white-tailed deer, the researcher must monitor study animals throughout the winter. If the objectives are to document total home range size, study animals must be monitored throughout the year. Hibernating species will not require monitoring throughout most of the winter, unless study objectives include the collection of physiological data through biotelemetry. Other species may exhibit circadian patterns in behaviour and/or habitat use. Radio-locations must be a random sample of the animal’s behaviour. This can be accomplished by sampling at random times or by sampling at regular intervals.

Researchers must ensure that they collect enough data to address project objectives, and do not rely on general inferences to interpolate between relocation data points when it is inappropriate (e.g., determining home range of a species when data were only collected for a portion of the year). Preliminary sampling (or pilot study) is an excellent way to determine the suitable sample size (relocation points) for a particular project. For example, in a home range study, a researcher can create asymptotic curves (home range size vs. number of data points) to evaluate whether additional relocations of an animal improve the description of its home range. Obviously, the number of relocations which are possible in a project will be dictated by more than good science; logistical considerations such as accessibility, size of study area, staff levels, behaviour of animals (e.g., migratory nature), and other factors will all play a role. Similarly, the number of animals which are tagged (i.e., the sample size needed for statistical testing) will influence the quality of conclusions drawn from a project. The number of individuals required to test a hypothesis should be determined *a priori* using power tests. The number of animals which can actually be tagged will be the product of factors such as the project budget, the number of separate transmitter frequencies possible in the project's assigned frequency range, and the natural history of the organism. As an example of the latter, if the objective is to determine the home range of an animal which lives in social groups such as herds or packs, it may be only necessary to tag one or two individuals in order to document the movements of an entire group.

When contingent with objectives, researchers should attempt to design telemetry projects in a manner that is logistically efficient. Thoughtful planning can help to minimize travel time and maximize relocations collected per trip while taking advantage of existing access within a study area (particularly when locations must be obtained at night). In some cases, this may be accomplished by tagging animals in the same general vicinity so that several radio locations can be obtained in a single outing. Obviously, the relocation efficiency must be properly balanced with study design and objectives. For example, the objective of quantifying turtle nest sites within British Columbia can not be realized by tagging only in the Peace River area. However, it is not always clear how best to distribute radio tags between multiple study areas. Although having numerous study areas will provide more complete coverage of a landscape, in certain situations, having many animals tagged within each study area can allow more information to be obtained for the same time and travel costs.

6.2.1 Data Forms and Data Collection

Provincially-standard protocols for collecting and recording information should always be used. Certain detailed information recorded in the field may depend on the nature of the project, but, at a minimum, should include information specified in the accompanying data forms. This includes detailed physiological information, particularly for large animals which are captured. In addition to information on data forms, the position of each animal should generally be plotted on an air photo or topographic/habitat map. For habitat-use studies, specific information on the habitats used may also be collected (generally using an Ecosystem Field Form) and, at a minimum, observers should attempt to estimate the Broad Ecosystem Unit in which an animal occurs.

At the end of each field trip, the researcher should review all radio locations to ensure all data are adequately recorded. This may involve coding data into a computer (or the Species Inventory data system) for later analysis. For detailed descriptions of minimum data requirements, see the attached data forms. In general, data can be subdivided into four groups.

- **Physiological data** Includes vital signs and morphometric information collected from captured animals.
- **Visit Characteristics** Includes date and environmental characteristics of relocation trips, such as temperature, cloud cover, wind speed, and precipitation.
- **Observation characteristics** Includes information about animals which are relocated. At a minimum, this should include time, animal's UTM grid location, sex/age classification, observation type (air, ground, remote), observation accuracy (sighted, accurate fix, weak signal, vague etc.), and possibly activity, group size, or other characteristics which are specific to an individual animal (snow depth, snow sinking depth, site position, distance from cover, etc.);
- **Habitat information** Includes as a minimum, Broad Ecosystem Unit, but may also include biogeoclimatic zone, biophysical habitat class, seral stage, dominant vegetation cover (crops, tree species), and/or reference to a standard ecosystem description form (e.g., Ecosystem Field Form or Ground Inspection Form).

All data should be entered into computer data files on an ongoing basis to determine trends, erroneous data points, number of fixes needed, appropriate time intervals, etc. Periodically (at the end of each seasonal time period, if applicable) data collected should be tabulated and inspected using frequency distribution functions to identify incorrect codes and correct errors. Scatter plots of radio location points should also be examined to identify and verify outliers. Original notes of personnel collecting the data should be available to assist in correcting ambiguous data.

If applicable, radio location data should be compared for males and females, between age groups or between study areas and combined if no significant differences are found. Data should only be pooled where appropriate, which will depend on the specific objectives of the study. Possible pseudoreplication errors may result from:

- inadequate representation of individuals, sexes or ages;
- inadequate representations of different seasons;
- inadequate representation of circadian patterns;
- inadequate representation of different habitats;
- pooling individuals that differ in space use; and
- using autocorrelated data.

6.3 Habitat Utilization Studies

Radio-telemetry can provide detailed information about an animal's use of habitat. Expected proportions of use (radio locations) in each habitat are calculated based on the relative availability of each habitat in the study area. Investigating habitat preference or critical habitat features are common themes among many studies. To make conclusions about how a population uses habitat, a researcher must carefully consider the objectives of the study and ensure adequate representation of all classes of individuals within the study population. In many studies both sexes must be represented among the tagged animals, as habitat use of males and females may be quite different. Researchers must also ensure that the location of capture is not biasing the selection of individuals for sampling. As an example, if a researcher wished to investigate the choice of roost sites by Barn Owls, a capture program based on mist-netting owls inside buildings would bias the sampling to birds which choose human-made over natural roosts. A better capture method might involve capturing foraging owls at night while they were away from their roost site. Traps set in a particular habitat or at a particular time might be more successful at capturing one sex or age over another. The researcher should carefully classify each animal captured before deciding whether to attach a radio tag. A common practice among many researchers is to randomly sample populations whenever possible.

Some species may exhibit circadian patterns of habitat use, occupying nocturnal or crepuscular habitats which differ substantially from daytime ones. To obtain an accurate picture of habitat use, radio locations may need to be split between day and night within in each season (Beyer and Haufler 1994). Sampling should also be done under all weather conditions and in all seasons as habitat use may vary. Habitat use may also vary between years (Schooley 1994). Ideally, a fixed schedule of sampling should be devised and adhered to. This schedule can still be random. For example, the researcher could randomly select dates within a given period of time to track animals, randomly select areas for capture, etc. The most important thing is that organisms are not being monitored simultaneously with a circadian rhythm of some description. For example, if moose always water at dawn then one would not always collect data at dawn. This would bias the results.

A fundamental feature of many of the parametric analysis programs is independence of radio locations. Several methods or definitions of this concept have been put forth. In one study it is assumed that radio location points are independent if sufficient time has elapsed to allow the animals to redistribute themselves (McNay *et al.* 1994). While another study uses the minimum time it takes for an animal to cross its home range as the basis for a test for the minimum interval between relocations which gives spatial independence (Swihart and Slade 1985). White and Garrott (1990) state that sufficient time must pass between relocations for an animal to move from one end of its home range to the other. More frequent locations or continuous tracking may be required to document intensity of use, dispersal, daily movement patterns, social interactions, weather effects, and for detailed studies on habitat selection where habitat patches are small. For example, more frequent locations may be required

to document daily movements from cover to foraging areas and back in early morning.

Habitat classification associated with relocation data points can be measured in several ways. It can be recorded in the field (when the animal is relocated or at a later date when the observer travels to the study area) or one can physically plot the location on a habitat map and transcribe the habitat type from the map. Observers should be trained to identify habitat type in the field. If, for some reason, the this is not possible, then a protocol should be in place to either mark the location physically or have the observer plot the position accurately on a detailed map. This becomes an issue especially during night work. Generally, habitat types should be defined using Broad Ecosystem Units while for more detailed work the Ecosystem Field Form should be used. For more information on standards for habitat description, consult *Species Inventory Fundamentals, No. 1*.

Although all radio-tracking studies must contend with uncertainty in animal relocations, those which evaluate habitat use/selection must also recognize the potential for error in habitat discrimination and delineation. As the number of habitats increases, multiple comparison error rates also increase so the number of habitats considered should be limited in the study design (Bibby *et al.* 1992). The choice of study area boundaries can also bias results where habitat features or types are aggregated, but boundaries are unimportant if habitats are regularly or randomly distributed (Porter and Church 1987).

Radio-telemetry error can introduce bias into a habitat selection study by misclassifying the habitat an animal actually used. The ability to detect habitat selection depends on the size of habitat patches, telemetry error, and the number of locations. This occurs most frequently when habitat patches are small relative to the size of the radio-location error polygon (Nams 1989). The error polygon formed by three radio bearing lines should be small enough to accurately place the animal in a single habitat polygon. If the location is near an edge, additional bearings should be obtained to accurately determine which habitat is being used. However, as the size of the error polygon is known, the probability that a location may be misclassified based on distance to nearest habitat boundary can be estimated.

If large telemetry errors are anticipated (e.g., habitat patches are small) then external validation of the locations should be tested using randomly located transmitters to determine the effect of telemetry error on habitat use.

Another important consideration is to determine the **Type I** and **Type II** error rates. The Type I error rate is the probability of rejecting the null hypothesis when in fact it is true and a Type II error is the probability of accepting the null hypothesis when it is false. Type II error is also referred to as the power of the statistical test. In general, the sample size determines the power of the test and should be calculated before the study begins. There are costs associated with both Type I and Type II errors. A Type I error would result in a significant difference in proportional selection when habitats are actually selected according to availability and could result in costly management programs to protect erroneous “critical” habitats. The implication for studies that lack sufficient power to reject the null hypothesis (Type II error), is that it is possible

to conclude that a certain habitat type is not important when in fact it is. Although most researchers choose a standard Type I error rate of 5%, the Type II error rate should be set according to the perceived cost of the error. Some authors suggest a Type II error rate equal to the Type I error (Peterman 1990), others have suggested 10 to 20% is acceptable (Snedcor and Cochran 1980). For RIC wildlife inventory, Type I error (α) should generally be set at 5% (0.05) while Type II (β) is set at 20% (0.2) although this may vary depending on objectives.

6.3.1 Data Analysis

Occurrence of animals by habitat type should be summed for each seasonal time period. Expected use should be based on an accurate tabulation of habitat quantities in each study area. Standard use/ availability analyses (Johnson 1980; Marcum-Loftsgaarden 1980; Neu *et al.* 1974) are often used to determine if observed use is significantly different from expected. It is important to be familiar with the assumptions implicit within these types of analysis, particularly as calculating the strength of habitat selection may be a product of the researcher's estimate of how much habitat is actually available. Although statistical techniques required to measure habitat use/availability remain controversial, compositional analysis (Aebischer *et al.* 1993) or standardized selection ratios (Manly *et al.* 1993) are recommended as analytical techniques because they address some of the more serious pitfalls associated with traditional use/availability analysis. For a complete discussion on the advantages and disadvantages of different statistical methods, see Alldredge and Ratti (1986, 1992).

Proportions of habitat use are not independent (e.g., if an animal spends more time in habitat A then it must spend less time in habitat B). Therefore, tests that assume independence of habitat cannot be used (Freidmann 1937; Aebischer *et al.* 1993).

Observations gathered during data collection can be most useful to determine the habitat attributes most important to animals. It is easier to understand what animals are doing at the time of field observations than from inspecting a table of numbers.

6.3.2 Locating Specific Habitat Features

Radio transmitters may be utilized to locate specific habitat features such as nests, dens or roosts for other types of studies. For example, applying temporary tags to birds during the nesting season allows researchers to locate nests easily. The nest can be located in a day or two, and when the tag drops off it can be placed on another bird. This technique may be used to identify similar habitat features for other species, such as bat roosts, snake hibernation dens, or amphibian breeding sites.

The use of radio-telemetry to find habitat features may become especially important in British Columbia with the implementation of the Forest Practices Code. Included in the Code are provisions for the protection of specific habitat features which are critical to the viability of certain species and subspecies through the designation of Wildlife Habitat Areas. Under the Code,

conservation of these taxa, which include numerous species at risk, is closely tied to habitat, and is contingent on the ability of provincial biologists to locate critical habitat features, such as roosts, hibernacula, or breeding sites. Radio-telemetry may be the most efficient way (and in some cases, the only way) to locate these features.

Biologists using telemetry to locate specific habitat features will need to take extra care when attaching transmitters to breeding or reproductive organisms (where this is deemed feasible). Such an exercise should not be taken lightly, as organisms of interest for such study are frequently red- or blue-listed, and poorly planned capture or handling can easily be disruptive to survival and successful reproduction. Additionally, researchers following tagged animals should exercise similar care when making observations in and around critical habitat features. Use of these features frequently occurs at those points in a species life cycle when it is particularly vulnerable to disturbance. It is of little use to locate the new nest of a red-listed bird only to have it abandoned shortly thereafter.

6.4 Home Range Determination

Studies of home range size usually seek to obtain a mathematical determination of home range size for representative animals in a population. Sample sizes are dependent on the study objectives, analysis methods and several biological parameters such as social structure. As previously mentioned, which particular subset of the population is sampled is dependent on the research objectives (e.g., whether or not to include different age/sex classes.)

Sample size as it pertains to number of relocations can be determined through pilot studies and asymptotic plots. Locations of each animal are used to calculate a home range size (see Data Analysis) which is recalculated each time the animal is relocated. Graphs for different ages/sexes/individuals may be compared to see how much variation exists between different groups, and what number of relocations is necessary to differentiate between groups. If there is little variation between animals of different sexes or ages, it may not be necessary to allocate sampling effort between different classes (i.e., increase number of tagged individuals). However, if, for instance, males are found to have a significantly larger home range size than females, a study concerned with determining average home range size for the species should allocate sampling efforts between the sexes according to the naturally-occurring sex ratio in the population (this would occur if individuals are randomly sampled). A safeguard against sex/age class differences is to randomly sample the population (this only works if the objective is a general home range over all sex/age classes combined). However, if the objective is to document differences between age/sex classes then equal representation should be met in order to meet requirements of the necessary statistical tests.

Preliminary sampling at random or systematic points in time also aids in determining circadian patterns of the study species. Preliminary sampling should be based on the natural history of the organism (i.e., try to sample throughout the time when the animal is active). For example, it may be important to identify the roosts of certain birds; however, prolonged radio

tracking of sedentary, roosting birds throughout the night may yield little useful information.

Possible differences due to habitat quality should also be identified during preliminary sampling. A Barn Owl in lush old-field habitat may require a significantly smaller home range than an owl in poorer-quality habitat. By testing for differences between characteristics of individuals and characteristics of the habitat, the researcher can often control for many variables other than the one under study.

Some authorities have concluded that approximately 30 relocations per individual will provide an adequate sample size for home range determination for many applications (Kenward 1987). This number is highly variable however so each researcher should test this during their pilot study (the asymptotic plot method provides a straightforward approach).

6.4.1 Data Independence

One problem with multiple relocations of the same individual is that the relocations may not be statistically independent, which may lead to underestimations of home range size (McNay *et al.* 1994). Lack of independence may be due to migratory movements or to infrequent movements due to unique places in the home range (e.g., periodic visits to a salt lick), or to sampling protocol (see above). Knowledge of the behaviour of the study species is necessary in order to interpret unusual movements and decide whether or not to include outlying fixes in home range calculations.

6.4.2 Data Analysis

An animal's home range size, shape, and position is often represented by joining the outermost fixes for that animal to form a minimum convex polygon (Mohr 1947). Outlying fixes (representing rare excursions) may unduly influence the polygon's shape and size to produce a misrepresentation of the space actually used by the animal (McNay *et al.* 1994). Analysis models which allow for data clumping (Don and Reynolls 1983), harmonic mean methods (Neft 1966; Dixon and Chapman 1980; Kenward 1987), ellipses (Jennrich and Turner 1969), cluster analysis, core convex polygons (Kenward 1987) or kernel estimation methods (Naef-daenzer 1993) may provide better representation of the data. The test of any method of depicting home range is the significance of its results in terms of the animal's use of space.

On a related topic, distances between consecutive radio locations of an individual are often used as an index of the total daily movement for that individual (Laundré *et al.* 1987). Rates of movement are often compared between demographic groups or time periods. However, perceived movement distances determined by daily locations may not necessarily be correlated with actual distances moved (Laundré *et al.* 1987). It is recommended that researchers planning to use telemetry data in this way, do preliminary sampling to compare data from once/daily locations with that obtained from round-the-clock hourly monitoring. If there is little correlation, the results obtained from daily locations will not be valid.

6.4.3 Software Packages for Home Range Estimation

The minimum convex polygon (MCP) method should only be used to determine the boundaries of a home range whereas the grid-cell approaches (e.g., harmonic mean (HM), adaptive kernel (AK)) are more suited to analyzing the " internal anatomy" or structure of the home range. Choosing the most appropriate home range estimator will largely depend on the distribution of the relocation data. If the locations are distributed in a uniform manner (i.e., there is no centre of activity) then the MCP can be used to estimate home range size. On the other hand, if the locations are not uniformly distributed (which is usually the case), then non-parametric techniques such as HM and AK are more suitable assuming adequate sample sizes have been taken. Most of the computer programs available will determine if your data set meets the assumptions required to use a parametric home range estimator as well as test for independence of observations. Determining which non-parametric method to use will vary with the study objectives and how accurately the home range is depicted. In general, the HM and AK techniques provide the most precise estimates; however, relatively large sample sizes (>100) are required.

Software packages for estimating home ranges have recently been reviewed by Larkin and Halkin (1994). Table 2 is adapted from data in their paper. Table 2 is not a complete list of existing packages. Users are encouraged to contact the Wildlife Telemetry Clearinghouse home page for more information (see resources list).

Table 4. Some software packages for analysis of home range. (modified from Larkin and Halkin 1994).

Package Name	Reference	Non/Parametric Techniques
CALHOME	J. Kie	both
DC80	Dixon and Chapman 1980	both
DIXON	Dixon and Chapman 1980	nonparametric
HOMERANGE	Ackerman *et al.* 1990	both
KERNELHR	Seaman and Powell 1991	nonparametric
Map and Image	Skrdla 1992	nonparametric
McPAAL	Stüwe and Blohowiak 1985	both
MICRO-DIXON	Timossi and Barrett 1985	nonparametric
RANGES IV	Kenward 1990	nonparametric
SEAS	none avail.	both
Wildtrak (Macintosh)	Gorman 1993	both
White and Garrott	White and Garrott 1990	both

6.5 Demographic Studies

Radio-telemetry may be used to improve the quality of other wildlife surveys which attempt to estimate population size and composition. This is because during a survey, observers will be able to assess the number of unseen radio-tagged animals which were known to be in the study area. This knowledge can be used to correct survey results for visibility bias (the failure to observe all animals during an aerial survey). The degree of visibility bias depends on a variety of factors including, the amount of vegetative cover, animal behaviour, animal size and coloration, observers, weather, and equipment. Radio equipped animals allow estimation of this bias since instrumented animals known to be in an area can be recorded as seen or not seen.

Radio-telemetry is often used to improve accuracy of classification counts of species which may be classified by means of survey flights (most big game species). Radio tags are placed on individuals of known sex and age. Classification counts done from aircraft can then be combined with relocation of tagged individuals. Whether or not the tagged animals are visible from the air provides a means of calculating sightability indices to be used as correction factors for the classification counts (Simpson *et al.* 1993). The use of radio collars enhances survey accuracy because:

- radio collared animals can be monitored after the survey to determine whether any left or entered different survey areas;

- the movements and behaviour of collared animals can be monitored to assess their detectability relative to unmarked animals;
- the loss of marked animals can be detected; and
- relocating marked animals immediately after a survey area is completed allows determination of the reasons that animals were missed.

More sophisticated sightability correction models have been developed for surveying large mammals using radio collared animals to correlate sightability with other parameters recorded during surveys such as group size, activity, snow cover and vegetation cover for animals observed (Unsworth and Garton 1991).

6.5.1 Mortality & Survival

In theory, radio-telemetry techniques should enable the importance of cause-specific mortality factors to be determined because tagged animals can be located soon after death and the agent of mortality ascertained (Heisey and Fuller 1985). In practice, it is often difficult determine the cause of mortality due to difficulties accessing the carcass soon enough after death and to distinguish mortalities from other tag losses such as tag failure and animal dispersal.

It is extremely important that the capture and attachment of a radio tag to the study animal does not affect its probability of death. Researchers engaging in this type of study should employ proper capture methodology and ensure tag attachment does not influence survivability by either evaluating the effects of tag attachment on mortality or using only tag types and attachment methods which have been previously proven to be unbiased. It is also important for researchers to re-evaluate their methods whenever an iatrogenic or researcher-influenced mortality occurs.

Defining adequate sample sizes for mortality studies is done by preliminary sampling to determine the variance in survivorship. Survival rates are estimated from the number of transmitter-days, the number of mortalities due to particular causes, and the number of days in the chosen interval of time over which daily mortality rates are assumed to be constant (Heisey and Fuller 1985). A study design described by Pollock *et al.* (1989) allows for new animals to be added to the tagged population after the study has begun.

The fate of lost tags and causes of mortality should be ascertained as closely as possible for results to be credible. Estimates of radio failure rate may be made by keeping accurate records of pulse rates of each transmitter over time, although some transmitters may not change overtly prior to failure, and so this is not always reliable. Kenward (1987) chose to classify as mortalities any tags which were lost a) well before the end of their expected cell life b) with no slowing or irregularity in their signals, and c) without subsequent recapture or resighting. Depending on the situation and the study species, this may not always be appropriate as transmitters will fail without warning and study animals will disperse beyond the limits of the study area. It is important that researchers divulge whatever assumptions they choose to make with regard to mortality, and, in some cases, they will have to accept that the fate of some individuals will remain unknown.

Also, “the time needed after marking for adjustment to a transmitter package, physical recovery from capture, stress or injury or resumption of normal social bonds (especially for young animals) should not be included in survival calculations” (Hersey and Fuller 1985).

7. REVIEW BY SPECIES GROUP

This section contains a literature review of different transmitter techniques and their relative success when used on different groups of species. It is intended to provide as much information as possible about what has worked in the past and what has not for different species. It is impractical to standardize transmitter attachment for all of British Columbia's species. In light of this, all telemetry projects should operate within the general protocols outlined in the previous chapters; however, specific details of transmitter attachment will vary from project to project. Inclusion of a method in this review should not be equated with a recommendation.

7.1 Amphibians

Amphibians pose a number of interesting challenges when it comes to telemetry because:

- they are usually aquatic;
- most are relatively small in size;
- their epidermis is very fragile;
- their skin is usually quite damp and serves a respiratory role in many species, making it inappropriate for skin cements or glues;
- their bodies may expand as a defensive response when captured, making certain attachments difficult to fit; and
- amphibians are often nocturnal and must be tracked in the dark.

Because of these difficulties, telemetry has had limited use in this group in the past. However, new techniques and technology are resulting in an increase in the popularity of amphibians in telemetry studies. Much work is still experimental and very few techniques have been adopted by the majority of amphibian researchers.

7.1.1 Frogs and Toads

Ingested tags are either force fed or hidden within food items. Behavioural change has been exhibited in individuals that have been equipped with too large a transmitter (Kenward 1987). However, several studies have used ingested tags quite successfully with both frogs and toads (Kenward 1987). Oldham and Swan (1991) force fed 2.5 g transmitters to fourteen adult Common Frogs (*Rana temporaria*) and Common Toads (*Bufo bufo*). The transmitters were regurgitated in 2 to 13 days in the frogs, and 2 to 38 days in the toads. The authors felt they were able to get useful short term data using this technique although it is unclear whether the transmitters influenced the animals' behaviour.

Surgical implants can be used in longer term studies provided the animal is large enough to accommodate the tag. For example, Red-legged frogs (*Rana aurora)* have not been implanted due to size constraints (N.J. Scott, National

Biological Service, San Simeon CA, pers. comm.). Implantation is typically characterized by a lateral incision directly into the coelomic cavity (Sinsch 1988; Seitz *et al.* 1992). A common anaesthetic used for surgical procedures in amphibians is MS-222© (Sandoz; Ethyl-m-amnobenzoate-methane-sulphonate) used at a concentration of 200 to 300 mg/l (Bonath 1977). Recovery periods vary between studies, but Seitz *et al.* (1992) were able to release animals back to their place of capture after only a few hours. This procedure requires training prior to its use in the field.

Rathbun and Murphey (submitted) have developed a waist-belt made of ball or beaded chain which has been used on California Red-legged Frogs (*Rana aurora draytonii*). Preliminary studies suggest that aluminum is the best material since it does not corrode or weigh as much as brass (Rathbun and Murphey 1993). The transmitter normally sits dorsally, but is unaffected if it rotates to the ventral position. This procedure takes approximately five minutes. There is a small danger of the chain becoming snagged on vegetation and it may cause irritation of the skin if the chain is too tight. Some frogs have slipped out of their belts following weight loss occurring towards the end of the dry season (Scott, pers. comm.).

Bartelt (1994) has developed a single harness belt for use with more terrestrial frogs and toads. This harness consists of soft, surgical grade polyethylene tubing that fits around the waist of the animal. This particular belt caused severe skin abrasions in Oregon Spotted Frog (*Rana pretiosa*) after one month, so it is not recommended for highly aquatic anurans in studies which will exceed one month. Western Toads (*Bufo boreas*) however, have slightly thicker skin and did not exhibit abrasions like *R. pretiosa*. The condition of telemetered individuals should be checked every two weeks. This technique is inexpensive, like that of Rathbun, but it probably advantageous in that the harness can be sized precisely in the field, it is very lightweight (0.01 g), and has been known to break off the animal after three to four months in water (or when the animal outgrew it).

Bartelt (pers. comm.) has also tried other techniques which involved using elastic straps. He found that these other methods affected behaviour or caused localized edema and are not recommended.

Transmitters may also be housed in a small pocket on the back of the vest with the antenna trailing behind. Any loose-weave elastic fabric (e.g., spandex) that allows air transfer is a suitable material (Anderka and Angehrn 1992). Others have used plastic (silicon) tubing (Loman, pers. comm. in Rathbun and Murphey) and latex rubber straps and bands (Van Nuland and Claus 1981; Fukuyama *et al.* 1988; Richards *et al.* 1994). The system develop by Van Nuland and Claus (1981) for the Common Toad (*Bufo bufo*) involved passing each of the animal's legs through different perforations in a piece of latex, creating a harness to hold the transmitter on the toad's back. No discernible effects on the toad or any noticeable changes in behaviour were observed but the harness occasionally caused a skin irritation and could be displaced in dense vegetation. Girdle material has also been successful as a harness with toads (Kingsmill 1991).

7.1.2 Salamanders and Newts

Surgically implanted transmitters have been successfully used on Pacific Giant Salamanders (*Dicamptodon tenebrosus*) greater than 10 cm (snout to tail), and Northwestern Salamanders (*Ambystoma gracile*). Transmitters (1.85 g) have been surgically implanted in Ambystoma (anaesthetized with MS-222©) by making as small an incision as possible in the peritoneal cavity. Individuals of 25 to 30 g were preferred for implantation although animals as small as 20g were also used. Wounds are reported to heal in about 8 to 10 days following surgery (A. Stringer, Univ. of Washington, Seattle WA, pers. comm.). Suture material should be of a non-absorbable type in order to avoid improper healing; however, it is important to note that there are many different types of non-absorbable suture, only some of which are suitable for amphibians. Researchers will often keep study animals in the lab until recovery is complete (Mallory, pers. comm.).

7.2 Reptiles

7.2.1 Snakes

By far, the majority of snake telemetric studies use implant methods. Obviously, body shape plays an important role in this and also the manner in which snakes digest food (i.e. large bolus moves down the body after ingestion and makes it difficult for external attachment devices to remain secure, given the stretching of the skin). Implants also usually afford the researcher the ability to measure body temperature. This method is limited, however, to larger snakes because of restrictions in size availability of implantable tags (L. Norman, Univ. of Victoria, Victoria, BC, pers. comm.). Generally, transmitters in snakes are kept at 5% of body mass, but some suggest that perhaps 3% would be a better figure to limit impact on snake behaviour (D. Parizek, SW Rodents, Vail, AZ, pers. comm.). Norman (pers. comm.) found that she could not implant any snakes under 60 g, which biased her study to the largest snakes in the population she was working with (i.e., adults, females, and larger species). Some researchers have experienced problems with stiff subcutaneous antennas in the past (N.J. Scott, National Biological Service, San Simeon, CA, pers. comm.), but antennas are now more flexible. Most implantable tags come equipped with whip antennas so that an adequate signal range can be achieved. Secor (1994) reports ranges of 250 to 600 m in his studies.

At least three types of anaesthetic have been used in British Columbia studies: isofluorane, halothane and methoxyfluorane. Use of inhalant anaesthesias should be preceeded by consultation with a veterinarian familiar with the species in question. It is important to understand that the immune system and surgical healing in poikilotherms is affected by their ambient temperature, and thus recovery from implantation will take longer than in birds or mammals. Because of this, the seasonal timing of surgical implants is also an important consideration.

Many species of snakes within British Columbia have been outfitted with implants including the Common Garter Snake (*Thamnophis sirtalis*), Western Terrestrial Garter Snake (*T. elegans*), Western Rattlesnake (*Crotalus viridis*), and Gopher Snake (*Pituophis catenifer*) (C. Shewchuk, Univ of Victoria, Victoria, BC, pers. comm). These are based mainly on size of species and abundance. For example, the Northwestern Garter Snake (*T. ordinoides*) has not been implanted because of its small size (Norman, pers. comm.).

Most researchers use either intra- or extraperitoneal implantation by making a small incision on the mid-lateral area of the snake with the whip antenna running up the longitudinal axis (direction varies between researchers).

Some researchers have experienced problems with infections developing at the implant site (up to 75% , W. Card, Dallas Zoo, Dallas, TX, pers. comm.; Norman, pers. comm.). Chances of infection can be markedly decreased with proper surgical technique (e.g., using sterile instruments, suturing incision properly, making sure transmitter parts are biologically inert, not implanting a snake that is close to shedding its skin). K. Larsen (Alberta-Pacific Forest Industries, Inc., Boyle AB, pers. comm) noticed high degrees of scar tissue

around implanted transmitters, and suspected that a transmitter may deterred female reproduction in his study. Norman (pers. comm.) used extraperitoneal implantation and reported that occasionally transmitters slip up the side of the animal and may even push out through the initial incision site or break through the skin.

Forcibly inserting transmitters so that they are ingested, has also been tried with snakes (Fitch and Shirer 1971; Fitch 1987; Lutterschmidt and Reinert 1990). Plummer and Congdon (1994) tested the possibility that intragastric placement may be a satiation stimuli, but found this not to be so in the Racer (*Coluber constrictor*) populations they tested.

A limited number of studies have used external attachment sites (Ciofi and Chelazzi 1991; Rathbun *et al.* 1993). Transmitters were taped to the tail skin of snakes with poor success.

7.2.2 Lizards and Skinks

Telemetry is difficult with lizards and skinks because few attachment sites are available. Most work has been done on slow moving "sit-and-wait" lizards and very little has been done on active species (T. Doan, Univ. of S. Florida, Tampa, FL, pers. comm.). In British Columbia, we have one very rare, slow moving species, the Pigmy Short-horned Lizard (*Phrynosoma douglassi*) and three quick ones: the Western Skink (*Eumeces skiltonianus*), Northern Alligator Lizard (*Elgaria coerulea*) and the introduced European Wall Lizard (*Podarcis muralis*). To our knowledge, none of these species have been tagged in British Columbia. It is unlikely that anyone would ever embark on a study of *Phrynosoma* within B.C., since only two specimens have ever been recorded within the province (Gregory and Campbell 1987).

Implants have the advantage of being concealed and remove any likelihood of an animal getting caught on vegetation. However, the major limitation associated with lizard implants is that body size dictates which species can be implanted. Although in past smaller implants have been associated with a decrease in the duration of battery power, new technology has allowed for the development of increasingly efficient and smaller power sources. Perhaps in a few years, technology will be at a stage where transmitters are small enough to make most, if not all, lizard species implantable.

Fast moving species can be more challenging to track than slower ones, and implants may create further difficulties. Range is reduced with the helical antenna and this can be further compounded by dense vegetation (Doan, pers. comm.). Many implant studies are concerned with internal body temperature as well. This method is well suited to this goal but more recently Bouskila (Ben-Gurion Univ. of Negev, Beer-Sheva, Israel, pers. comm.) developed an external package which can be used to measure body temperature (see below).

External transmitters can be very practical when long term continuous monitoring is not needed. They offer a great advantage in that transmitters can be reused on several individuals with relative ease and can be removed and deactivated to save batteries. External attachment also minimizes chances of infection due to experimental manipulation.

External transmitter may be mounted with backpacks or adhesive mounts, in those situations where implantation is not possible or desired. Several designs have been used to attach transmitters to lizards. One of the newest methods for backpack attachment in lizards has been developed by Fisher and Muth (1995) with the Flat-tailed Horned Lizard (*Phrynosoma mcalli*), a congener of *P. douglassi*. The method involves attaching the transmitter to polypropylene pleating tape, and using polyurethane elastic to form harnesses for attachment dorsally behind the neck. Packages that approach 25% body weight have been used in *P. mcalli*, and this appears to be approximately equal to the mass of an egg clutch in this species (Pianka and Parker 1975; Fisher and Muth 1995). Captive lizards resumed feeding immediately after transmitter attachment, and released lizards also resumed "normal" activities.

Munger (1984) used a similar system to Fisher and Muth except that he used a loop antenna to secure the transmitter to the body. This is similar to the method employed by Muth *et al.* (1978) with desert iguanas (*Dipsosaurus dorsalis*). Individuals were outfitted with a rectangular package that was mounted slightly anterior to or between the forelegs with the antenna passing anteriorly and over the base of the neck. A yoke closely followed the body contour and fit snugly around the neck to prevent snagging. This method was designed specifically to alleviate abdominal constriction during egg development; however, the authors note that a simple "waist collar" would be suitable for non-gravid individuals, with the transmitter attached to a belt and mounted against the lizard's lower back (Muth *et al.* 1978).

Some researchers have had success using tape to secure transmitters to the tail (Houston *et al.* 1995). There is, however, the possibility that this makes the animal more obvious to predators (S. Burgin, Univ. of W. Sydney, Hawkesbury, Richmond, Australia, pers. comm.). Bouskila (pers. comm.) used externally attached transmitters (above the base of the tail) with cloacal probes to measure body temperature, a measure which previous to this relied upon implants. These were attached temporarily by gluing a Velcro patch at the dorsal base of the tail and then doing the same with the transmitter, for ease of removal. Researchers interested in this technique should be aware that some lizard species are capable of shedding their tails and this presents certain problems during handling and attaching these units, as well as for maintaining them.

7.2.3 Turtles

Most turtle researchers employ carapace mounts with few exceptions (Galbraith *et al.* 1987; Kaufmann 1995). We have included references for several non-native species of turtles and tortoises because the techniques are applicable to turtles found within B.C. Freshwater turtle species in the province are essentially limited to the Painted Turtle (*Chrysemys picta*), a blue-listed species found in portions of southern B.C. Although there have been sightings of other freshwater species (e.g., Snapping Turtle) in the province, these are not known to occur in established populations. Recently however, several populations of the introduced Red-eared Slider (*Chrysemys scripta*) have established themselves (C. Shewchuk, Univ. of Victoria, Victoria, B.C., pers. comm.).

The predominate way to attach a transmitter to a turtle is by mounting the tag on to its carapace. Different techniques of accomplishing this have met with

varying levels of success depending upon life-history traits, age, and size of study animals. Mounting a transmitter on top of a turtle provides an obvious possibility for utilizing solar power; however, Scott (National Biological Service, San Simeon, CA, pers. comm.) reports difficulties with this approach as each time a turtle dives, the signal is switched off, making it difficult to locate individuals. Care must always be taken when fastening objects to the carapace to minimize any interference effects on mating (Holland, pers. comm). As well, antennas should be kept as short as feasible to minimize snagging on vegetation (de Solla, Holland, pers. comm.).

In terms of attachment, one method has been to use drilled holes and wire to attach transmitters (S. de Solla, Univ. of Guelph, Guelph, ON, pers. comm). Other researchers have used “five-minute” epoxies to secure the transmitter to the carapace; however, both submersion and ultraviolet light are suspected to cause degradation and detachment of the unit within 2 to 12 weeks (Rathbun *et al.* 1992; D.C. Holland, Fallbrook, CA, pers. comm; R.A. Saumure, McGill University, Montreal, PQ, pers. comm). Carter (Virginial Poly. and State Univ., Blacksburg, VA, pers. comm.) uses a liquid vinyl coating (e.g., Pastidip) over epoxy to ensure waterproofing of the attachment site, whereas other researcher choose alternatives such as PC-7 (a water-resistant epoxy paste available in most hardware stores) or dental acrylic. Wilson (Univ of S Florida, Tampa, FL, pers. comm.) found that when transmitters were glued to the carapace in juvenile tortoises that the shell deformed somewhat near the transmitter site. Saumure (pers. comm.) attempts to avoid interfering with shell development by first making a well out of silicon before applying PC-7 adhesive so that when the transmitter is pressed into place, the resin will not cross over a scute line and impede growth. In addition, when it is time to remove the transmitter, it can be gently pried loose in one piece with no residue.

Brown (1990) has used thermistor (a resistor which is sensitive to changes in heat) implantation in order to gather data on internal temperature. Studies with larger oceanic turtles (e.g., Green) have used subcutaneous implants (inguinal region) in the past, but this method has largely fallen out of use with recent advancements in adhesive technologies. A few researchers have used esophageal ingestion as a means of measuring internal body temperatures (S. Eckert, San Diego State Univ., San Diego, CA, pers. comm).

7.3 Small Mammals

7.3.1 Small Rodents

Collars have been used on a variety of species. In some cases, they provide surprisingly strong signals; Douglass (1989) reported a signal range up to 160 m with collar transmitters fitted on deer mice. Typically, collars for rodents have consisted of a radio package encased in some sort of plastic tubing with the antenna circling the neck. However, in some instances an encasing material was not used in the collar design. The design of rodent collars should strive to minimize any potential for snagging. For example, Mahon (Simon Fraser Univ., Burnaby, B.C., pers. comm.) reports that 25% of voles and mice in his study died as a consequence of getting caught up in vegetation. Other reported problems associated with rodent collars include: transmitter loss, neck irritation and/or hair loss, restricted movement through burrows and/or dense vegetation, increased ectoparasite load beneath the collar and changes in behaviour (Hamley and Falls 1975; Madison 1977; Smith and Whitney 1977; Filipovich 1983; Eagle *et al.* 1984). Because radios are external, they can also be damaged by extreme weather conditions, mechanical wear (Eagle *et al.* 1984), and / or mutual grooming episodes (Madison 1977). Todd (Univ. of Herfordshire, Hatfield, UK, pers. comm) reports habituation to collars within one day in wood mice.

Jumping mice have been radio tagged using glue-on methods (“superglue”) to the back (Wunder, Colorado State Univ., Fort Collins, CO, pers. comm). The package was frequently dislodged at 3 to 4 days. Range was reported as approximately 80 m even when the animal was 0.6 m underground.

Subcutaneous implants have been used in small mammals since 1964 (Rawson and Hartline 1964). However, intraperitoneal implants were found to be superior and used successfully with a variety of species (Neely and Campbell 1973; Smith and Whitney 1977; Smith 1980a,b; Koehler *et al.* 1987). Eventual adhesion of implanted capsules transmitters to peritoneal structures was noted following abdominal implantation in beavers in one study (Guynn *et al.* 1987).

7.3.2 Bats

Fenton *et al.* (1985, 1993) tagged bats using 0.9 g transmitters attached to the lower mid back with “skin bond” cement. These transmitters had a range of 2.5 to 4.0 km, but other studies using the same techniques, only reported a 1 km range (Brigham and Fenton 1986). The same method was used by Brigham (1991) with Big Brown Bats (*Eptesicus fuscus*) in B.C. The package used in his study was 6% body weight and the study animals showed no adverse effects. Most bats lose their transmitter 1 to 20+ days after attachment (R. Barclay, Univ. of Calgary, Calgary, AB, pers. comm.).

Lancaster *et al.* (1992) glued transmitters to the heads of bats using eyelash adhesive. The head fur was first removed using a hair removal lotion (“Neet”). This study was done under controlled conditions (i.e., captivity) and signal range was only 3 m. Grindal (pers. comm., Axys Environmental Consulting

Ltd., Calgary, AB) notes that exposing the skin beneath a bat's fur is generally unnecessary for transmitter attachment and potentially detrimental to a wild bat. Hair removal lotion should not be used. Caution should also be exercised when using eyelash adhesive as Fry (Minneapolis, MN, pers. comm.) reported "considerable damage to the skin" under the transmitter.

Fenton *et al.* (1985) radio tagged bats using 4.5 g transmitters attached by collars. These transmitters had a range of 10 km.

7.3.3 Insectivores

Little telemetry work has been done on this group, probably because of their fossorial nature and small size. Most studies use radioactive substances to track as opposed to telemetry (Meese and Cheeseman 1969). Gorman and Racey (1992) glued transmitters to the dorsal surface of the tail. Radio signals were readily detectable through the soil and an accuracy of +/- 0.25 m was reported.

Collars have been used by Rado and Terkel (1989) on mole rats (a subterranean rodent) with some success. One type of collar failed because the transmitter protruded too far from the collar, and interfered with movement in the tunnel. Their second, more streamlined type was more successful, and had a range of 30 to 100 m from within the mole tunnel. Merritt (Carnegie Museum, Pittsburgh, PA, pers. comm.) reports that many animals cannot forage properly with collars on.

Implants have been used by Gorman and Racey (1992). The transmitters were placed intraperitonealy, by a mid-ventral incision, in moles anaesthetized with halothane.

More recently, McShea (Smithsonian Institute, Front Royal, VA, pers. comm) has implanted Star-nosed Moles (*Condylura cristata*) and Merritt (pers. comm.) has implanted shrews. Merritt reports close to 100% survivorship following surgery using inhalant anaesthesia.

7.4 Furbearers and Large Carnivores

Radio collars are the most popular method for attaching transmitters to most furbearers and large carnivores (Anderka 1987). Collars have been used successfully on coyote (Babb and Kennedy 1987), fisher (Arthur 1988), marten (Hodgman *et al.* 1994), wolverine (Whitman *et al.* 1986), lynx (Schwartz and Becker 1988), bobcat (Knick 1990), snowshoe hare (Keith *et al.* 1984; Boutin and Krebs 1986), raccoon (Jordan *et al.* 1986; F. Lebebvre, Univ. de Sherbrooke, Sherbrooke, PQ, pers. comm), black bear (Schwartz and Franzmann 1991), grizzly bear (Hamilton and Archibald 1985), wolves (Peterson *et al.* 1984; Fuller and Snow 1988), and cougar (Beier 1995). Design of transmitter attachments for large carnivores should be extremely sturdy and long-wearing, as these animals are very powerful.

Although they have been successful in many past studies, collars may not be the best choice for every situation. Rigid collars of metal wire are not recommended for mammals which live in burrows or crevices, as the collars may become lodged and result in the animal's death (Skirnisson and Feddersen 1985). G. Mowat (Nelson, BC, pers. comm.) notes that collar fitting is critical for mustelids, as the difference between head and neck circumference is very small. Melquist and Hornocker (1979) attempted to use collars on river otter, but reported problems with collar loss, poor reliability and neck irritation. They recommended the use of implants in this species, an approach used in later studies (Melquist and Hornocker 1979, Reid *et al.* 1986). Implanted transmitters have also be used for beaver (Gyunn *et al.* 1987), striped skunks (Rosatte and Kelly-Ward 1988), mink (Eagle *et al.* 1984), muskrats (Lacki *et al.* 1989), marmots (A. Bryant, Nanaimo, B.C., pers. comm.; van Vuren 1989), wolverines and kits (J. Krebs, Nelson, BC), and a number of canids (Green *et al.* 1985). However, some negative effects of implants have been reported (Woolf *et al.* 1984). Implanted transmitters have been used on grizzly bears (Philo *et al.* 1971) and black bears (Jessup and Koch 1984), as have ear-mounted transmitters (Serveen *et al.* 1981).

Expanding breakaway collars have been used on young black bears (Strathearn *et al.* 1984) and coyote pups less than six weeks old (Andelt 1985). In the latter case, the pups lost their collars very quickly so implants were used instead. The implants had poor range, so when the pups reached three months old, they were fitted with standard radio collars.

Harnesses are generally not practical for use on most medium-sized mammals due to the danger of entanglement. However, expandable harnesses have been used on bobcat kittens (Jackson 1985; Blackwell *et al.* 1991). Backpack-mounted satellite transmitters are available for use on wolverine and foxes (Burger and Carroll 1994).

7.5 Ungulates

Collars are the preferred method of attaching transmitters to ungulates in most situations. Collars have been used on caribou, mule, white-tail and black-tail deer (Gillingham and Bunnell 1985; Harestad 1985), moose (Simpson *et al.* 1995), elk (Edge and Marcum 1989), mountain goats and mountain sheep (Krausman *et al.* 1989). Expandable collars have been used on deer fawns (Keister *et al.* 1988) and moose calves (Boertje *et al.* 1987), but may be lost prematurely due to grooming activities (Schulz and Ludwig 1985). Bighorn sheep rams may damage transmitter crystals during head-butting contests during the rut, so Krausman *et al.*(1989) placed two transmitters on each collar that was fitted on a mature ram.

As some ungulate species are wide-ranging, satellite collars are a practical means of tracking individuals over long distances (Craighead and Craighead 1987; Fancy *et al.* 1989; Keating and Key , n.d.). However, current sattelite collar designs are heavy, and anecdotal information suggests that animals may become very disturbed by the weight of the collar continually hitting their chins each time the put their heads down to graze.

Levine (Merlin Systems Inc., Meridian, ID, pers. comm.) reports that testing of a subcutaneous implant for elk is underway. The implant is designed to be inserted under the skin between the shoulder blades, and is being tested as an alternative to visible transmitter attachments such as collars.

Ear-tag transmitters (Bartmann *et al.* 1992) have also been used on deer. Implanted biotelemetry transmitters have been used in mule deer and mountain sheep (Stemp 1982; Garrott and Bartmann 1984). Vaginal implants have recently been used in plains bison in Yellowstone National Park to determine time of partuition or abortion.

7.6 Birds

7.6.1 Web-footed birds

A variety of transmitter mounting methods has been tried on these species. Collars have been used on Redheads and Marbled Murrelets (Sorenson 1989; A. Derocher, Ministry of Forests, Vancouver Forest Region, pers. comm.). Transmitters have been sutured to the backs of Mallard ducklings (Mauser and Jarvis 1991), adult ducks (P. Pietz, National Biological Service, Jamestown, ND, pers. comm.; Wheeler 1991), Rhinoceros Auklets and Marbled Murrelets (G. Davoren, Univ. of Victoria, Victoria, B.C., pers. comm.). Giroux *et al.* (1990) used tail-mounted transmitters on waterfowl. Morris and Burness (1992) used transmitters epoxied to metal leg bands to locate Common Terns. Implanted transmitters with external whip antennas have been used successfully on Mallards and Canvasbacks (Korschgen *et al.* 1996). Nasal-saddle mounted transmitters have been used on this group of birds (Swanson and Keuchle 1976), but have been found to cause behavioural changes (Perry 1981). Harness-mounted transmitters (Dwyer 1972) have also been reported to have adverse effects (Greenwood and Sargeant 1973; Amlaner et al 1978; Perry 1981). Harnesses also produce drag and possible loss of insulation in water birds (Kenward 1987).

Satellite transmitters attached as backpacks have been designed for use on swans and geese (Burger and Carroll 1994).

7.6.2 Shorebirds

C. Marn (Oregon State Univ., Corvallis, OR, pers. comm.) has sutured <1.5 g transmitters to the backs of newly-hatched American Avocets and Black-necked Stilts, and reports no problems due to infection. Glue-on transmitters seem to be the preferred method of instrumenting birds in this group. R. Butler (Canadian Wildlife Service, Delta, B.C., pers. comm.) glued 0.8 g transmitters to the backs of Western Sandpipers, and M. Robert (Canadian Wildlife Service, Sainte-Foy, PQ, pers. comm.), and P. Shepherd (Simon Fraser Univ., Burnaby, B.C., pers. comm.) used the same technique on Yellow Rails in Quebec and Dunlin on the Fraser River, respectively.

7.6.3 Raptors

Tail-mounted transmitters are generally the choice of most researchers working with raptors. Sodhi *et al.* (1991) reported no apparent effects of tail-mounted transmitters on Merlins, and Taylor (1991) reported no effects on Barn Owls.

Backpack-mounted transmitters with elastic-web or Teflon harnesses have been used with species such as Barn Owls (Andrusiak 1994), Boreal Owls (Hayward *et al.* 1993), Bald Eagles (Garrett *et al.* 1993), and Red-tailed Hawks (Demarchi and Searing 1995). However, Foster *et al.* (1992) reported deaths and life-threatening abrasions caused by improperly fitting harnesses on Spotted Owls. Harnesses which place the transmitter ventrally on the breast of the bird have also been used on owls, but had adverse affects on the birds (Nicholls and

Warner 1968). Solar-powered transmitters may be useful for diurnal raptors which commonly hunt in open areas (Snyder *et al.* 1989). Backpack-mounted and neoprene-harnessed satellite transmitters have both been used on Peregrine Falcons (S. Feliciano, pers. comm.).

Some telemetry suppliers offer bewit-mounted transmitters which are attached to a raptor's tarsi via a bewit. "Bewit" is a falconry term which refers to a piece of prestretched leather which is normally used to attach a bell to a raptor's leg. This method of attachment is not recommended for hard-stooping birds as the shock may damage the transmitter T. Weiss (Saarbruecken, Germany, pers. comm.) used this type of attachment on an eagle, but observed that the antenna seemed to always be in contact with the bird's toes. He also felt that the bird's ability to capture prey may have been compromised.

Poncho-mounted transmitters and necklaces similar to those used on game birds have proven to be useful in studies on Burrowing Owls (Haug and Oliphant 1990; D. Grier, Univ. of Guelph, Guelph, ON, pers. comm.). Patagial tags have been used on California Condors (Ogden 1985).

7.6.4 Game Birds

Game birds have frequently been studied with the use of radio-telemetry (Hill and Robertson 1987). Poncho-mounted transmitters have been used on many game bird species (Amstrup 1980; Pekins 1988). Solar-powered transmitters mounted on herculite ponchos worked well on Ring-necked Pheasants (Leif 1994). Burger *et al.* (1991) used bib-mounted transmitters and reported that heavier transmitter weights were correlated with decreased survival. Slaugh *et al.* (1990) and Lutz *et al.* (1994) used backpack transmitters on Chukar and Attwater's Prairie-chicken, respectively with apparent success**,** but harness-mounted transmitters have been reported to have adverse effects on Red Grouse (Boag 1972) and Woodcock (Ramakka 1972). Sharp-tailed Grouse have been fitted with radio collars (Marks and Marks 1987). Necklaces have gained favour for use on game bird species in recent years (Riley and Fistler 1992).

7.6.5 Herons and cranes

This group of birds has long legs which are suitable for attaching leg-mounted transmitters (Melvin *et al.* 1983). Implants have also been used on Sandhill Cranes (Klugman and Fuller 1990). Backpack-mounted satellite transmitters have also been used on Sandhill Cranes by B. Johns (Canadian Wildlife Service, Saskatoon, SK, pers. comm.).

7.6.6 Swallows, Swifts and Goatsuckers

We could not find any reference to swift radio tagging in the literature. Glue-ons have been used by Brigham (1989) with Barn Swallows, but he found that the tags affected foraging in a negative manner. Brigham (1989b, 1992) has used a backpack comprised of two elastic hair bands knotted in a figure-eight pattern and slipped over the wings in Common Nighthawks and Common Poorwills. Both of these species have bred successfully wearing radio tags which are attached in this manner, suggesting that the transmitters do not have

negative effects on their behaviour (Csada and Brigham 1994b; Wang *et al.* 1995).

7.6.7 Passerines, Pigeons and Doves

Five % of body weight is the generally accepted size for avian telemetry work, but the rationale behind this figure is really not known (Caccamise and Hadin 1985). Certain studies of thrushes and warblers have had apparent success using weights between 5 to 10% (Graber and Wunderle 1966; Knittle *et al.* 1985; Cochran *et al.* 1987). Caccamise and Hedin (1985) have developed data which suggests that small passerines can handle a greater transmitter:bird weight ratio because they are more aerodynamically suited than larger birds.

Raim (1978) pioneered some of the first passerine work. He glued transmitters interscapularly to cowbirds using a piece of cloth glued to the skin and feathers and another piece glued to the transmitter. This technique was duplicated by Sykes *et al.* (1990) who trimmed the feathers of Common Yellowthroats and Kirtland's Warblers to within 1 to 3 mm prior to mounting transmitters via chiffon fabric. They report little success when using only adhesive without the fabric layer. However, Walters (Univ. of Victoria, Victoria, B.C., unpubl. data) had very good success without using any fabric with his work on Orange-crowned Warblers, Pygmy and Red-breasted Nuthatches, and Hermit Thrushes. Perhaps this difference is related to the adhesive used: Walters used cyanoacrylic glue whereas Sykes et. al. (1990) were using latex eyelash adhesive. For the Kirtland Warbler work, however, Sykes *et al.*(1990) switched to skin bond cement which they found held longer, dried quicker, and was generally easier to use. Walters (unpubl. data) has found that birds can be tagged in less than 10 minutes with the adhesive method, and batteries usually give out long before the tag falls off. In another version of this attachment technique, Sykes *et al.* (1990) used Velcro in addition to the chiffon fabric. They found it was not as aerodynamically sound as the other method and do not recommend it.

Other researchers working on Red-winged Blackbirds have gone one step further to not only glue the transmitter, but suture it in place (Martin and Bider 1978). For suturing, inhalant anaesthetics, such as isofluorane, can be used in consultation with a veterinarian. The advantage with this method of attachment is that it is unaffected by moult, unlike adhesive methods alone (Martin and Bider 1978).

Sykes *et al.* (1990) found median retention was 24 days for transmitters mounted using adhesive and cloth. As well, when the transmitter fell-off, it pulled the attached feathers out of the folicle with it. This stimulated new feather growth within 2 to 4 days, producing fully-formed feathers in 17 to 24 days. Winker *et al.* (1990) report that tags fell off Wood Thrushes after 40 days because of feather growth. Zebra Finches, whose feathers were plucked during a study by Langman (1973), dislodged the transmitter within 3 to 7 days. It is usually recommended that feathers be cut, as opposed to plucked, to guard against this stimulated growth pattern.

Knittle *et al.* (1985) report an unbelievable range of 13 km for their 1.1 gram tags when signals were received by aircraft at altitudes of 500m to 1500m.

Ground tracking ranges were significantly less with values of 400 m to 8 km depending on terrain. This is in marked contrast to Langman (1973) whose finches' transmitters had a range of 3 m during physiological experimentation.

Harnesses have rarely been used with passerines, mainly due to weight constraints. Sykes *et al.* (1990) designed one for use with Common Yellowthroats (neck and abdominal loops), but found adhesive methods to be superior. One characteristic of harnesses is that they rarely fall off, compared with adhesive methods; this can be advantageous for data collection but also detrimental to the long term well-being of the subject animal.

Traditional harnessing methods such as wing loop or neck loops have met with less favour in recent years due to problems with behavioural changes. In the past, studies have reported harness slippage in approximately 10 to 15% of tagged birds, generally resulting in immobilization of the study animal (Rappole and Tipton 1991).

Rappole and Tipton (1991) have developed a harness method that they claim allows faster processing time and longer tag retention. Their method involves slipping looped ligature material over each thigh with the transmitter sitting dorsally over the synsacrum. The method only works well with species that have long, external thighs, so it will not be effective on ducks or doves.

Implant work with doves has begun by Schulz (Missouri Dept of Conservation, Columbia, MO, pers. comm.). Mourning Doves have been outfitted with subcutaneous and intra-abdominal transmitters. External antennas pass through the skin or body wall and thus yield a better signal for detection by the researcher.

Besides the interscapular gluing method, Knittle *et al.* (1985) have used tail mounts (base of the four central tail feathers) with Pine Siskins, MacGillivray's Warblers and Yellow Warblers. This method proved satisfactory during their study, but premature loss of tail feathers poses a potential problem. This method has not been adopted by any other researchers, as far as we are aware.

The more traditional raptor technique of rectrice attachment has been used successfully on Northern Shrikes (Atkinson 1993). This method differs from Knittle *et al.*'s (1985) as the transmitter is tied to the central retrices rather than glued.

Another form of tail mount has been used in Gray Jays where the tag has been attached to the two central retrices with duct tape. Barnard (Norwich Univ., Northfield, VT, pers. comm.) has usually had the batteries fail before the tag has become dislodged.

7.6.8 Woodpeckers

Nesbitt *et al.* (1978) were some of the first researchers to tag woodpeckers. They glued the transmitter interscapularly with a cotton fabric cushion between transmitter and bird. Tags weighed approximately 6.5 to 9% body weight. Several others have used the technique since (Odom *et al.* 1982; Hooge 1991; Bull *et al.* 1992; E. Walters, Univ. of Victoria, Victoria, B.C., unpub. data; C. Steeger, Ymir, B.C., unpub. data); but without the piece of cotton fabric. Tags were secured with cyanoacrylic glue ("superglue") in most cases.

The work by Odom *et al.* (1982) with endangered Red-cockaded Woodpeckers was not very successful, and they suggest that glue-on transmitters impaired the function of an already stressed bird. Their study was compounded by the fact that they were tagging relocated individuals.

One bird in Walters' studies was found to be unable to exit its cavity with the transmitter on its back. The tag jammed against the roof of the cavity, effectively trapping the bird within the hole. The entrance had to be slightly enlarged (2 mm) to enable the bird to exit (Walters, unpub. data). This problem should be considered with any method when cavity-nesting species are involved.

Harnesses have been used mostly with Pileated Woodpeckers (Renken and Wiggers 1989; Bull *et al.* 1992; Mellen *et al.* 1992; Bull and Holthausen 1993; R. Bonar, Weldwood of Canada Ltd., Hinton, AB, pers. comm). The package is held to the bird with Teflon ribbon and sits dorsally in the mid-region of the back. The harness extends around the body on both the anterior and posterior edges of the wing to hold the package in place mid-dorsally. Broken or bent antennas caused by Pileated Woodpecker preening were reported by Mellen *et al.* (1992).

A comparison of harnesses with glue-on methods was made by Hooge (1991) in Acorn Woodpeckers. He found that harnesses decreased flying behaviours even when compared to heavier packages applied with adhesive. As well, attachment time increased markedly as did the chance of entanglement when using harnesses.

Several studies have used the tail-mount method to monitor woodpeckers (Goggans *et al.* 1988). The transmitters are attached to the underside of one central tail retrix by a series of nylon ties extending along the feather shaft. Some researchers have reported whip antennas becoming stuck in bark when this method is used with woodpeckers, a family of birds which normally forage on trunks using the tail as a brace.

8. GLOSSARY

ABSOLUTE ABUNDANCE: The total number of organisms in an area. Usually reported as absolute density: the number of organisms per unit area or volume.

BIODIVERSITY: Jargon for biological diversity: the variety of life forms, the ecological roles they perform, and the genetic diversity they contain (Wilcox 1984 cited in Murphy 1988).

CURRENT DRAIN: The rate at which a power source is exhausted.

GLOBAL POSITIONING SYSTEM (GPS): Electronic device which determines its location utilizing signals from satellites.

"H" ANTENNA: A two element, H-shaped directional, receiving antenna.

HOME RANGE: The area required by an animal throughout a specified period of time, usually a season, a year, or a lifetime.

LINE OF SIGHT (LOS): The maximum unobstructed distance between transmitter and receiver which produces an adequate signal.

LOOP ANTENNA: A loop-shaped antenna used to send a signal from a radio-transmitter. Loop antennas may also be used to receive signals within a 1 km radius.

ONE STAGE TRANSMITTER: The simplest radio transmitter design which utilizes a single pulse capacitor to govern signal pulses.

OPERATIONAL LIFE: The period of time for which a radio-transmitter will produce a signal of sufficient quality to allow it to be tracked with a receiver.

PERIOD: The interval between signals.

PRESENCE/NOT DETECTED (POSSIBLE): A survey intensity that verifies that a species is present in an area or states that it was not detected (thus not likely to be in the area, but still a possibility).

PROJECT AREA: An area, usually politically or economically determined, for which an inventory project is initiated. A project boundary may be shared by multiple types of resource and/or species inventory. Sampling generally takes place within smaller study areas within this project area.

PULSE: A single signal (i.e. one "beep") from a radio-transmitter.

PULSE INTERVAL MODULATION (PIM): The ability of a transmitter to vary its pulse rate, usually in conjunction with animal behaviour.

RANDOM SAMPLE: A sample that has been selected by a random process, generally by reference to a table of random numbers.

REAL TIME SENSOR: A sensor which instantly alters the pulse rate of a transmitter as its position is changed. (Generally as the result of a change in behaviour of a tagged animal).

RELATIVE ABUNDANCE: The number of organisms at one location or time relative to the number of organisms at another location or time. Generally reported as an index of abundance.

SIGHTABILITY CORRECTION MODEL: A mathematical equation used to correct the results of a wildlife survey in an attempt to eliminate visibility bias.

SIGNAL: The audible, repeated pulse from a radio transmitter.

STRATIFICATION: The separation of a sample population into non-overlapping groups based on a habitat or population characteristic that can be divided into multiple levels. Groups are homogeneous within, but distinct from, other strata.

STUDY AREA: A discrete area within a project boundary in which sampling actually takes place. Study areas should be delineated to logically group samples together, generally based on habitat or population stratification and/or logistical concerns.

SURVEY: The application of one RIC method to one taxanomic group for one season.

SYSTEMATIC SAMPLE: a sample obtained by randomly selecting a point to start, and then repeating sampling at a set distance or time thereafter.

TAG: A radio transmitter.

TWO STAGE TRANSMITTER: A radio transmitter which incorporates a simple amplification stage to increase power output.

TIME DELAY SENSOR: Sensor which changes its pulse rate if an internal switch is not triggered for a specified period of time. Often used in mortality studies.

WHIP ANTENNA: A flexible transmitting or receiving antenna which is anchored at one end.

YAGI ANTENNA: A directional receiving antenna composed of lateral boom to which elements are attached so that they lie perpendicular to the boom and parallel to one another.

9. REFERENCES

9.1 Internet Resources

Biotelemetry Resources
http://www.biotelem.org/

Biotelem Listserver Home Page
http://www.bgu.ac.il/life/bouskila/telemetry.html

Wildlife Telemetry Clearinghouse
http://www.uni-sb.de/philfak/fb6/fr66/tpw/telem/telem.htm

Illinois Natural History Survey Wildlife Ecology
Software Server (telemetry data analysis programs)
http://nhsbig.inhs.uiuc.edu/

9.2 Telemetry Equipment Manufacturers

Note: The inclusion of any manufacturer on this list should in no way be interpreted as an endorsement of their products.

AVM Instrument Company, Ltd.
2356 Research Drive, Livermore, CA , USA 94550
Phone: +1.510.449.2286 Fax: +1.510.449.3980 Emerg. 24h Fax: +1.510.7362528
e-mail: avmtelem@ix.netcom.com

Advanced Telemetry Systems Inc.
470 1st Ave. No., Box 398, Isanti, Minnesota, USA 55040
Phone: +1.612.444.9267 Fax: +1.612.444.9384
e-mail: 70743.512@compuserve.com

Biotrack *(note: as of July 1998 Biotrack had not been approved for use in Canada)*
Stoborough Croft, Grange Road, Wareham, Dorset , UK BH20 5AJ
Phone: +44.929.552.992 Fax: +44.929.554.948

Custom Electronics of Urbana, Inc.
2009 Silver CT. W., Urbana, Illinois, USA 61801
Phone: +1.217.344.3460 Fax: +1.217.344.3460

Custom Telemetry Co.
1050 Industrial Drive, Watkinsville, Georgia, USA 30677
Phone: +1.706.769.4024 Fax: +1.706.769.4026

Holohil Systems Ltd.
112 John Cavanagh Road, Carp, Ontario K0A 1L0
Phone: +1.613.839.0676 Fax: +1.613.839.0675

Lotek Engineering Inc.
115 Pony Drive, Newmarket, Ontario L3Y 7B5

Phone: +1.905.836.6680 Fax: +1.905.836.6455
e-mail: telemetry@lotek.com

Mariner Radar Ltd.
Bridleway, Campsheath, Lowestoft, Suffolk, England NR32 5DN
Phone: +44.502.567195 Fax: +44.502.567195

Merlin Systems, Inc.
445 W Ustick Rd, Meridian, Idaho 83642
Phone:+1.208.884.3308 Fax:+1.208.888.9528
E-Mail: merlin@cyberhighway.net

Microwave Telemetry Inc.
10280 Old Columbia Road, Suite 260, Columbia, Maryland, USA 21046
Phone: +1.410.290.8672 Fax: +1.410.290.8847
e-mail: Microwt@aol.com

Mini-Mitter Co., Inc.
P.O. Box 3386, Sunriver, Oregon, USA 97707
Phone: +1.503.593.8639 Fax: +1.503.593.5604
e-mail: rrushmmtr@aol.com

Televilt International AB
Box 53 S-711 22 Lindesberg, Sweden
Phone: +46.581.17195 Fax: +46.581.17196

Telonics.
932 East Impala Avenue, Mesa, Arizona USA 85204-66990
Phone: +1.602.892.4444 Fax: +1.602.892.9139

Toyocom *(see note below)
20-4, Nishi-Shimbaxhi 3-chome, Minato-ku, Tokyo, Japan 105
Phone: +03.3459.7320 Fax: +03.3436.1434

Toyocom Chicago
Phone: +1.708.593.8780 Fax: +1708.593.5678
Toyocom LA
Phone: +1.714.668.9081 Fax: +1.714.668.9158
* Although Toyocom manufactures Argos transmitters for use in biotelemetry, they are normally not interested in small projects requiring custom manufacturing.

Wildlife Materials Inc.
Route 1, Box 427A, Carbondale, Illinois, USA 62901
Phone: +1.618.549.6330 Fax: +1.618.457.3340

10. BIBLIOGRAPHY

1. Ackerman, B.B., F.A. Leban, M.D. Samuel, and E.O. Garton. 1990. Users manual for program Home Range. 2nd ed. Univ. of Idaho For., Wild. and Range Exp. Stn. Tech. Rep. 15, Moscow, Id. 79pp.

2. Aebischer, N.J. and P.A. Robertson. 1992. Practical aspects of compositional analysis as applied to pheasant habitat utilization. Pp. 285-293 in I.G. Priede and S.M. Swift (eds.). Wildlife Telemetry: Remote Monitoring and Tracking of Animals.

3. Aebischer, N.J., P.A. Robertson and R.E. Kenward. 1993. Compositional analysis of habitat use from animal radio-tracking data. Ecology 74:1313-1325.

4. Aldridge H.D.J.N. & R.M. Brigham. 1991. Factors influencing foraging time in two aerial insectivores; the bird, *Chordeiles minor* and the bat, *Eptesicus fuscus*. Can. J. Zool. 69:62-69.

5. Aldridge, H.D.J.N. & R.M. Brigham. 1988. Load carrying and maneuverability in an insectivorous bat: a test of the 5% “rule” of radio-telemetry. J. Mamm. 69:379-382.

6. Alldredge, J.R. and J.T. Ratti. 1986. Comparison of some statistical techniques for analysis of resource selection. J. Wildl. Manage. 50:157-165.

7. Alldredge, J.R. and J.T. Ratti. 1992. Further comparison of some statistical techniques for analysis of resource selection. J. Wildl. Manage. 56:1-9.

8. Ames, J.A., R.A. Hardy and F.E. Wendell. 1986. A simulated translocation of sea otters, Enhydra lutris, with a review of capture, transport, and holding techniques. California Dept. of Fish and Game, Marine Resources Technical Report 52. 17pp.

9. Anderka, F.W. 1987. Radio telemetry techniques for furbearers. 216-277 In Novak, M., J.A. Baker, M.E. Obbard, and B. Malloch (eds). Wild Furbearer Management and Conservation in North America. Min. of Nat. Resources, Ont.

10. Anderka, F.W. and P. Angehrn. 1992. Transmitter attachment methods. Pp. 135 146 In: Priede, I.G. and S.M. Swift (eds.). Wildlife Telemetry: Remote Monitoring and Tracking of Animals. Ellis Horwood, Chichester, U.K.

11. Anderson, D.J. 1982. The home range: a new nonparametric estimation technique. Ecology 63:103-112.

12. Anderson-Sprecher, R. 1994. Robust estimates of wildlife location using telemetry data. Biometrics 50(2):406-416.

13. Andrews, R.D., and D.G. Calkins. 1995. Determining the precise timing and location of foraging by Steller sea lions. Page 4 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

14. Andrusiak, L. 1994. Nest and roost site choice and breeding biology of the Barn Owl, *Tyto alba pratincola*, in the Lower Mainland of British Columbia. M. Sc. Thesis, University of B. C. , Vancouver.

15. Anonymous. 1992. Workshop on tagging and tracking technology. Northeast Fisheries Science Center Reference Document 93-08. National Marine Fisheries Service, Woods Hole, MA.

16. Armlaner, C. J., R. Sibly and R. McCleery. 1978. Effects of transmitter weight on breeding success in Herring Gulls. Biotelem. and Patient Monitoring 5:154-163.

17. Arthur, S.M. 1988. An evaluation of techniques for capturing and radio collaring fishers. Wildl.Soc. Bull. 16(4):417-421.

18. Atkinson, E.C. 1993. Winter territories and night roosts of Northern Shrikes in Idaho. Condor 95:515-527.

19. Auffenberg, W. 1988. Gray's Monitor Lizard. University of Florida Press, Gainesville, FL.

20. Baba, N., and M. Kiyota. 1995. Characteristics of northward migration of female northern fur seals in the western North Pacific. Page 6 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995

21. Babb, J.G., and M.L. Kennedy. 1987. Home range of the coyote in western Tennessee. J. Tenn. Acad. Sci. 62(2):43.

22. Baekken, B.T., J.D. Nybo, and G.A. Sonerod. 1987. Home range size of Hawk Owls - dependence on calculation method, number of tracking days and number of plotted perchings. U.S. For. Serv. Gen. Tech. Rep. RM No. 142:145-148.

23. Baird, R.W. 1994. Diving behaviour of killer whales. Page 51 in Abstracts of the 19th Reunion Internacional para el Estudio de los Mamiferos Marinos, May 1994, La Paz, Baja California Sur.

24. Baird, R.W. 1994. Foraging behaviour and ecology of transient killer whales (*Orcinus orca*). Ph.D. Thesis, Simon Fraser University, Burnaby, B.C.

25. Baird, R.W., and J.D. Goodyear. 1993. An examination of killer whale diving behavior using a recoverable, suction-cup attached TDR/VHF tag. Page 25 in Abstracts of the Tenth Biennial Conference on the Biology of Marine Mammals, Galveston, TX. Novem

26. Baker, J.D., G.A. Antonelis and T.J. Ragen. 1995. Activity patterns of northern fur seal pups around the time of weaning and migration. Page 7 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-1

27. Banks, E.M., R.J. Brooks and J. Schnell. 1975. A radiotracking study of home range and activity of the brown lemming (*Lemmus trimucronatus*). J. Mamm. 56:888-901.

28. Bartelt, P.E. 1994. A plastic belt for attaching radiotransmitters to anurans. Poster paper given at HL/SSAR Meetings, Athens, GA.

29. Bartmann, R.M., G.C. White, L.H. Carpenter, and R.A. Garrott. 1987. Aerial mark-recapture estimates of confined mule deer in pinyon-juniper woodland. J. Wildl. Manage. 51(1):41-46.

30. Bayne, E.M. & R.M. Brigham. 1995. Prey selection and foraging constraints in Common Poorwills (*Phalaenoptilus nuttallii*: Aves: Caprimulgidae). J. Zool. (London) 235:1-8.

31. Beaumont, Paul. 1990. Sometimes I hear it and sometimes I don't...Telonics Quarterly 3(2):1.

32. Beier, P., and D.R. McCullough. 1988. Motion-sensitive collars for estimating white-tailed deer activity. J. Wildl. Manage. 52(1):11-13.

33. Beier, Paul. 1995. Dispersal of juvenile cougars in fragmented habitat. J. Wildl. Manage. 59(2):228-237.

34. Bekkby, T., A.J. Bjorge, and D. Thompson. 1995. Using stomach temperature to estimate meal size in captive and free ranging harbour seals. Page 10 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December

35. Bengtson, J.L., and B.S. Stewart. 1992. Diving and haul out behaviour of crabeater seals in the Weddell Sea, Antarctica, during March 1986. Polar Biology 12:635-644.

36. Bengtson, J.L., and P.L. Boveng. 1995. Seasonal movements and habitat utilization of crabeater seals. Page 10 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

37. Benson, R.H., and K.L.P. Benson,. 1988. The amateur radio service as a long-range wildlife tracking tool. Nat. Wildl. Fed. Sci. Tech. Serv. No.11:274-276.

38. Bevan, R.M., P.J. Butler, I.L. Boyd and A.J. Woakes. 1995. The cardiovascular adjustments associated with swimming and diving in the free-ranging Antarctic fur seal. Page 12 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mamma

39. Biggins, D.E., and E.J. Pitcher. 1978. Comparative efficiencies of telemetry and visual techniques for studying ungulates, grouse and raptors on energy development lands in south western Montana. Sci. Tech. Sec. Natl. Wildl.Fed. No. 4:188-193.

40. Blackwell, B.H., Frost, G.T., Flinders, J.T., and Barber, H.A. 1991. A radio harness system for bobcat kittens. Gr. Basin Nat. 51(4):343-347.

41. Boag, D. A. 1972. Effect of radio packages on behaviour of captive Red Grouse. J. Wildl. Manage. 36:511-518.

42. Bonath, K. 1977. Narkose der Reptilien, Amphibien, Fische. Schriftreihe Versuchstierkunde no. 4, Berlin, Hamburg.

43. Bonde, R.K., J.P. Reid, S.L. Tyson and D.E. Easton. 1995. Captive manatee releases and monitoring along Florida's east coast. Page 14 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

44. Boness, D.J., W.D. Bowen, G. Marshall and B. Buhleier. 1995. Reproductive behaviour of harbor seal males at sea. Page 14 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

45. Boulanger, J.G. and G.C. White. 1990. A comparison of home-range estimators using Monte Carlo simulation. J. Wildl. Manage. 54:310-315.

46. Boutin, S., and C.J. Krebs. 1986. Estimating survival rates of snowshoe hares. J. Wildl. Manage. 50(4):592-594.

47. Bowers, C.A., and Henderson, R.S. 1972. Project deep ops: deep object recovery with pilot and killer whales. Naval Undersea Center Technical Publication 306.

48. Boyd, I.L. 1993. Selecting sampling frequency for measuring diving behaviour. Marine Mammal Science 9:424-430.

49. Boyd, I.L. 1995. Balancing oxygen use and gain during the dive cycle: a behavioural approach. Page 15 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

50. Boyd, I.L. and J.P. Croxall. 1992. Diving behaviour of female Antarctic fur seals. Can. J. Zool. 70, 919-928.

51. Boyd, I.L. and T. Arnbom. 1991. Diving behaviour in relation to water temperature in the southern elephant seal: foraging implications. Polar Biology 11:259-266.

52. Boyd, I.L., J.P.Y. Arnould, T. Barton, and J.P. Croxall. 1994. Foraging behaviour of Antarctic fur seals during periods of contrasting prey abundance. J. Animal Ecology (in press).

53. Boyd, I.L., J.P.Y. Arnould, T. Burton, and J.P. Croxall. 1994. Foraging behaviour of Antarctic fur seals during periods of contrasting prey abundance. J. of Animal Ecology 63:703-713.

54. Boyd, I.L., N.J. Lunn, C.D. Duck and T. Barton. 1990. Response of Antarctic fur seals to immobilization with ketamine, a ketamine-diasepam or detamine-xylazine mixture, and Zoletil. Marine Mammal Science 6:135-145.

55. Brand, C.J., R.H. Vowles, and L.B. Keith. 1975. Snowshoe hare mortality monitored by telemetry. J. Wildl. Manage. 39:741-747.

56. Brandon, E.A.A., R.W. Davis, D.G. Calkins and T.R. Loughlin. 1995. Foraging trip duration in lactating Steller sea lions as an index of foraging effort. Page 16 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando,

57. Bray, O.E. and G.W. Corner. 1972. A tail clip for attaching transmitters to birds. J. Wildl. Manage. 36:640-642.

58. Bray, O.E., K.H. Larsen and D.F. Mott. 1975. Winter movements and activities of radio-equipped starlings. J. Wildl. Manage. 39:795-801.

59. Brigham, R.M, M.J. Vonhof and R.M.R. Barclay. Submitted. Roost site preferences by forest dwelling California bats. J. Mamm.

60. Brigham, R.M. & A.C. Brigham. 1989. Evidence for association between a mother bat and its young during and after foraging. American Midland Naturalist 121:205-207.

61. Brigham, R.M. & M.B. Fenton. 1986. The influence of roost closure on the roosting and foraging behaviour of Eptesicus fuscus (Chiroptera: Vespertilionidae). Can. J. Zool. 64:1128-1133.

62. Brigham, R.M. & M.B. Fenton. 1987. The effect of roost sealing as a method to control maternity colonies of big brown bats. Can. J. Publ. Health 78:47-50.

63. Brigham, R.M. & M.B. Fenton. 1991. Convergence in foraging strategies by two morphologically and phylogenetically distinct nocturnal aerial insectivores. J. Zool. (London) 223:475-489.

64. Brigham, R.M. & R.M.R. Barclay. 1992. Lunar influence on foraging and nesting activity of Common Poorwills (*Phalaeonoptilus nuttallii*). Auk 109:315-320.

65. Brigham, R.M. 1989a. Effects of radio transmitters on the foraging behaviour of Barn Swallows. Wilson Bull. 101:505-506.

66. Brigham, R.M. 1989b. Roost and nest sites of Common Nighthawks: Are gravel roofs important? Condor 91:722-724.

67. Brigham, R.M. 1991. Apparent drinking by the Common Poorwill (*Phalaenoptilus nuttallii*). Northwestern Nat. 72:82-84.

68. Brigham, R.M. 1991. Flexibility in foraging and roosting behaviour by the big brown bat (*Eptesicus fuscus*). Can. J. Zool. 69:117-121.

69. Brigham, R.M. 1992. Daily torpor in a free-ranging goatsucker, the Common Poorwill (*Phalaenoptilus nuttallii*). Physiological Zoology 65:457-472.

70. Brillinger, D., B.S. Stewart and A. Wang. 1995. Computer-assisted, automatic evaluation of two-dimensional profiles (time vs. depth) of time-series data for diving marine mammals. Page 17 in Abstracts of the 11th Biennial Conference on the Biology o

71. Brooks, R.J. and E.M. Banks. 1971. Radio tracking of lemming home range. Commun. Behav. Biol. Part A 6:1-5.

72. Brown, G. 1990. Can. J. Zool. 68:1659-1663.

73. Brown, G. 1991. J. Herpetol. 25:273-278.

74. Brown, G. 1992. M.Sc. Thesis, University of Guelph, Guelph, ON.

75. Brown, G. 1993. Herpetologica 49:311-318.

76. Brown, G. 1994. Copeia 1994:222-226

77. Brown, G. 1994. J. Herpetol. 28:405-410.

78. Brown, W.S. and W.S. Parker. 1976. Movement ecology of Coluber constrictor near communal hibernacula. Copeia 1976:225-242.

79. Bryant, E.B., S.P. Kingsley and D. Thompson. 1995. Improving marine mammal tracks using Kalman filters. Page 18 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

80. Buehler, David A., James D. Fraser, and D. Seegar. 1995. Captive and field-tested radio transmitter attachments for Bald Eagles. J. Field Ornith. 66(2):173.

81. Bull, E.L. and R.S. Holthausen. 1993. Habitat use and management of Pileated Woodpeckers in northeastern Oregon. J. Wildl. Manage. 57:335-345.

82. Bull, E.L., R.S. Holthausen and M.G. Henjum. 1992. Roost trees used by Pileated Woodpeckers in northeastern Oregon. J. Wildl. Manage. 56:786-793.

83. Bunck, C.M., C. Chen, and K. Pollock. 1995. Robustness of survival estimates from radio-telemetry studies with uncertain relocation of individuals. J. Wildl. Manage. 59(4):790-794.

84. Burger, Bill. 1988. Which way did he go? Special sensors help to quantify activity data. Telonics Quarterly 1 (1):1.

85. Burger, Bill. 1989a. Biological Notes - temperature sensing with VHF telemetry. Telonics Quarterly 2 (1):2.

86. Burger, Bill. 1989b. Satellite PTTs. Telonics Quarterly 2 (2):4.

87. Burger, Bill. 1989c. Transmitter attachment collars. Telonics Quarterly 2 (4):2.

88. Burger, Bill. 1991. Receiving antenna ‘accuracy’. Telonics Quarterly 4 (2):2.

89. Burger, L.W., Jr., M.R. Ryan, D.P. Jones, and A.P. Wywialowski. 1991. Radio transmitters bias estimation of movements and survival. J. Wildl. Manage. 55(4):693-697.

90. Burt, W.H. 1943. Territoriality and home range concepts as applied to mammals. J. Mamm. 24:346-352.

91. Bury, B.R. 1972. Habits and home range of the Pacific pond turtle, *Clemmys marmorata*, in a stream community. Unpubl. Ph.D. dissert., University of California, Berkeley, CA.

92. Butler, P. J. 1989. Telemetric recording of physiological data from free-living animals. Pp. 63-84 in Grubb, P.J., and Whittaker, J.B. (eds.). Towards A More Exact Ecology. Blackwell Scientific Publications, Oxford.

93. Butler, R.W. and J.G. Jennings. 1980. Radio tracking of dolphins in the eastern tropical Pacific using VHF and HF equipment. Pages 757-759 in C.J. Amlaner and D.W. MacDonald (eds.). A Handbook on Biotelemetry and Radio Tracking. Pergamon Press, Ox

94. Byers, C.R., R.K. Steinhorst and P.R. Krausman. 1984. Clarification of a technique for analysis of utilization - availability data. J. Wildl. Manage. 48:1050-1053.

95. Byles, R.A. 1988. Behaviour and ecology of sea turtles from Chesapeake Bay, Virginia. Ph.D. Diss., Coll. William and Mary in Virginia, Williamsburg, VA.

96. Caccamise, D.F. and R.S. Hedin. 1985. An aerodynamic basis for selecting transmitter loads in birds. Wilson Bull. 97:306-318.

97. Calkins, D.G., and U. Swain. 1995. Movements and diving behavior of female Steller sea lions in southeastern Alaska. Page 19 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

98. Campagna, C., B.J. Le Boeuf, S.B. Blackwell, D.E. Crocker, and F. Quintana. 1995. Diving behavior and foraging location of female southern elephant seals from Patagonia. J. Zool. Lond. 236:55-71.

99. Carey, A.B., S.P. Horton, and J.A. Reid. 1989. Optimal sampling for radio-telemetry studies of Spotted Owl habitat and home range. U.S. For. Serv. Res. Pap. PNW No. 416:1-17.

100. Chabot, D. 1991. The use of heart rate telemetry in assessing the metabolic cost of disturbances. Trans. N. Am. Wildl. Nat. Res. Conf. No. 56:256-263.

101. Chute, F.S., W.A. Fuller, P.R.J. Harding and T.B. Herman. 1974. Radio tracking of small mammals using a grid of overhead wire antennas. Can. J. Zool. 52:1481-1488.

102. Ciofi, C. and G. Chelazzi. 1991. Radiotracking of *Coluber viridiflavus* using external transmitters. J. Herpetol. 25:37-40.

103. Cipriano, F. 1985. Dusky dolphin research at Kaikoura, New Zealand. A progress report. Mauri Ora 12:151-158.

104. Clark, B.S., D.M. Leslie, Jr. And T.S. Carter. 1993. Foraging activity of adult female Ozark Big-eared bats (*Plecotus townsendii ingens*) in summer. J. Mamm. 74:422-427.

105. Cochran, W.W., G.G. Montgomery and R.R. Graber. 1967. Migratory flights of Hylocichla thrushes in spring: a radiotelemetry study. Living Bird 6:213-225.

106. Collazo, J.A., and S.P. Epperly. 1995. Accuracy tests for sonic telemetry studies in an estuarine environment. J. Wildl. Manage. 59(1):181-188.

107. Coltman, D.W., W.D. Bowen and D.J. Boness. 1995. Does body mass affect aquatic behaviour of harbour seal (*Phoca vitulina*) males during the mating season? Page 24 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando,

108. Cooper, H.M. and P. Charles-Dominique. 1985. A microcomputer data acquisition - telemetry system: a study of activity in the bat. J. Wildl. Manage. 49:850-854.

109. Cooper, W.E., Jr. 1978. Home range criteria based on temporal stability of areal occupation. J. Theor. Biol. 73:687-695.

110. Costa, D.P. 1991. Reproductive and foraging energetics of high latitude penguins, albatrosses and pinnipeds: Implica

111. Costa, D.P. 1991. Reproductive and foraging energetics of high latitude penguins, albatrosses and pinnipeds: Implications for life history patterns. American Zoologist 31`:111 130.

112. Cottrell, P.E. 1995. Diet, activity budgets, and movement patterns of harbour seals (*Phoca vitulina*) in Cowichan Bay and adjacent areas. M.Sc. thesis University of Victoria, Victoria, Canada. pp 1-118

113. Craighead, D.J., and J.J. Craighead. 1987. Tracking caribou using satellite telemetry. Natl. Geogr. Res. 3(4):462-479.

114. Cresswell, W.J. and G.C. Smith. 1992. The effects of temporally autocorrelated data on methods of home range analysis. Pp. 272-284 in: I.G. Priede and S.M. Swift (eds.). Wildlife Telemetry: Remote Monitoring and Tracking of Animals.

115. Crocker, D.E., LeBoeuf, B.J., and Costa, D.P. 1995. Drift Diving in female northern elephant seals: Implications for food processing. Can. J. Zool. (accepted pending revision).

116. Crocker, D.E., LeBoeuf, B.J., Naito, Y., Asaga, T. and Costa, D.P. 1994.Swim Speed and Dive Function in a Female Northern Elephant Seal. Pp. 328 342 in B.J. LeBoeuf and R.M. Laws (eds.). The Biology of Elephant Seals. UC Press, Berkeley.

117. Croll, D., D. Demer, R Hewitt, B. Tershy, S. Hayes, D. Gendron and J. Urban. 1995. Foraging ecology and behavior of blue and fin whales. Page 26 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December

118. Crow, S. 1988. Field notes on receivers - static electricity may be the problem. Telonics Quarterly 1 (1):1.

119. Croxall, J.P., I. Everson, G.L. Kooyman, C. Ricketts, and R.W. Davis. 1985. Fur seal diving behavior in relation to vertical distribution of krill. J. Anim. Ecol. 54, 1 8.

120. Csada, R.D. & R.M. Brigham. 1994a. Breeding biology of the Common Poorwill at the northern edge of its distribution. J. Field Ornith. 65:186-193.

121. Csada, R.D. & R.M. Brigham. 1994b. Reproduction constrains the use of daily torpor by free Ranging Common Poorwills *(Phalaenoptilus nuttallii*). J. Zool. (London) 234:209-216.

122. da Silva, V.M.F., and A.R. Martin. 1995. Studies of the boto, Inia geoffrensis, in the Brazilian Amazon. Page 28 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

123. Davis, J.L., and P. Valkenburg. 1984. Demography of the Delta caribou herd under varying rates of natural mortality and harvest by humans. Project Prog. Rep. Alaska. Dep. Fish and Game Project W-22-2, Job3-27R. 1-35.

124. Davis, R.W. 1985. Fur seal diving behavior in relation to vertical distribution of krill. J. Anim. Ecol. 54, 1-8.

125. de Vos, J. 1989. The utility of biotelemetry in wildlife research. Wildl. Views. 32(6):20.

126. De Young, C. A. 1989. Mortality of adult male white-tailed deer in south Texas. J. Wildl. Manage. 53(3):513-518.

127. Decker, Dan. 1988 (a)Lab notes on transmitters - proper care and exercise are key to operational life. Telonics Quarterly 1 (1):1.

128. Decker, Dan. 1988. Can I reuse those old radio-collars? Telonics Quarterly 1(2):6.

129. DeLong, R.L., B.S. Stewart and R.D. Hill. 1992. Documenting migrations of northern elephant seals using day length. Marine Mammal Science 8:155-159.

130. Demarchi, M. 1992. Influence of the thermal environment on forest cover selection and activity of moose in summer. M.Sc. Thesis. University of B.C., Vancouver.

131. Desty, E.A., G.O. Batzli and L. Jike. 1989. Comparison of vole movements assessed by live trapping and radiotracking. J. Mamm. 70:652-656.

132. Deutsch, C.J., J.P. Reid, R.K. Bonde and H.I. Kochman. 1995. Manatee (*Trichechus manatus*) movements and spatial use patterns along the east coast of Florida. Page 30 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orl

133. Diemer, J.E. 1992. Home range and movements of the tortoise Gopherus polyphemus in northern Florida. Journal of Herpetology 26:158-165.

134. Dixon, K.R., and J.A. Chapman. 1980. Harmonic mean measure of animal activity areas. Ecology 61:1,040-1,044.

135. Dodge, W.E., and A.J. Steiner. 1986. XYLOG: A computer program for field-processing locations of radio-tagged wildlife. U.S. Fish and Wildl. Serv. Tech. Rep. 4. 22p.

136. Don, B.A.C. and K. Rennolls. 1983. A home range model incorporating biological attraction points. J. Anim. Ecol. 52:69-81.

137. Doncaster, C.P. 1990. Non-parametric estimates of interaction from radio-tracking data. J. Theor. Biol. 143:431-443.

138. Douglass, R.J. 1989. The use of radio-telemetry to evaluate microhabitat selection by deer mice. J. Mamm. 70:648-652.

139. Dunn, J.E. and P.S. Gipson. 1977. Analysis of radio telemetry data in studies of home range. Biometrics 33:85-101.

140. Dwyer, T.J. 1972. An adjustable radio-package for ducks. Bird-banding 43:282-284.

141. Eagle, T.C., J. Choromanski-Norris and V.B. Kuechle. 1984. Implanting radio transmitters in mink and Franklin's ground squirrels. Wildl.Soc. Bull. 12:180-184.

142. Eberhardt, L.E., and L.L. Cadwell. 1985. Radio-telemetry as an aid to environmental contaminant evaluation of mobile wildlife species. Environment. Monit. Assess. 5(3):283-289.

143. Edge, W.D., and C.I. Marcum. 1989. Determining elk distribution with pellet-group and telemetry techniques. J. Wildl. Manage. 53(3):621-624.

144. Edge, W.D., C.L. Marcum, and S.L. Olson. 1985. Effects of logging activities on home-range fidelity of elk. J. Wildl. Manage. 49(3):741-744.

145. Eguchi, T., and J.T. Harvey. 1995. Diving behavior and movements of the Pacific harbor seal (*Phoca vitulina richardsi*) in Monterey Bay, California. Page 34 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL.

146. Emery, L. and R. Wydoski. 1987. Marking and tagging of aquatic animals: An indexed bibliography. U.S. Dept. of Interior, Fish and Wildlife Service, Resource Publication 165. 57pp.

147. Erickson, A.W. 1978. Population studies of killer whales (*Orcinus orca*) in the Pacific northwest: a radio-marking and tracking study of killer whales. U.S. Mar. Mamm. Comm. MMC-75/10.

148. Evans, W.E. 1971. Orientation behavior of delphinids: radio telemetric studies. Ann. N.Y. Acad. Sci. 188:142-160.

149. Evans, W.E. 1974. Radio-telemetric studies of two species of small odontocete cetaceans. In W.E. Schevill (ed.). The Whale Problem. Harvard University Press, Cambridge. pp. 385-394.

150. Evans, W.E. 1974. Telemetring of temperature and depth data from a free ranging yearling California grey whale, *Eschrichtius robustus*. Marine Fisheries Review 36(4):52-58.

151. Evans, W.E., J.D. Hall, A.B. Irvine and J.S. Leatherwood. 1972. Methods for tagging small cetaceans. Fishery Bulletin 70:61-65.

152. Fancy, S.G., and R.G. White. 1985. Energy expenditures by caribou while cratering in snow. J. Wildl. Manage. 49(4) 987-993.

153. Fancy, S.G., Pank, L.F., Whitten, K.R., and W.L. Regelin. 1989. Seasonal movements of caribou in Arctic Alaska as determined by satellite. Can. J. Zool. 67(3):644-650.

154. Fedak, M.A., B.J. McConnell and P. Rohani. 1995. The development of foraging patterns in phocids: the first foraging trips in species with no obvious parental input. Page 35 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mamm

155. Fenton, M.B., C.M. Swanepoel, R.M. Brigham, J.E. Cebek, & M.B.C. Hickey. 1990. Foraging behavior and prey selection by large slit-faced bats (*Nycteris grandis*; Chiroptera : Nycteridae). Biotropica 22:2-8.

156. Fenton, M.B., R.M. Brigham, A.M. Mills & I.L. Rautenbach. 1985. The roosting and foraging areas of *Epomophorus wahlbergi* (Pteropodidae) and *Scotophilus viridis* (Vespertilionidae) in Kruger National Park, South Africa. J. Mamm. 66:461-468.

157. Ferner, J.W. 1979. A review of marking techniques for amphibians and reptiles. Society for the Study of Amphibians and Reptiles, Herpetological Circular 9. 41 pp.

158. Filipovich, M.A. 1983. Small mammal density, movement, and food habits on the SL-1 radioactive-waste disposal area, Idaho National Engineering Laborator. M.S. Thesis, Idaho State University, Pocatello. 60 p.

159. Finley, K.J. and J.D. Goodyear. 1993. Dive patterns and feeding habitat of the bowhead whale in Baffin Bay. Page 47 in Abstracts of the Tenth Biennial Conference on the Biology of Marine Mammals, November 11-15, 1993.

160. Firman, M.C., R.M. Brigham & R.M.R. Barclay. 1993. Do free-ranging Common Nighthawks enter torpor? Condor 95:157-162.

161. Fisher, M. and A. Muth. 1995. A backpack method for mounting radio-transmitters to small lizards. Herp. Rev. 26:139-140

162. Fitch, H.S. 1987. Collecting and life-history techniques, p. 143-164. In: R.A. Seigel, J.T. Collins and S.S. Novak (eds.). Snakes: Ecology and Evolutionary Biology. Macmillan Publ. Co., New York, NY.

163. Fitch, H.S. and H.W. Shirer. 1971. A radiotelemetric study of spatial relationships in some common snakes. Copeia 1971:118-128.

164. Fitzgerald, M.R., R.O. Flamm and B.L. Wigle. 1995. Movement patterns of radio-tagged female manatees. Page 37 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

165. Fletcher, S., B.J. Le Boeuf, D.P. Costa and P. Tyack. 1995. Onboard acoustic recordings from diving elephant seals. Page 38 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

166. Folkow, L.P., and A.S. Blix. 1995. Diving and feeding of hooded seals, *Cystophora cristata*. Page 38 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

167. Ford, R.G. and D.W. Krumme. 1979. The analysis of space use patterns. J. Theor. Biol. 76:125-155.

168. Foster, C.C., Forsman, E.D., Meslow, E.C., Miller, G.S., Reid, J.A., Wagner, F. F., Carey, A.B., and J.B. Lint. 1992. Survival and reproduction of radio-marked Spotted Owls. J. Wildl. Manage. 56(1):91-95.

169. French, J. 1985. Satellite technology for tracking birds and sea mammals. Ph.D. Dissertation University of Aberdeen.

170. French, J., D.M. Latham, R.S. Oldham and D.J. Bullock. 1992. An automated radio tracking system for use with amphibians. Pp. 477 483 in Priede, I.G. and S.M. Swift (eds.) Wildlife Telemetry: Remote Monitoring and Tracking of Animals. Ellis Horwood

171. Friedmann, M. 1937. The use of ranks to avoid the assumption of normality implicit in the analysis of variance. J. Am. Stat. Assoc. 32:675-701.

172. Frost, K.J., L.F. Lowry and R.R. Nelson. 1985. Radiotagging studies of belukha whales (*Delphinapterus leucas*) in Bristol Bay, Alaska. Marine Mammal Science 1:191-202.

173. Fukuyama, K., T. Kusano and M. Nakane. 1988. A radio tracking study of the behavior of females of the frog *Buergeria buergeri* (Rhacophoridae, Amphibia) in a breeding stream in Japan. Japanese Journal of Herpetology 12:102 107.

174. Fuller, T.K., and W.J. Snow. 1988. Estimating winter wolf densities using radiotelemetry data. Wild Soc. Bull. 16(4):367-370.

175. Galbraith, D.A., M.W. Chandler and R.J. Brooks. 1987. The fine structure of home ranges of male *Chelydra serptentina*: are snapping turtles territorial? Can. J. Zool. 65:2623-2629.

176. Gales, N.J., and R.H. Mattlin. 1995. Summer diving behaviour of female New Zealand sea lions: the deepest diving otariid. Page 41 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

177. Gallo Reynoso, J.P., B.J. Le Boeuf and A.L. Figueroa. 1995. Track, location, duration and diving behavior during foraging trips of Guadalupe fur seal females. Page 41 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orla

178. Garrett, M.G., J.W. Watson, R.G. Anthony. 1993. Bald Eagle home range and habitat use in the Columbia River estuary. J. Wildl. Manage. 57(1):19-27.

179. Garrott, R.A., and R.M. Bartmann. 1984. Evaluation of vaginal implants for mule deer. J. Wildl. Manage. 48(2) 1984:646-648.

180. Garrott, R.A., G.C. White, R.M. Bartmann and D.M. Weybright. 1986. Reflected signal bias in biotelemetry triangulation systems. J. Wildl. Manage. 50:747-752.

181. Garshelis, D.L. 1983. The role of sampling intensity in the selection of a home range model. Proc. Int. Conf. Wildl. Biotelemetry 4:270-275.

182. Garshelis, D.L. and D.B. Siniff. 1983. Evaluation of radio-transmitter attachments for sea otters. Wildl. Soc. Bull. 11:378-383.

183. Garshelis, D.L. and J.A. Garshelis. 1984. Movements and management of sea otters in Alaska. J. Wildl. Manage. 48:665-678.

184. Gaskin, D.E., G.J.D., and A.P. Watsonl. 1975. Preliminary study of harbor porpoises (*Phocoena phocoena*) in the Bay of Fundy using radiotelemetry. Can. J. Zool. 53:1466-1471.

185. Gaulin, S.J. and R.W. Fitzgerald. 1988. Homerange size as a predictor of mating systems in Microtus. J. Mamm. 69:311-319.

186. Gearin, P.J., J.R. Thomason, S.J. Jeffries, M.E. Gosho and M.T. Wilson. 1995. Migration and movement patterns of male California sea lions. Page 42 inAbstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14

187. Gearin, P.J., J.R. Thomason, S.J. Jeffries, M.E. Gosho and M.T. Wilson.1995. Migration and movement patterns of male California sea lions. Page 42 in Abstracts of the 11th Biennial Conference on the Biology of MarineMammals, Orlando, FL. December

188. Gent, A.H. and I.F. Spellerberg. 1993. Movement rates of the smooth snake *Coronella austrica* (Colubridae): a radiotelemetric study. Herp. J. 3:140-146.

189. Gentry, R.L., and J.R. Holt. 1982. Equipment and techniques for handling northern fur seals. U.S. Dept. of Commerce, NOAA Technical Report NMFS SSRF-758.

190. Gessaman, J.A. and K.A. Nagy. 1988. Transmitter loads affect the flight speed and metabolism of homing pigeons. Condor 90:662-668.

191. Gessaman, J.A., Workman, G.W., and M.R. Fuller. 1991. Flight performance, energetics and water turnover of tippler pigeons with a harness and dorsal load. Condor 93(3):546-554.

192. Giard, J., R. Michaud and J.D. Goodyear. 1995. Use of succion [sic] cup VHF tag to measure fin whale exposure to whale watching and evaluate activity pattern in the St. Lawrence estuary. Page 44 in Abstracts of the 11th Biennial Conference on the B

193. Gillingham, M.P., and F.L. Bunnell. 1985. Reliability of motion-sensitive radio collars for estimating activity of black-tailed deer. J. Wildl. Manage. 49(4):951-958.

194. Gillingham, M.P., and K.L. Parker. 1992. Simple timing device increases reliability of recording telemetric activity data. J. Wildl. Manage. 56(1):191-196.

195. Gilmer, D.S., L.M. Cowardin, R.M. Duval, L.M. Mechlin, C.W. Shaiffer, V.B. Kuechle. 1981. Procedures for the use of aircraft in wildlife biotelemetry studies. U.S. Dept. of Int. Fish and Wildlife Service Resource Publ. 140. Washington DC.

196. Giroux, J.F., Bell, D.V., Percival, F., and R.W. Summers. 1990. Tail-mounted radio-transmitters for waterfowl. J. Field Ornithol. 61(3):303-309.

197. Gjertz, I., K. Kovacs, C. Lydersen and O. Wiig. Satellite tracking of bearded seals from Svalbard. Page 44 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

198. Godfrey, G.A. 1970. A transmitter harness for small birds. IBBA News 42:3-5.

199. Goggans, R., R.D. Dixon and L.C. Seminara. 1988. Habitat use by Three-toed and Black-backed Woodpeckers, Deschutes National Forest, Oregon. Nongame Project Number 87-3-02, Oregon Dept. of Fish & Wildlife.

200. Goodyear, J. 1981. “Remora” tag effects the first tracking of an Atlantic humpback. P. 46 in Abstracts of the Fourth Biennial Conference on the Biology of Marine Mammals, San Francisco, CA.

201. Goodyear, J.D. 1989. Night behavior and ecology of humpback whales (*Megaptera novaeangliae*) in the western North Atlantic. M.Sc. thesis, San Jose State University, San Jose, CA.

202. Goodyear, J.D. 1993. A tag for monitoring dive depths and underwater movements of whales. J. Wildl. Manage. 57:503-513.

203. Goodyear, J.D. 1995. Dive behavior, and the question of food limitation in right whales. Page 46 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

204. Goodyear, J.D. and R. Andrews. 1993. The first whale ECG with self-contained tag, and radio and satellite-linked depth and heart-monitoring tags for whales. Page 54 in Abstracts of the Tenth Biennial Conference on the Biology of Marine Mammals, Gal

205. Gorman, M. 1993. Wildtrak: A suite of non-parametric home range analyses for the Macintosh computer. Anim. Behav. 45:1,253.

206. Gorman, M.L., S. Frears and P.A. Racey. 1992. Radio-tracking and the function of the fortress of the mole (*Talpa europaea*). Pp. 510-520 In: I.A. Priede and S.M. Swift (eds.). Wildlife Telemetry: Remote Monitoring and Tracking of Animals. Ellis Hor

207. Goulet, A.M., M.O. Hammill and C. Barrette. 1995. Foraging behavior of female grey seals (*Halichoerus grypus*) in the Gulf of St. Lawrence, Canada. Page 47 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. Dece

208. Graber, R.R. 1965. Night flight with a thrush. Aud. Mag. 67:368-374.

209. Graber, R.R. and S.L. Wunderle. 1966. Telemetric observations of a robin (*Turdus migratorius*). Auk 83:674-677.

210. Green, J.S., R.T. Golightly, S. Lyndaker-Lindsey, and B.R. LeaMaster. 1985. Use of radio transmitter implants in wild canids. Gr. Basin Nat. 45(3):567-570.

211. Green, P. 1985. Some results from the use of a long life radio transmitter package on corvids. Ringing Migr. 6(1):45-51.

212. Greenwood, R. J., and A. B. Sargeant. 1973. Influence of radio packs on captive Mallards and Blue-winged Teal. J. Wildl. Manage. 43:1001-1007.

213. Gregory, P.T. and R.W. Campbell. 1987. The reptiles of British Columbia. British Columbia Provincial Museum Handbook. Victoria.

214. Griffiths, D., O. Wiig and I. Gjertz. 1993. Immobilization of walrus with etorphine hydrochloride and Zoletil. Marine Mammal Science 9:250-257.

215. Guetterman, J.H., Burns, J.A., Reid, J.A., Horn, R.B., and C.C. Foster. 1991. Radio-telemetry methods for studying spotted owls in the Pacific Northwest. U. S. Forest Serv. Gen. Tech. Rep. PNW No. 272:1-43.

216. Guynn, D.C., Jr., J.R. Davis, and A.F. von Recum. 1987. Pathological potential of intra peritoneal transmitter implants on beavers. J. Wildl. Man. 51(3):605-606.

217. Hamilton, A.N., and W.R. Archibald. 1985. Grizzly bear habitat in the Kimsquit River valley; coastal B.C. Pages 50-57 In Contreras, G.P., and K.E. Evans (eds). Proc. Grizzly Bear Habitat Symp. Missoula, Montana, Apr. 30-May 2 1985. Intermountain

218. Hamley, J.M. and J.B. Falls. 1975. Reduced activity in transmitter-carrying voles. Can. J. Zool. 53:1476-1478.

219. Hansen, T., and P. Cox. 1991. New implantable heart rate transmitter. Telonics Quarterly 4(1):2.

220. Harestad, A.H. 1985. Habitat use by black-tailed deer on northern Vancouver Island. J. Wildl. Manage. 48(4):946-950.

221. Harris, R.B., Fancy, S.G., Douglas, D.C., Garner, G.W., Amstrup, S.C., McCabe, T.R., and L.F. Pank. 1990. Tracking wildlife by satellite: current systems and performance. U.S. Fish Wildl.Serv. Fish Wildl.Tech Rep. No. 30:1-52.

222. Harris, S., Cresswell, W.J., Forde, P.G., Trewhella, W.J., Woolard, T. and S. Wray. 1990. Home range analysis using radio-tracking data - a review of problems and techniques particularly as applied to the study of mammals. Mammal Rev. 20(2-3):97-12

223. Harvey, J.T. and B.R. Mate. 1984. Dive characteristics and movements of radio-tagged grey whales in San Ignacio Lagoon, Baja California Sur, Mexico. Pages 577-583 in M.L. Jones, S.L. Swartz and S. Leatherwood(eds.) The Grey Whale, Eschrichtius ro

224. Hayne, D.W. 1949. Calculation of size of home range. J. Mamm. 30:1-18.

225. Heezen, K.L., and J.R. Tester. 1967. Evaluation of radio-tracking by triangulation with special reference to deer movements. J. Wildl. Manage. 31:124-141.

226. Heide-Jorgensen, M.P., and R. Dietz. 1995. Some characteristics of narwhal, *Monodon monoceros*, diving behaviour in Baffin Bay. Page 52 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995

227. Heisey, D.M. 1985. Analyzing selection experiments with log-linear models. Ecology 66:1744-1748.

228. Heisey, D.M., and Fuller, T.K. 1985. Evaluation of survival and cause-specific mortality rates using telemetry data. J. Wildl. Manage. 49(3):668-674.

229. Hellgren, E.C., D.W. Carney, N.P. Garner, and M.R. Vaugh. 1988. Use of cotton spacers on radio-collars. Wildl.Soc. Bull. 16(2):216-218.

230. Heydal, P.L., and T.A. Gatz. 1978. Technology of radio-tracking for various birds and mammals. Sci. Tech. Sec. Nat. Wildl.Fed. No. 4:204-206.

231. Heyer, W.R., M.A. Donnelly, R.W. McDiarmid, L.C. Hayek and M.S. Foster (eds.). 1994. Measuring and Monitoring Biological Diversity. Standard Methods for Amphibians. Smithsonian Institution Press, Washington, D.C. 364 pp.

232. Hill, D.A., and P.A. Robertson. 1987. The role of radio-telemetry in the study of galliformes. World Pheas. Assoc. J. 12:81-92.

233. Hill, L.An, and L.G. Talent. 1990. Effects of capture, handling, banding and radio-marking on breeding Least Terns and Snowy Plovers. J. Field Ornith. 61(3):310-319.

234. Hindell, M.A. and M. Lea. 1995. Heart rate and swimming velocity in an adult female southern elephant seal. Page 54 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

235. Hindell, M.A., Slip, D.J., and Burton, H.R. 1991. The diving behaviour of adult male and female southern elephant seals, *Mirounga leonina* (Pinnipedia: Phocidae). Aust. J. Zool. 39:595 619.

236. Hines, J.E., and F.C. Zwickel. 1985. Influence of radio packages on young Blue Grouse. J. Wildl. Manage. 49(4)1050-1054.

237. Hobbs, L. 1982. Tags on whales, dolphins, and porpoises. Pages 218-230 in Whales, Dolphins and Porpoises of the Eastern North Pacific and Adjacent Arctic Waters. NOAA Technical Report NMFS Circular 444.

238. Hobbs, L.J. and M.E. Goebel. 1982. Bowhead whale radio tagging feasibility study and review of large cetacean tagging. NOAA Technical Memorandum NMFS F/NWC-21.

239. Hobbs, R.C., J.M. Waite, D.J. Rugh, J.A. Lerczak and K.E.W. Shelden. 1995. Estimation of the abundance of beluga whales in Cook Inlet, Alaska from aerial surveys and RF tagging, time-at-depth and tracking experiments. Page 54 in Abstracts of the 1

240. Hohn, A., M. Scott, A. Westgate, J. Nicolas and B. Whitaker. 1995. Radiotracking of a rehabilitated pygmy sperm whale. Page 55 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

241. Holland, D.C. 1991. Status and reproductive dynamics of a population of western pond turtles (*Clemmys marmorata*) in Klickitat Co., WA. Report to Nongame Division, Washington Dept. of Wildlife, Olympia, WA.

242. Holland, D.C. 1994. Western Pond Turtle: habitat and history. DOE/BP publication #62137-1, Bonneville Power Administration, Portland, OR

243. Hooge, P.N. 1991. The effects of radio weight and harnesses on time budgets and movements of Acorn Wodpeckers. J. Field Ornith. 62:230-238.

244. Horning, M. 1995. Developmental aspects of diving in Galapagos fur seals. Page 55 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

245. Houston, D., S. Burgin, C. Herlihy and M. Burgin. 1995. Comparison of home ranges of *Pogona barbata* (Cuvier) and *Tiliqua scincoides* (White, ex Shaw). Abstract, 23rd meeting of the Australia Society of Herpetologists, February 9-12, 1995, Laurel Hil

246. Huber, H.R., S.R. Jeffries, R.F. Brown and R.L. DeLong. 1995. Correcting minimum population counts to estimate the true abundance of harbor seals in Washington and Oregon, 1991-1993. Page 56 in Abstracts of the 11th Biennial Conference on the Biolo

247. Huegel, C.N., R.B. Dahlgren, and H.L. Gladfelter. 1985. Use of doe behaviour to capture white-tailed deer fawns. Wildl.Soc. Bull. 13(3):287-289.

248. Hyvarinen, H., E. Hamalainen and M. Kunnasranta. 1995. Diving behavior of the Saimaa ringed seal (*Phoca hispida saimensis* Nordq). Marine Mammal Science 11:324-334.

249. Jackson, D.H., L.S. Jackson, and W.K. Seitz. 1985. An expandable drop-off transmitter harness for young bobcats. J. Wildl. Manage. 49(1):46-49.

250. Jackson, J.A., B.J. Schardien and G.W. Robinson. 1977. A problem associated with the use of radio transmitters on tree surface foraging birds. IBBA News 49:50-53.

251. James, D.D., 1984. Home range dynamics of wolf packs on winter range of the western Arctic caribou herd. Final Rep. Alaska Dep. Fish and Game Job No. 14.12 R:1-5.

252. Jaremovic, R.V. and D.B. Croft. 1987. Comparisons of techniques to determine eastern grey kangaroo home range. J. Wildl. Manage. 51:921-930.

253. Jeffries, S.J., P.J.Gearin, M.E. Gosho, J.R. Thomason and M.T. WIlson. 1995. Capture, marking, and handling of male California sea lions. Page 58 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December

254. Jennings, J.G. 1982. Tracking marine mammals by satellite - status and technical needs. Pages 751-754 in Oceans ‘82 Conference Record, Marine Technological Society, Washington, D.C., September 20-22, 1982.

255. Jennings, J.G., and W.F. Gandy. 1980. Tracking pelagic dolphins by satellite. Pages 757-759 in C.J. Amlaner and D.W. MacDonald (Eds.) A Handbook on Biotelemetry and Radio Tracking. Edited by. Pergamon Press, Oxford, New York.

256. Jennrich, R.I. and F.B. Turner. 1969. Measurements of non-circular home range. J. Theor. Biol. 22:227-237.

257. Jessup, D.A., and D.B.Koch. 1984. Surgical implantation of a radio telemetry device in wild black bear *Ursus americanus*. Calif. Fish and Game 70(3):163-166.

258. Jewell, P.A. 1966. The concept of home range in mammals. Symposium of the Zoological Society of London 18:85-109.

259. Jike, L., G.O. Batzli and L.L. Getz. 1988. Home ranges of prairie voles as determined by radiotracking and by powdertracking. J. Mamm. 69:183-186.

260. Jimenez-Marrero, N.M., A.A. Mignucci-Giannoni, J.P. Reid, R.K. Bonde, N.M. Lee and E.H. Williams. 1995. First successful release of a captive-raised orphaned Antillean manatee in the Caribbean. Page 59 in Abstracts of the 11th Biennial Conference o

261. Johnson, D.H. 1980. The comparison of usage and availability measurements for evaluations of resource preference. Ecology 61:65-71.

262. Johnson, G.D., Pebworth, J.L., and H.O. Krueger. 1991. Retention of transmitters attached to passerines using a glue-on technique. J. Field Ornith. 62(4):486-491.

263. Jones, Gary. 1988. Attach an airplane to your antenna. Telonics Quarterly 1(2):3.

264. Jones, Gary. 1990. Glossary of terms. Telonics Quarterly 3(3):4.

265. Jordan, R. A., E.D. Michael, and E.C. Soutiere. 1986. A comparison of sampling strategies for radio-tracking farmland racoons. Trans. Northeast Fish Wildl. Conf. 43:40-45.

266. Joyce, G.G., J. Sigurjonsson and G. Vikingsson. 1990. Radio tracking a minke whale (*Balaenoptera acutorostrata*) in Icelandic waters for the examination of dive-time patterns. Report of the International Whaling Commission 40: 357-361.

267. Karl, B.J., and M.N. Clout. 1987. An improved radio transmitter harness with a weak link to prevent snagging. J. Field Ornith. 58(1):73-77.

268. Karlsson, O., and M. Sjoberg. 1995. Statistical classification of dive data from grey seals in the Baltic Sea. Page 60 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

269. Kaufmann, J.H. 1995. Home ranges and movements of Wood Turtles, *Clemmys insculpta*, in Central Pennsylvania. Copeia 1995:22-27.

270. Keating, K. A., Brewster, W. G., and Key, C. H. 1991. Satellite telemetry: performance of animal-tracking systems. J. Wildl. Manage. 160-171.

271. Keating, K.A. 1994. An alternative index of satellite telemetry location error. J. Wildl. Manage. 58:414-421.

272. Keating, Kim, A., and C.H. Key. Tracking bighorns with satellites: system performance and error mitigation. Bienn. Symp. North. Wildl.Sheep and Goat Counc. 7:149-170.

273. Keating, Kim. 1995. Mitigating elevation-induced errors in satellite telemetry locations. J. Wildl. Manage. 59(4):801-808.

274. Keister, G.P. Jr., C.E. Trainer, and M.J. Willis. 1988. A self-adjusting collar for young ungulates. Wildl. Soc. Bull. 16(3):321-323.

275. Kelsall, J. P., and K. Simpson. 1987. The impacts of highways on ungulates: a review and selected bibliography. Report prepared for B. C. Ministry of Highways, Victoria, and B. C. Ministry of Environment, Penticton and Kamloops.

276. Kenward, R. 1987. Wildlife Radio Tagging: Equipment, Field Techniques and Data Analysis. Academic Press, New York. p. 38.

277. Kenward, R. 1990. RANGES IV. Software for analysing animal location data. Inst. of Terrestrial Ecol., Wareham, U.K. 33pp.

278. Kenward, R.E. 1991. Using software in radio-tag projects: not the final decision. J. Raptor Res. 25(4):156 (Abstract)

279. Kenward, R.E. 1992. Quantity versus quality: programmed collection and analysis of radio-tracking data. Pp. 231-246. in I.G. Priede and S.M. Swift (eds.), Wildlife Telemetry: Remote Monitoring and Tracking of Animals.

280. King, D., B. Green and E. Herrara. 1994. Thermoregulation in a large teigid lizard, *Tupinambis teguixin*. Copeia 1994:806-808.

281. Kingsmill, S. 1991. How to track a toad: attach a designer backpack and radio, of course. Int. Wildl. 21:29.

282. Kissner, K.J. & R.M. Brigham. 1993. Evidence for the use of torpor by incubating and brooding Common Poorwills *Phalaenoptilus nuttallii*. Ornis Scand. 24:333-334.

283. Kjos, C.G. and W.W. Cochran. 1970. Activity of migrant thrushes as determined by radio-telemetry. Wilson Bull. 82:225-226.

284. Klugman, S.S., and M.R. Fuller. 1990. Effects of implanted transmitters on captive Florida Sandhill Cranes. Wildl.Soc. Bulletin 18(4):394-399.

285. Knittle, C.E., A.L. Kolz, J.B. Bourassa and R.E. Johnson. 1985. Miniature radio-transmitter development for Kirtland's Warbler tracking studies. Pages 1-18 in R.W. Weeks and F.M. Long (eds.). Proc. Fifth International Conf. Wildl. Biotelemetry. U

286. Koeppl, J.W., N.A. Slade and R.S. Hoffmann. 1975. A bivariate home range model with possible application to ethological data analysis. J. Mammal. 56:81-90.

287. Koeppl, J.W., N.A. Slade, K.S. Harris and R.S. Hoffman. 1977. A three-dimensional home range model. J. Mamm. 58:213-220.

288. Kohler, D.K., T.D. Reynolds, and S.H. Anderson. 1987. Radio-transmitter implants in 4 species of small mammals. J. Wildl. Manage. 51(1):105-108.

289. Kokjer, K.J., and R.G. White. 1986. A simple telemetry system for monitoring chewing activity of reindeer. J. Wildl. Manage. 50(4) 737-740.

290. Kolz, A.L. and G.W. Corner. 1966. A 160-megahertz telemetry transmitter for birds and bats. West. Bird Bander 50:38-40.

291. Kooyman, G.L., Castellini. M.A., Costa, D.P., Billups, J.O., and Piper, S.C. 1979. Diving characteristics of free-ranging Weddell seals. Antarctic Journal 14:179.

292. Koskela, J.T., H. Hyvarinen, and M. Kunnasranta. 1995. Movements and habitat use of radio-tagged Saimaa ringed seals. Page 63 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

293. Krutzikowsky, G.K. and B.R. Mate. 1995. Dive behavior of individual bowhead whales (*Balaena mysticetus*) monitored by satellite radio-telemetry. Page 64 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. Dec

294. Kufield, R.C., DC Bowden, and P.I. Schrupp. 1987. Estimating mule deer density by combining mark-recapture and telemetry data. J. Mamm. 68(4):818-825.

295. Kunkel, K.E., Chapman, R.C., Mech, L.D., and Gese, E.M. 1991. Testing the Wildlink activity-detection system on wolves and white-tailed deer. Can. J. Zool. 69:2466-2469.

296. Lacki, M.J., P.N. Smith, W.T. Peneston, and F.D. Vogt. 1989. Use of methoxyflurane to surgically implant transmitters in muskrats. J. Wildl. Manage. 53(2):3331-333.

297. Lagerquist, B.A., K.M. Stafford and B.R. Mate. 1995. Dive habits of satellite-monitored blue whales (*Balaenoptera musculus*) off the central California coast. Page 65 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orl

298. Lair, H. 1987. Estimating the location of the focal center in red squirrel home ranges. Ecology 68:1092-1101.

299. Lancaster, W., A.W. Keating and O.W. Heson, Jr. 1992. Ultrasonic vocalizations of flying bats monitored by radiotelemetry. J. Exp. Biol. 173:43-58.

300. Lance, A.N. and A. Watson. 1980. A comment on the use of radio tracking in ecological research. Pp. 355-359 in C.J. Amlaner and D.W. Macdonald (eds.). A Handbook on Biotelemetry and Radio Tracking. Pergamon Press, Oxford.

301. Lander, M., J.T. Harvey, K. Hanni and L. Morgan. 1995. Assessment of rehabilitated and free-ranging harbor seal (*Phoca vitulina*) pup success in the wild. Page 66 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando,

302. Langman, V.A. 1973. A radio-biotelemetry system for monitoring body temperature and activity levels in the Zebra Finch. Auk 90:375-383.

303. Larsen, K.W. 1987. Movements and behaviour of migratory garter snakes, *Thamnophis sirtalis*. Can. J. Zool. 65:2241-2247.

304. Laundré, J.W., T.D. Reynolds, S.T. Knick, and I. J. Ball. 1987. Accuracy of daily point relocations in assessing real movement of radio-marked animals. J. Wildl. Manage. 51(4):937-940.

305. Le Boeuf, B.J., Crocker, D.E., Blackwell, S.B., Morris, P.A., and Thorson, P.H. 1993. Sex differences in diving and foraging behaviour of northern elephant seals. Symp. Zool. Soc. Lond. 66:149-178.

306. Le Boeuf, J., and A.L. Figueroa. 1995. Track, location, duration and diving behavior during foraging t 1995. Migration and movement patterns of male California sea lions. Page 42 in Abstracts of the 11togy of Marine Mammals, Orlando, FL. December

307. Leaf, F.A., T.R. Spraker, M.B. Hanson, S.D. Osmek and R.L. DeLong. 1995. Morphological evaluation of the harbor porpoise dorsal fin as an attachment site for telemetry devices. Page 67 in Abstracts of the 11th Biennial Conference on the Biology of

308. Leatherwood, S. and D.K. Ljungblad. 1979. Night-time swimming and diving behavior of a radio-tagged spotted dolphin, *Stenella attenuata*. Cetology 34:1-6.

309. Leatherwood, S., and W.E. Evans. 1979. Some recent uses and potentials of radiotelemetry in field studies of cetacans. Pages 1-31 in H.E. Winn and B.L. Olla (eds.) Behavior of Marine Animals Volume 3. Plenum Press, New York.

310. LeBoeuf, B.J., Costa, D.P., Huntley, A.C., Kooyman, G.L., and Davis, R.W. 1986. Pattern and depth of dives in Northern Elephant Seals, *Mirounga angustirostris*. J. Zool. 208:1-7.

311. LeBoeuf, B.J., Morris, P.A., Blackwell, S.B., Crocker, D.E., and Costa, D.P. 1995. Diving behavior of juvenile northern elephant seals. Anim. Behav. (submitted).

312. LeBoeuf, B.J., Naito, Y., Asaga, T., Crocker, D., and Costa, D.P. 1992. Swimming speed in a female northern elephant seal: Metabolic and foraging implications. Can. J. Zool.: 70:786-795.

313. Lee, J.E., G.C. White, R.A. Garrott, R.M. Bartmann and A.W. Alldredge. 1985. Accessing [sic] the accuracy of a radiotelemetry system for estimating mule deer locations. J. Wildl. Manage. 49:658-663.

314. Lesage, V., M.O. Hammill and K.M. Kovacs. 1995. Comparison of dive behaviour and movements of harbour and grey seals from the St. Lawrence Estuary, Quebec, Canada. Page 68 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammal

315. Lessard, J. 1989. VHF transmitters. Telonics Quarterly 2 (2):5.

316. Leuze, C.C.K. 1980. The application of radio tracking and its effect on the behavioral ecology of the water vole, *Arvicola terrestris* (Lacepede). Pages 361-366 in: C.J. Amlander, Jr. And D.W. MacDonald (eds.). A Handbook on Biotelemetry and Radio

317. Lewis, J.C., and T.L. Haithcoat. 1986. TELEMPC, a personal computer program for analyzing radio-telemetry data, based on TELEM5 written by Gregory T. Koeln. Geogr. Resour. Cent. Extension Div., Univ. of Missouri, Columbia. 32 pp.

318. Loft, E.R., Evans, C.J., Ragotzkie, K.E., and J.G. Kie. 1989. Design and accuracy considerations for wildlife telemetry studies: some examples from ungulates. Trans. West. Sect.Wildl. Soc. 25:91-97.

319. Lokanath, S. 1995. Activity patterns and home range of Tiliqua scincodies in late autumn, winter and early spring. Honour's Thesis, University of Western Sydney - Hawkesbury, Richmon, Australia.

320. Lowry, L.F. and K.J. Frost. 1995. Movements of satellite-tagged harbor seals in Prince William Sound, Alaska, 1991-1994. Page 69 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

321. Lutterschmidt, W.I. and H.K. Reinert. 1990. The effect of ingested transmitters upon the temperature preference of the northern water snake, *Nerodias sipedon*. Herpetologica 46:39-42.

322. Lutz, R.S., J.S. Lawrence and N.J.Silvy. 1994. Nesting ecology of Attwater's prairie-chicken. J. Wildl. Manag. 58(2):230-233.

323. MacArthur, R.A., V. Geist, and R.H. Johnston. 1986. Cardiac responses of bighorn sheep to trapping and radio instrumentation. Can. J. Zool. 64(5):1197-1200.

324. Macartney, J.M., K.W. Larsen and P.T. Gregory. 1989. Body temperatures and movements of hibernating snakes (*Crotalus* and *Thamnophis*) and thermal gradients of natural hibernacula. Can. J. Zool. 67:108-114.

325. Macdonald, D.W., F.G. Ball and N.G. Hough. 1980. The evaluation of home range size and configuration using radio tracking data. Pp. 405-424 in: C.J. Amlaner and D.W. Macdonald (eds.). A Handbook on Biotelemetry and Radio Tracking.Pergamon Press, Oxf

326. Machlis, L., P.W.D. Dodd and J.C. Fentress. 1985. The pooling fallacy: problems arising when individuals contribute more than one observation to the data set. Zeitschr. Tierpsychol. 68:201-214.

327. Mackay, A., P. Thompson and D.J. Tollit. 1995. Characteristics of harbour seal foraging trips. Page 71 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

328. Madden, R. and L.F. Marcus. 1978. Use of the F distribution in calculating bivariate normal home ranges. J. Mammal. 59:870-871.

329. Madison, D.M. 1977. Movements and habitat use among interacting *Peromyscus leucopus* as revealed by radiotelemetry. Can. Field-Nat. 91:273-281.

330. Madison, D.M. 1980. Space use and social structure in meadow voles *Microtus pennsylvanicus*. Behav. Ecol. Soc. 7:65-71.

331. Madison, D.M., R.W. Fitzgerald and W.J. McShea. 1985. A user's guide to the successful radiotracking of small mammals in the field. Pages 28-39 in: R.W. Weeks and F.M. Long (eds.). Proceedings Fifth International Conference on Wildlife Biotelemet

332. Madsen, T. 1984. Movements, home range size and habitat use of radio-tracked grass snakes (*Natrix natrix*) in southern Sweden. Copeia 1984:707-713.

333. Malcolm, C.D., D.A. Duffus and S.G. Wischniowski. 1995. An examination of grey whale foraging behaviour utilizing a recoverable, suction-cup attached VHF/TDR tag. Page 71 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals

334. Malcolm, C.D., D.A. Duffus, and S.G. Wischniowski. in press. Small scale behaviour of large scale subjects: diving behaviour of a grey whale (*Eschrichtius robustus*). Western Geography.

335. Manly, B.F., L.L. McDonald, and D.L. Thomas. 1993. Resource Selection by Animals: Statistical Design and Analysis of Field Studies. Chapman & Hall, London.

336. Mano, S. 1990. Analysis of diving behaviour of sperm whale *Physeter catodon*. Nippon Suisan Gokkaishi Bulletin of the Japanese Society of Scientific Fisheries 56(2):179-187.

337. Marcum, C.L. and D.O. Loftsgaarden. 1980. A nonmapping technique for studying habitat preferences. J. Wildl. Manage. 44:963-968.

338. Marks, J.S., and V.S. Marks. 1987. Influence of radio-collars on survival of Sharp-tailed Grouse. J. Wildl. Manage. 51(2):468-471.

339. Marsh, H. and Rathbun,G.R. 1990. Development and application of conventional and satellite tracking techniques for studying dugong movements and habitat use. Austral. Wildl. Res. 17:83-100.

340. Martin, A.R. 1995. How do whales find the next breathing site when travelling under heavy sea-ice? Page 73 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

341. Martin, A.R., and Smith, T.G. 1992. Deep diving in wild, free-ranging beluga whales, *Delphinapterus leucas*. Can. J. Fish. Aquat. Sci. 49:462-466.

342. Martin, A.R., Kingsley, M.C.S., and Ramsay, M.A. 1994. Diving behaviour of narwhals (*Monodon monoceros*) on their summer grounds. Can. J. Zool. 72:118-125.

343. Martin, A.R., T.G. Smith, & D.P. Cox. 1993. Studying the behaviour and movements of high Arctic belugas with satellite telemetry. Symp. Zool. Soc. Lond. 66:195-210.

344. Martin, M.L. and J.R. Bider. 1978. A transmitter attachment for blackbirds. J. Wildl. Manage. 42:683-685.

345. Martin, T. 1992. Satellite telemetry of whales in the Arctic. ARGOS Newsletter 43:5-7.

346. Massey, B.W., K. Keane, and C. Boardman. 1988. Adverse affects of radio-transmitters on the behaviour of nesting Least Terns. Condor 90(4):945-947.

347. Mate, B., G. Rathburn and J. Reed. 1986. An ARGOS-monitored radio tag for tracking manatees. ARGOS newsletter 26.

348. Mate, B.R, Stafford, K.M., Nawojchik, R. and Dunn, J.L., 1994. Movements and dive behavior of a satellite monitored Atlantic white-

sided dolphin (*Lagenorhynchus acutus*) in the Gulf of Maine. Marine Mammal Science 10:116-121.

349. Mate, B.R. 1988. Tracking whales by satellite. Pages 83-87 in Alaska OCS Region 1987 Arctic Information Transfer Meeting Conference Proceedings.

350. Mate, B.R. 1989. Satellite-monitored radio tracking as a method for studying cetacean movements and behaviour. Report of the International Whaling Commission 39:389-391.

351. Mate, B.R. 1989. Watching habits and habitats from earth satellites. Oceanus 32(1):14-18.

352. Mate, B.R., and G. Worthy. 1995. Tracking the fate of rehabilitated dolphins. Page 74 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

353. Mate, B.R., and J.T. Harvey. 1984. Ocean movements of radio-tagged grey whales. Pages 577-583 in M.L. Jones, S.L. Swartz and S. Leatherwood (eds.) The Grey Whale *Eschrichtius robustus*. Academic Press, New York.

354. Mate, B.R., J.T. Harvey, L. Hobbs and R.R. Maiefski. 1983. A new attachment device for radio-tagging large whales. J. Wildl. Manage. 47:868-872.

355. Mate, B.R., K.A. Rossbach, S.L. Nieukirk, R.S. Wells, A.B. Irvine, M.D. Scott and A.J. Read. 1995. Satellite-monitored movements and dive behavior of a bottlenose dolphin (*Tursiops truncatus*) in Tampa Bay, Florida. Marine Mammal Science 11:452-463

356. Mate, B.R., R. Mesecar and T. Martin. 1992. Application of remote sensing methods for tracking large cetaceans: North Atlantic right whales. Final report to the 001-30411.

357. Mate, B.R., S. Nieukirk, R. Mesecar, and T. Martin. 1992. Application of remote sensing methods for tracking large cetaceans: North Atlantic Right Whales. Final Report OCS Study MMS 91-0069, U.S. Dept of Interior MMS, Alaska and Atlantic OCS Region

358. Mate, B.R., S.L. Nieukirk, S.D. Kraus, R.S. Mesecar and T.J. Martin. 1991. Satellite-monitored movements and dive patterns of radio-tagged North Atlantic right whales, *Eubalaena glacialis*. In Abstracts of the Ninth Biennial Conference on the Biolo

359. Mauser, D.M., and R.L. Jarvis. 1991. Attaching radio-transmitters to 1-day-old Mallard ducklings. J. Wildl. Manage. 55(3):488-491.

360. McGinnis, S.M. and L.L. Dickson. 1967. Thermoregulation in the desert iguana *Dipsosaurus dorsalis*. Science 156(3783):1757-1759.

361. McNay, R.S., J.A. Morgan, and F.L. Bunnell. 1994. Characterizing independence of observations in movements of Columbian black-tailed deer. J. Wildl. Manage. 58(3):422-429.

362. Meese, G.B. and C.L. Cheeseman. 1969. Radioactive tracking of the mole (*Talpa europaea*) over a 24-hour period. J. Zool. (London) 158:197-224.

363. Mellen, T.K., E.C. Meslow and R.W. Mannan. 1992. Summertime home range and habitat use of Pileated Woodpeckers in western Oregon. J. Wildl. Manage. 56:96-103.

364. Mendonca, M.T. 1983. Movements and feeding ecology of immature green turtles (*Chelmia mydas*) in a Florida Lagoon. Copeia 1983:1013-1023.

365. Metzgar, L.H. 1972. The measurement of home range shape. J. Wildl. Manage. 36:643-645.

366. Michener, M.C. and C. Walcott. 1966. Navigation of single homing pigeons: airplane observations by radio tracking. Science 154:410-413.

367. Mikesic, D.G. and L.C. Drickamer.1992. Effects of radiotransmitters and fluorescent powders on activity of wild house mice (*Mus musculus*). J. Mamm. 73:663-667.

368. Mills, A.M. 1986. The influence of moonlight on the behavior of goatsuckers (Caprimulgidae). Auk 103:370-378.

369. Mills, L.S., and F.F.Knowlton. 1989. Observer performance in known and blind radio-telemetry tests. J. Wildl. Manage. 53(2):340-342.

370. Mohr, C.O. 1947. Table of equivalent populations of North American small mammals. Am. Midl. Nat. 37:223-249.

371. Montgomery, G.G., A.S. Rand and M.E. Sunquist. 1973. Postnesting movements of iguanas from a nesting aggregations. Copeia 1973:620-622.

372. Morhardt, J.E. and S.S. Morhardt. 1971. Correlations between heart rate and oxygen consumption in rodents. Amer. J. Physiol. 221:1580-1586.

373. Morris, R. D., and G. P. Burness. 1992. A new procedure for transmitter attachment: effects on brood attendence and chick feeding rates by male Common Terns. Condor 94:230-243.

374. Morris, R. D., and J. E. Black. 1980. Radiotelemetry and Herring Gull foraging patterns. J. Fld. Ornithol. 51:110-118.

375. Morris, R. D., M. C. Benkel, A. Biernacki and J. M. Ross. 1981. A new transmitter package assembly for adult Herring Gulls. J. Fld. Ornithol. 52:242-244.

376. Mullican, T.R. 1988. Radio telemetry and fluorescent pigments: a comparison of techniques. J. Wildl. Manage. 52:627-631.

377. Munger, J.C. 1984. Home ranges of horned lizards (Phrynosoma): Circumscribed and exclusive? Oecologia 62:351-360.

378. Muth,A, R. Philbin and J.V. Muth. 1978. A temperature sensitive tracking telemetry system for small reptiles (Reptilia, Lacertilia). J. Herp. 12:533-536.

379. Naef-daenzer, B. 1993. A new transmitter for small animals and enhanced methods of home-range analysis. J. Wildl. Manage. 57(4):680-689.

380. Nakamura, A., M. Soma and M. Tsutsumi. 1985. A satellite-linked transmitter to study migration of dolphin and its application. J. Faculty of Marine Sci. and Tech. - Tokai University 21:65-77.

381. Nams, V.O. 1989. Effects of radio-telemetry location error on sample size and bias when testing for habitat selection. Can. J. Zool. 67:1631-1636.

382. Nams, V.O. and S. Boutin. 1991. What is wrong with error polygons. J. Wildl. Manage. 55:172-176.

383. Nams, V.O., 1989. A technique to determine the behaviour of a radio-tagged animal. Can. J. Zool. 67(2):523-528.

384. Neely, R.D. and R.W. Campbell. 1973. A system for gathering small mammal mortality data. U.S. For. Serv. Res. Pap. NE-280. 6 p.

385. Nesbitt, S.A., D.T. Gilbert and D.W. Warner. 1978. Red-cockaded Woodpecker fall movements in a Florida flatwoods community. Auk 95:145-151.

386. Neu, C.W., C.R. Byers, J.M. Peek and V. Boy. 1974. A technique for analysis of utilization-availability data. J. Wildl. Manage. 38:541-545.

387. Nicholls, T. H., and D. W. Warner. 1968. A harness for attaching radio transmitters to large owls. Bird Banding 39:209-214.

388. Nicholls, T.H., and M.R. Fuller. 1987. Owl telemetry techniques. U.S. For. Serv. Gen. Tech. Rep. R.M. No. 142:294-301.

389. Nordoy, E.S., L.P. Folkow, V. Potelov, V. Prichtchemikhine and A.S. Blix. 1995. Distribution and dive behaviour of White Sea harp seals, between breeding and moulting. Page 83 in Abstracts of the 11th Biennial Conference on the Biology of Marine Ma

390. Norris, K.S., W.E. Evans and G.C. Ray. 1974. New tagging and tracking methods for the study of marine mammal biology and migration. Pages 395-408 in W.E. Schevill (ed.) The Whale Problem: A Status Report. Harvard University Press, Cambridge, Massa

391. Obbard, M.E. 1977. A radio-telemetry and tagging study of activity in the common snapping turtle, *Chelydra serpentina*. M.Sc. Thesis, University of Guelph, Guelph, ON.

392. Obrecht, H.H., III, C.J. Pennycuick and M.R. Fuller. 1988. Wind tunnel experiments to assess the effect of back-mounted radio-transmitters on bird body drag. J. Exp. Biol. 135:265-273.

393. Odgen, J.C., L. Robinson, K. Whitlock, H. Daganhardt and R. Cebula. 1983. Diel foraging patterns in juvenile green turtles (*Chelonia mydas* L.) in Saint Croix, United States Virgin Islands. J. Exp. Mar. Biol. Ecol. 66:199-205.

394. Odom, R., J.H. Rappole, J. Evans, D. Charbonneau and D. Palmer. 1982. Red-cockaded Woodpecker relocation experiment in coastal Georgia. Wildl. Soc. Bull. 10:197-203.

395. Ogden, J. 1985. The California Condor - capture and radio telemetry. International Council for Bird Preservation Technical Publication 5:475-476.

396. Olders, J.H.J, J.J. van Gelder, and J. Krammer. 1985. A thermo-sensitive transmitter for radio-tracking small animals. Netherlands J. Zool. 35(3):469-478.

397. Oldham, R.S. and M.J.S. Swan. 1992. The effects of ingested radio transmitters on *Bufo bufo* and *Rana temporaria*. Herp. J. 2:82 85

398. Olesiuk, P.F., T.G. Smith, G. Horonowitsch and G.M. Ellis. 1995. Translocation of harbour seals (*Phoca vitulina*): a demonstration of homing ability and site fidelity. Page 84 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mam

399. Oliver, G.W. 1995. The MAP tracking system. Page 85 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

400. Oliver, G.W., Morris, P.A., and Le Boeuf, B.J. 1993. High resolution dive records of elephant seals yield different perspectives. pp. 82 in Abstracts of the Tenth Biennial Conference on the Biology of Marine Mammals, Galveston, TX, November 11-15,

401. Ormston, B.G. 1985. Effects of a subminiature radio collar on activity of free-living white-footed mice. Can. J. Zool. 63:733-735.

402. Orr, T., and D. Aurioles-Gamboa. 1995. Foraging characteristics and activity patterns of California sea lions (*Zalophus californianus*) on Los Islotes, Bay of La Paz. Page 85 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

403. Orthmeyer, D.L. 1991. Attachment method for radio-transmitters on mallard ducklings. Calif. Fish and Game 77(1):22-26.

404. Osgood, D.W. (no date). Biotelemetry Basics. Mini-Mitter Company, Inc, Sunriver, Oregon.

405. Pace, R.M., III and H.P. Weeks, Jr. 1990. A nonlinear weighted least-squares estimator for radiotracking via triangulation. J. Wildl. Manage. 54:304-310.

406. Page, R.E. 1982. Technological concerns for the use of radio telemetry for animal habitat identification. Research Branch, Ministry of Forests WHR-2. Victoria, BC. 40 pp.

407. Palomares, F., and M. Delibes. 1992. Data analysis design and potential bias in radio-tracking studies of animal habitat use. Acta Oecol. Int. J. Ecol. 13(2):221-226.

408. Paton, P.W., Zabel, C.J., Neal, D.L., Steger, G.N., Tilghman, N.G., and Noon, B.R. 1991. Effects of radio tags on Spotted Owls. J. Wildl. Manage. 55(4):617-622.

409. Patton, K.T., W.C. Crawford Jr., and W. Sawyer. 1984. Telemetry of heart rates in large raptors: A method of transmitter and electrode replacement. Raptor Res. 18(2):59-61.

410. Pearson, O.P. and D.F. Bradford. 1976. Thermoregulation of lizards and toads at high altitudes in Peru. Copeia 1976:155-170.

411. Pekins, P.J. 1988. Effects of poncho-mounted radios on Blue Grouse. J. Field Ornith. 59(1):46-50.

412. Perry, M. C. 1981. Abnormal behaviour of Canvasbacks equipped with radio transmitters. J. Wildl. Manage. 45:786-789.

413. Perry, M.C., G.H. Haas and J.W. Carpenter. 1981. Radio transmitters for mourning doves: a comparison of attachment techniques. J. Wildl. Manage. 45:524-527.

414. Peterman, R.M. 1990. Statistical power can improve fisheries research and management. Can. J. Fisheries and Aquatic Sciences 47: 2-15.

415. Philo, L. M., E. H. Follman and H. V. Reynolds. 1981. Field surgical techniques for implanting temperature-sensitive transmitters in grizzly bears. J. Wild. Manage. 45:772-775.

416. Pianka, E.R. and W.S. Parker. 1975. Ecology of horned lizards: a review with special reference to *Phrynosoma platyrhinos*. Copeia 1975:141-162.

417. Plummer, M.V. 1990. Nesting movements , nesting behavior, and nest sites of green snakes (*Opheodrys aestivus*) revealed by radiotelemetry. Herpetologica 46:186-191.

418. Plummer, M.V. and J.D. Congdon.1994. Radiotelemetric study of activity and movements of racers (*Coluber constrictor*) associated with a Carolina Bay in South Carolina. Copeia 1994:20-26.

419. Pollock, K.H., S.R. Winterstein, C.M. Bunck, and P.D. Curtis. 1989a. A survival analysis in telemetry studies: the staggered entry design. J. Wildl. Manage. 53:7-15.

420. Pollock, K.H., S.R. Winterstein, C.M. Bunck, P.D. Curtis, and J.M. Conroy. 1989b. Estimation and analysis of survival distributions for radio-tagged animals. Biometrics. 45:99-109.

421. Preen, A. 1995. Movements and home range of dugongs in the south-west Gulf of Carpentaria, as determined by satellite telemetry. Report to the Australian Heritage Commission, the Conservation Commission of the Northern Territory and McArthur River

422. Preen, A.R. 1993. Interactions between dugongs and seagrasses in a subtropical environment. Ph.D Thesis. James Cook University, Townsville, Australia.

423. Priede, I.G., S.M. Swift (eds). 1992. Wildlife Telemetry: Remote Monitoring and Tracking of Animals. Ellis Horwood Ltd., 708 p.

424. Quinn, N.W.S. and D.P. Tate. 1991. Seasonal movements and habitat of wood turtles (*Clemmys insculpta*) in Algonquin Park, Canada. J. Herpetol. 25:217-220.

425. Quintana, F., C. Campagna, D. Crocker and B.J. Le Boeuf. 1995. Diving behaviour of female southern elephant seals in Patagonia. Page 93 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 199

426. Rado, R. and J. Terkel. 1989. A radio-tracking system for subterranean rodents. J. Wildl. Manage. 53:946-949.

427. Raim, A. 1978. A radio transmitter attachment for small passerine birds. Bird Banding 49:326-332.

428. Ralls, K, D.B. Siniff, T.D. Williams and V.B. Kuechle. 1989. An intraperitoneal radio transmitter for sea otters. Marine Mammal Science 5:376-381.

429. Ramakka, J. M. 1972. Effects of radio-tagging on breeding behaviour of male Woodcock. J. Wildl. Manage. 36:1309-1312.

430. Rappole, J.H. and A.R. Tipton. 1991. New harness design for attachment of radio transmitters to small passerines. J. Field Ornith. 62:335-337.

431. Rappole, J.H., M.A. Ramos and K. Winkler. 1989. Movements and mortality in wintering Wood Thrushes. Auk 106:402-410.

432. Rathbun, G.B. and T.G. Murphey. Submitted. An evaluation of a radio belt for ranids. Herp Review.

433. Rathbun, G.B. and T.G. Murphy. 1993. A new radio transmitter attachment for large ranid frogs. Research Information Bulletin, U.S. Dept. of the Interior, Fish and Wildlife Service.

434. Rathbun, G.B., M.R. Jennings, T.G. Murphey and N.R. Siepel. 1993. Status and ecology of sensitive aquatic vertebrates in Lower San Simeon and Pico Creeks, San Luis Obispo County, California. California Dept. of Parks and Recreation, San Simeon Regi

435. Rathbun, G.B., N. Siepel and D. Holland. 1992. Nesting behavior and movements of Western Pond Turtles, *Clemmys marmorata*. Southwest. Nat. 37:319-324.

436. Rawson, K.S. and P.H. Hartline. 1964. Telemetry of homing behavior by the deermouse, *Peromyscus*. Science 146:1596-1598.

437. Ray, G.C., E.D. Mitchell, D. Wartzok, V.M. Kozicki and R. Maiefski. 1978. Radio tracking of a fin whale (*Balaenoptera physalus*). Science 202:521-524.

438. Read, A.J., and D.E. Gaskin. 1985. Radio tracking the movements and activities of harbour porpoises, *Phocoena phocoena* (L.), in the Bay of Fundy, Canada. Fishery Bulletin, U.S. 83:543-552.

439. Reid, D.G., W.E. Melquist, J.D. Woolington, and J.M. Noll. 1986. Reproductive effects of inraperitoneal transmitter implants in river otters. J. Wildl. Manage. 50(1):92-94.

440. Reid, J.P., C. Kruer, L.W. Lefebvre, H.I. Kochman and W. Martinez. 1995. Distribution of radio-tagged manatees in relation to near-shore habitats at Roosevelt Roads Naval Station, Puerto Rico. Page 95 in Abstracts of the 11th Biennial Conference of

441. Reinert, H.K. 1992. Radiotelemetric field studies of pitvipers: data acquisition and analysis. P. 185-197 in J.A. Campbell and E.D. Brodie (eds.). The Biology of Pitvipers. Selva Publ. Co., Tyler, Texas.

442. Reinert, H.K. and D. Cundall. 1982. An improved surgical implantation method for radio-tracking snakes. Copeia 1982:702-705.

443. Rempel, R.S., A.R. Rodgers, and K.F. Abraham. 1995. Performance of a GPS animal location system under boreal forest canopy. J. Wildl. Manage. 59(3):543-551.

444. Renken, R.B. and E.P. Wiggers. 1989. Forest characteristics related to Pileated Woodpecker territory size in Missouri. Condor 91:642-652.

445. Renner, M. 1994. Tagging of whales and dolphins - a critical review. B.Sc. Thesis, University of Otago, Dunedin, New Zealand.

446. Reynolds, R.T., and B.D. Linkhart. (1984). Methods and materials for capturing and monitoring Flammulated Owls. Gr. Basin Nat. 44(1):49-51.

447. Richard, P.R., A.R. Martin, P.A. Hall and J.R. Orr. 1995. Population level differences in the summer behaviour of Canadian Arctic belugas (*Delphinapterus leucas*) equipped with satellite-linked transmitters. Page 96 in Abstracts of the 11th Biennial

448. Richards, S.J., U. Sinsch and R.A. Alford. 1994. Radio Tracking. Pp. 155 158 in Heyer, W.R., M.A. Donnelly, R.W. McDiarmid, L.C. Hayek and M.S. Foster (eds.). Measuring and Monitoring Biological Diversity, Standard Methods for Amphibians, Smithson

449. Riley, T.Z., and B.A. Fistler. 1992. Necklace radio transmitter attachment for pheasants. J. Iowa Acad. Sci. JI. 99(2-3):65.

450. Rivera-Velez, N. and A.R. Lewis. 1994. Threshold temperatures and the thermal cycle of a heliothermic lizard. J. Herp. 28:1-6.

451. Rivest, L.P., H. Crepeau, and M. Crete 1990. A 2 phase sampling plan for estimation of the size of a moose population. Biometrics 46(1):163-176.

452. Romesburg, H. C. 1981. Wildlife science: gaining reliable knowledge. J. Wildl. Manage. 45: 293-313.

453. Rosatte, R.C., and P.M. Kelly-Ward. 1988. A surgical procedure for implanting radio-transmitters in striped skunks *Mephitis mephitis*. Can. Field-Nat. 102(4):713-715.

454. Ross, D.A, K.N. Brewster, R.K. Anderson, N. Ratner and C.M. Brewster. 1991. Aspects of the ecology of wood turtles, *Clemmys insculpta*, in Wisconsin. Can. Field-Nat. 105:363-367.

455. Rotella, J.J., D.W. Howerter, T.P. Sankowski, and J.H. Devries. 1993. Nesting effort by Mallards with 3 types of radio transmitters. J. Wildl. Manage. 57:690-695.

456. Saltz, D. 1994. Reporting error measures in radio location by triangulation: a review. J. Wildl. Manage. 58(1):181-184.

457. Saltz, D. and G.C. White. 1990. Comparison of different measures of the error in simulated radio-telemetry locations. J. Wildl. Manage. 54:169-174.

458. Saltz, D., and P. Alkon. 1985. A simple computer-aided method for estimating radio-location error. J. Wildl. Manage. 49(3):664-668.

459. Samuel, M.D. and E.O. Garton. 1985. Home range: a weighted normal estimate and tests of underlying assumptions. J. Wildl. Manage. 49:513-519.

460. Samuel, M.D. and E.O. Garton. 1987. Incorporating activity time in harmonic home range analysis. J. Wildl. Manage. 51:254-257.

461. Samuel, M.D. and R.E. Green. 1988. A revised test procedure for identifying core areas within the home range. J. Anim. Ecol. 57:1067-1068.

462. Samuel, M.D., D.J. Pierce and E.O. Garton. 1985. Identifying areas of concentrated use within the home range. J. Anim. Ecol. 54:711-719.

463. Sanderson, G.C. and B.C. Sanderson. 1964. Radio-tracking rats in Malaya - a preliminary study. J. Wildl. Manage. 28:752-768.

464. Sayre, M.W., T.S. Basket and P.B. Blenden. 1981. Effects of radio-tagging on breeding behavior of Mourning Doves. J. Wildl. Manage. 45:428-434.

465. Schevill, W.E. and W.A. Watkins. 1966. Radio tagging of whales. Report of the Woods Hole Oceanographic Institution Ref. No. 66-17. 15 pp.

466. Schmutz, J.A. and G.C. White. 1990. Error in telemetry studies: effects of animal movement on triangulation. J. Wildl. Manage. 54:506-510.

467. Schneider, K., R.W. Baird, S.M. Dawson and I. Visser. In prep. Reactions of bottlenose dolphins to tagging attempts using a suction-cup attached tag.

468. Schoener, T.W. 1981. An empirically based estimate of home range. Theor. Popul. Biol. 20:281-325.

469. Schreer, J.F. and J.W. Testa. 1995. Statistical classification of diving behavior. Marine Mammal Sci. 11:85-93.

470. Schreer, J.F., K.M. Kovacs and R.J. O'Hara Hines. 1995. Quantitative analyses of marine mammal diving behavior. Page 102 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

471. Schwartz, C.C., and E.F. Becker. 1988. Development of population assessment techniques for lynx. Alaska Dept. Fish and Game Fed. Aid Wildl. Restor. Proj. Prog. Dept. Project W-22-6 job 7.14:1-16.

472. Scott, M., R. Olson, S. Chivers and K. Holland. 1995. Tracking of spotted dolphins and yellowfin tuna in the eastern tropical Pacific. Page 102 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14

473. Scott, M.D., Chivers, S.J., Olson, R.J., and Lindsay, R.J. 1993. Radiotracking of spotted dolphins associated with tuna in the eastern tropical Pacific. In Abstracts of the Tenth Biennial Conference on the Biology of Marine Mammals, Galveston, TX,

474. Seaman, D.E., and R.A. Powell. 1991. Kernel home range estimation progam. North Carolina State Univ., Raleigh. 11pp.

475. Searing, G. F. 1995. Avian ecology and air-traffic safety at Vancouver International Airport. Report prepared for Transmport Canada by LGL Limited, Sidney, B. C.

476. Secor, S.M. 1994. Ecological significance of movements and activity range for the sidewinder, *Crotalus cerastes*. Copeia 1994:631-645.

477. Seitz, A., U. Faller Doepner and W. Reh. 1992. Radio tracking of the common frog (*Rana temporaria*). Pp. 484 489 in Priede, I.G. and S.M. Swift (eds.). Wildlife Telemetry: Remote Monitoring and Tracking of Animals. Ellis Horwood, Chichester, U.K.

478. Serveen, C., T. Thier, C. Jonkel and D. Beatty. 1981. An ear-mounted tranmitter for bears. Wild. Soc. Bull. 9:56-57.

479. Shaw, A. 1991. ARGOS data collection and location system. Telonics Quarterly 4(2):1.

480. Shine, R. and R. Lambeck. 1985. A radiotelemetric study of movements, thermoregulation and habitat utilization of Arafura filesnakes (Serpentes: Acrochordidae). Herpetologica 41:351-361.

481. Shulz, J.H., and J.R. Ludwig. (1985). A possible cause of premature loss for deer fawn transmitters. J. Mamm. 66(4):811-812.

482. Sievert, P.R., and L.B. Keith. 1985. Survival of snowshoe hares at a geographic range boundary. J. Wildl. Manage. 49(4):854-866.

483. Simpson, K., and L.W. Gyug. 1995. Effectiveness and maintenance of wildlife mitigation structures installed on new highways in southern British Columbia. Rept. to Ministry of Transportation and Hwys., Victoria.

484. Simpson, K., D. Hatler, J. Stroman, I. Hatter and J. Kelsall. 1993. Aerial inventory of large mammals in British Columbia - A manual. B. C. Environment, Victoria, B. C.

485. Simpson, K., L.W. Gyug, and J. Kelsall. 1995. The effect of a new freeway on mule deer and moose. Rept. to Ministry of Transportation and Hwys., Victoria.

486. Siniff, D.B. and J.R. Tester. 1965. Computer analysis of animal movement data obtained by telemetry. Bioscience 15:104-108.

487. Siniff, D.B., and K. Ralls. 1991. Reproduction, survival and tag loss in California sea otters. Marine Mammal Science 7:211-229.

488. Sinsch, U. 1988. Temporal spacing of breeding activity in the natterjack toad, *Bufo calamita*. Oecologia 76:399 407.

489. Sjoberg, M., and B. McConnell. 1995. Movements, home ranges and actvitity of grey seals in the Baltic. Page 106 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14 18, 1995.

490. Skirnisson, K., and D. Feddersen. 1985. Erfahrungen mit der Implantation von Sendern bei freilebenden Steinmardern. Zeitschrift für Jagdwissenschaft 30:228-235.

491. Skrdla, M.P. 1992. A Guide to Map and Image Processing. MicroImages Press, Lincoln, Nebr. 292pp.

492. Slaugh, B.T., Flinders, J.T., Roberson, J.A., and N.P. Johnson. 1990. Effect of backpack radio-transmitters on Chukar mating. Gr. Basin Nat. 50(4):379-380.

493. Slaugh, Bartel T., Jerran T. Flinders, and Jay A. Roberson. 1989. Radio transmitter attachment for Chukars. Gr. Basin Nat. 49(4):632.

494. Slip, D.J. and R. Shine. 1988. Habitat use, movements and activity patterns of free ranging diamond pythons, *Morelia spilota* (Serpentes: Boidae): a radiotelemetric study. Aust. Wildl.Res. 15:515-531.

495. Small, R.J. and D.H. Rusch. 1985. Backpacks vs ponchos: survival and movements of radio-marked Ruffed Grouse. W. Soc. Bull. 13(2):163-165.

496. Smith, H.R. 1980a. Growth, reproduction and survival in Peromyscus leucopus carrying intraperitoneally implanted transmitters. Pages 367-374

in: C.J. Amlaner, Jr. And D.W. Macdonald (eds.). A Handbook on Biotelemetry and Radio Tracking. Pergamon

497. Smith, H.R. 1980b. Intraperitoneal transmitters in suckling white-footed mice, Peromyscus leucopus. Biotelem. Patient Monitor 7:221-230.

498. Smith, H.R. and G.D. Whitney. 1977. Intraperitoneal transmitter implants - their biological feasibility for studying small mammals. Proc. Int. Conf. Wildl. Biotelem. 2:109-117.

499. Smith, W.P. 1983. A bivariate normal test for elliptical home-range models: biological implications and recommendations. J. Wildl. Manage. 47:613-619.

500. Smits, A.W. 1984. Activity patterns and thermal biology of the toad *Bufo boreas halophilus*. Copeia (1984):689 696.

501. Snedcor, G.W. and W.G. Cochran. 1980. Statistical methods. 7th ed. The Iowa State Univ. Press.Ames Iowa.

502. Snyder, N.F.R., S.R. Beissinger, and M.R. Fuller. 1989. Solar radio-transmitters on Snail Kites in Florida. J. Field. Ornith. 60(2):171-177.

503. Snyder, W.D. 1985. Survival of radio-marked hen pheasants in Colorado. J. Wildl. Manage. 1044-1050.

504. Sorenson, M.P., 1989. Effects of neck radio-collars on female Redheads. J. Field. Ornith. 60(4):523-528.

505. Spencer, W.D. and R.H. Barrett. 1984. An evaluation of the harmonic mean measure for defining carnivore activity areas. Acta Zool. Fenn. 171:255-259.

506. Springer, J.T. 1979. Some sources of bias and sampling error in radio triangulation. J. Wildl. Manage. 43:926-935.

507. Stüwe, M., and C.E. Blohowiak. 1985. McPAAL, micro-computer programs for the analysis of animal locations. Conservation and Research Center, National Zoological Park, Smithsonian Institiution, Front Royal, Va. 20pp.

508. Stabbins, R.C. and R.E. Barwick. 1968. Radiotelemetric study of thermoregulation in a lace monitor. Copeia 1968:541-567.

509. Stemp, R. 1982. Heart rate responses of bighorn sheep to some environmental factors. Proceedings of the Third Annual Biennial Symposium on Northern Wild Sheep and Goat Council, J. A. Bailey and G.G. Schoonveld (eds.). p 314-319.

510. Stewart, B.S., P.H. Thorson and P.K. Yochem. 1995. Development of a satellite-linked radio-transmitter package for small cetaceans. Page 110 in

Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18

511. Stewart, B.S., S. Leatherwood, P.K. Yochem and M. P. Heide Jorgensen. 1989. Harbor seal tracking and telemetry by satellite. Marine Mammal Science 5:361 375.

512. Stickel, L.F. 1954. A comparison of certain methods of measuring ranges of small mammals. J. Mamm. 35:1-15.

513. Stickel, L.F. 1989. Home range behavior among box turtles *(Terrapene c. carolina*) of a bottom land forest in Maryland. J. Herpetol. 23:40-44.

514. Stone, G., Goodyear, J., Hutt, A., and Yoshinaga, A. 1995. A new non-invasive tagging method for studying wild dolphins. MTS Journal 28:11-16.

515. Stouffer, R.H., J.E. Gates, L.H. Holutt and J.R. Stauffer. 1983. Surgical implantation of a transmitter package for radio tracking endangered hellbenders. Wildl.Soc. Bull. 11:384 386.

516. Strathearn, S.M., J.S. Lotimer, G.B. Kolenosky, and W.M. Lintack. 1984. An expanding breakaway radio-collar for black bear. J. Wildl. Manage. 48(3):939-942.

517. Swanson, G. A., and V. Keuchle. 1976. A telemetry technique for monitoring waterfowl activity. J. Wildl. Manage. 40:187-189.

518. Swartz, S.L., M.L. Jones, J. Goodyear, D.E. Withrow and R.V. Miller. 1987. Radio-telemetric studies of grey whale migration along the California coast: a preliminary comparison of day and night migration rates. Report of the International Whaling

519. Sweeney, J.C. and J.L. Mattsson. 1974. Surgical attachment of a telemetry device to the dorsal ridge of a yearling California grey whale, *Eschrichtius robustus*. Marine Fisheries Review 36:20-22.

520. Swihart, R.K. and N.A. Slade. 1985. Influence of sampling interval on estimates of home-range size. J. Wildl. Manage. 49:1019-1025.

521. Swihart, R.K. and N.A. Slade. 1985. Testing for independence of observations in animal movements. Ecology 66:1176-1184.

522. Swihart, R.K. and N.A. Slade. 1986. The importance of statistical power when testing for independence in animal movements. Ecology 67:255-258.

523. Sykes, P.W., III, J.W. Carpenter, S. Holzman and P.H. Geissler. 1990. Evaluation of three miniature radio transmitter attachment methods for small passerines. Wildl. Soc. Bull. 18:41-48.

524. Tanaka, S. 1987. Satellite radio tracking of bottlenose dolphins *Tursiops truncatus*. Nippon Suisan Gokkaishi Bulletin of the Japanese Society of Scientific Fisheries 53:1327 1338.

525. Tanaka, S., K. Takao and N. Kato. 1987. Tagging techniques for bottlenose dolphins *Tursiops truncatus*. Nippon Suisan Gokkaishi Bulletin of the Japanes Society of Scientific Fisheries 53:1317 1325.

526. Tanner, R.W., K.M. Kilbride, J.A. Crawford, B.A. Williams, and A.J. Kimerling. 1992. Automated mapping of radio telemetric locations for wildlife studies. Wildl.Soc. Bull. 20(2):232-233.

527. Taylor, Ian R. 1991. Effects of nest inspections and radio tagging on Barn Owl breeding success. J. Wildl. Manage. 55(2):312.

528. Testa, J.W., K. Kovacs, J. Francis, A. York, M. Hindell and B. Kelly. 1993. Analysis of data from time depth recorders and satellite linked time depth recorders: report of a technical workshop. School of Fisheries and Ocean Sciences, University of Al

529. Thorson, P.H. 1995. Development of diving in the northern elephant seal. Page 114 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

530. Tom, J. 1994. Microhabitats and use of burrows of Bolson tortoise hatchlings. Pages 139-146 in R.B. Bury and D.J. Germano (eds.). Biology of North American Tortoises. National Biological Survey, Fish and Wildlife Research 13.

531. Trout, R.C., and J.C. Sunderland. 1988. A radio transmitter package for the wild rabbit (*Oryctolagus cuniculus*). J. Zool. (London) 215(2):377-379.

532. Unsworth, J. W., F. A. Leban, E. O. Garton and J. R. Pope. 1991. Elk Sightability Surveys. Revised Edition. Idaho Dept. of Fish and Game, Boise, ID.

533. Van Berkum, F.H., R.B. Huey and B.A. Adams. 1986. Physiological consequences of thermoregulation in a tropical lizard (*Ameiva festiva*). Physiol. Zool. 59:464-472.

534. Van Gelder, J.J., H.M.J. Aarts and H.W.M. Staal. 1986. Routes and speed of migrating toads (*Bufo bufo* L.): A telemetric study. Herpetological Journal 1:111 114.

535. Van Nuland, G.J. and P.F.H. Claus. 1981. The development of a radio tracking system for anuran species. Amphibia Reptilia 2:107 116.

536. Van Parijs, S., P.M. Thompson, D.J. Tollit and A. MacKay. 1995. Aquatic display behaviour of mating male harbour seals: distribution, vocalisations and dive patterns. Page 118 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

537. van Vuren, D. 1989. Effects of intra peritoneal transmitter implants on yellow-bellied marmots. J. Wildl. Manage. 53(2):320-323.

538. Van Winkle, W. 1975. Comparison of several probablistic home range models. J. Wildl. Manage. 39:118-123.

539. Varosi, S.M., R.L. Brigmon, and E.L. Besch. 1990. A simplified telemetry system for monitoring body temperature in small animals. Lab Anim. Sci. 40(3):299-302.

540. Voight, D.R. and R.R. Tinline. 1980. Strategies for analysing radio tracking data. Pp. 387-404 in C.J. Amlaner and D.W. Macdonald (eds.). A Handbook on Biotelemetry and Radio Tracking. Pergamon Press, Oxford.

541. Vonhof, M.J. 1995. Roost-site selection and roosting ecology of forest-dwelling bats in southern British Columbia. M.Sc. Thesis, University of Calgary, Calagary, AB.

542. Vonhof, M.J. 1996. A survey of the abundance, diversity, and roost-site preferences of bats in the Pend d'Oreille Valley, British Columbia. Report prepared for the Columbia Basin Fish and Wildlife Compensation Program.

543. Vonhof, M.J. and R.M.R. Barclay. Submitted. Roost-site selection and roosting ecology of forest-dwelling bats in southern British Columbia. Can. J. Zool.

544. Vonhof, M.J. and R.M.R. Barclay. Submitted. Use of tree stumps as roosts by the western long-eared bat. J. Wildl. Manage.

545. Vonhof, M.J. In Press. A comparison of the roost-site preferences of big brown bats (*Eptesicus fuscus*) and silver-haired bats (*Lasionycteris noctivagans*) in the Pend d'Oreille valley in southen British Columbia. Proceedings of the Bats and Forests

546. Waldschmidt, S.R. 1979. The effect of statistically based models on home range size estimate in Urta stansburiana. Amer. Midl. Nat. 101:236-240.

547. Wallingford, B.D., and R.A. Lancia. 1991. Telemetry accuracy and a model for predicting telemetry error. Proc. Ann. Conf. Southeast Assoc. Fish Wildl.Agencies 45:178-188.

548. Wang K., M.C. Kalcounis, D.J. Bender, D.L. Gummer & R.M. Brigham. 1995. Predation on free-ranging Common Poorwills in Saskatchewan. J. Field Ornith., 66:400-403.

549. Wanless, S., M.P. Harris, and J.A. Morris. 1985. Radio-monitoring as a method of estimating time budgets of Guillemots Uria aalge. Bird Study 32(3):170-175.

550. Ward, D.H., and P.L. Flint. 1995. Effects of harness-attached transmitters on premigration and reproduction of Brant. J. Wildl. Manage. 59(1):39-46.

551. Watkins, W.A. 1978. A radio tag for big whales. Oceanus 21:48-54.

552. Watkins, W.A. 1979. A point for penetrating whale blubber. Deep-Sea Research 26:1301-1308.

553. Watkins, W.A. 1981. Reaction of three species of whales, *Balaenoptera physalus*, *Megaptera novaeangliae* and *Balaenoptera edeni* to implanted radio tags. Deep-Sea Research 28A:589-599.

554. Watkins, W.A. and W.W. Schevill. 1977. The development and testing of a radio whale tag. Woods Hole Oceanographic Institution Report Ref. No. 77-58.

555. Watkins, W.A., and C.A. Goebel. 1984. Sonar observations explain behaviors noted during boat maneuvers for radio tagging of humpback whales (*Megaptera novaeangliae*) in the Glacier Bay area. Cetology 48:1-8.

556. Watkins, W.A., and P. Tyack. 1991. Reaction of sperm whales (*Physeter catodon*) to tagging with implanted sonar transponder and radio tags. Marine Mammal Science 7(4):409-413.

557. Watkins, W.A., D. Wartzok, H.B. Martin and R.R. Maiefski. 1980. A radio whale tag. Pages 227-241in F.P. Diemer, F.J. Vernberg and D.Z. Mirkes (eds.) Advanced Concepts in Ocean Measurements in Marine Biology. Edited by. University of South Caroli

558. Watkins, W.A., Daher, M.A., Fristrup, K.M., Howald, T.J., and di Sciara, G.N. 1993. Sperm whales tagged with transponders and tracked underwater by sonar. Mar. Mamm. Sci. 9:55-67.

559. Watkins, W.A., G.N. di Sciara and K.E. Moore. 1979. Observations and radio tagging of *Balaenoptera edeni* near Puerto La Cruz, Venezuela. Woods Hole Oceanographic Institution Technical Report WHOI-79-89. 8pp.

560. Watkins, W.A., K.E. Moore, D. Wartzok and J.H. Johnson. 1981. Radio tracking of finback (*Balaenoptera physalus*) and humpback (*Megaptera novaeangliae*) whales in Prince William Sound, Alaska. Deep-Sea Research 28A(6):577-588.

561. Watkins, W.A., K.E. Moore, J. Sigurjonsson, D. Wartzok and G.N.di Sciara. 1984. Fin whale (*Balaenoptera physalus*) tracked by radio in the Irminger Sea. Rit Fiskideildar 8:1-14.

562. Watson, J.W. 1985. Trapping, marking and radio-monitoring Rough-legged Hawks. N. Am. Bird Banding 10(1):9-10.

563. Webster, A.B. and R.J. Brooks. 1980. Effects of radiotransmitters on the meadow vole, *Microtus pennsylvanicus*. Can. J. Zool. 58:997-1001.

564. Werner, R., and C. Campagna. 1995. Satellite tracking of South American sea lions during the breeding season in Patagonia. Page 122 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

565. Westgate, A.J., and A.J. Read. 1995. Monitoring the movements of harbour porpoises using satellite telemetry. Page 122 inAbstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

566. Westgate, A.J., Read, A.J., Berggren, P., Koopman, H.N. and Gaskin, D.E. 1995. Diving behaviour of harbour porpoises, *Phocoena phocoena*. Can. J. Fish. Aquat. Sci. 52:in press.

567. Wheeler, W. E. 1991. Suture and glue attachment of radio transmitters on ducks. J. Field Ornith. 62(2):271-178.

568. White, G.C. 1983. Numerical estimation of survival rates from band-recovery and biotelemetry data. J. Wildl. Manage. 47:716-728.

569. White, G.C. and R.A. Garrott. 1986. Effects of biotelemetry triangulation error on detecting habitat selection. J. Wildl. Manage. 50:509-513.

570. White, G.C., and R.A. Garrott. 1990. Analysis of Wildlife Radio-tracking Data. Academic Press, San Diego, California.

571. Williams, T.D., A.L. Williams and D.B. Siniff. 1981. Fentanyl and azaperone produced neuroleptanalgesia in the sea otter (*Enhydra lutris*). J. Wildl. Dis. 17:337-342.

572. Williams, T.D., and D.B. Siniff. 1983. Surgical implantation of radiotelemetry devices in the sea otter. J. Am. Vet. Med. Assoc. 183:1290-1291.

573. Wilson, D.S. 1991. Estimates of survival for juvenile gopher tortoises, *Gopherus polyphemus*. Journal of Herpetology 25:376-379.

574. Wilson, D.S., H.R. Mushinsky and E.D. McCoy. 1994. Home range, activity, and burrow use of juvenile gopher tortoises in a central Florida population. Pages 147-160 in R.B. Bury and D.J. Germano (eds.). Biology of North American Tortoises. Nationa

575. Wilson, R.P. and D.C. Duffy. 1986. Recording devices on free-ranging marine animals: does measurement affect performance? Ecology 67:1091-1093.

576. Wingenroth, J.L. 1995. Enhanced satellite data telemetry and geographic positioning via the ARGOS system. Page 123 in Abstracts of the 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL. December 14-18, 1995.

577. Winker, K., J.H. Rappole and M.A. Ramos. 1990. Population dynamics of the Wood Thrush (*Hylocichla mustelina*) in southern Veracruz, Mexico. Condor 92:444-460.

578. Withrow, D.E., and T.R. Loughlin. 1995. Harbor seal abundance and haulout behavior in Alaska, including correction factors to estimate the proportion of harbor seals missed during molt census surveys. Page 123 in Abstracts of the 11th Biennial Confer

579. Woods, R., S. McLean, S. Nicol and H. Burton. 1994. A comparison of some cyclohexamine based drug combinations for chemical restraint of southern elephant seals (*Mirounga leonina*). Marine Mammal Science 10:412-429

580. Woolf, A., J.L. Curl, and E. Anderson. 1984. Inanition following implantation of a radio-telemetry device in a river otter. J. Am. Vet. Med. Assoc. 185(11):1415-1416.

581. Worthy, G.A.J., and R.W. Davis. 1995. Diving behavior and movement patterns of an Atlantic spotted dolphin (*Stenella frontalis*) obtained by satellite telemetry. Page 124 inAbstracts of the 11th Biennial Conference on the Biology of Marine Mammals,

582. Worton, B.J. 1987. A review of models of home range for animal movements. Ecological Modelling 38:277-298.

583. Worton, B.J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70:164-168.

584. Wray, S., W.J. Cresswell and D. Rogers. 1992. Dirichlet tesselations: a new, non-parametric approach to home range analysis. Pp.247-255. in I.G. Priede and S.M. Swift (eds.), Wildlife Telemetry: Remote Monitoring and Tracking of Animals.

585. Wray, S., W.J. Cresswell, P.C.L. White and S. Harris. 1992. What, if anything, is a core area? An analysis of the problems of describing internal range configurations. Pp. 256-271 in I.G. Priede and S.M. Swift (eds.). Wildlife Telemetry: Remote Moni

586. Wursig, B. 1982. Radio tracking dusky porpoises in the South Atlantic. Pp. 145-160 in Mammals in the seas. Volume 4: small cetaceans, seals, sirenians and otters. FAO Fish. Ser. No. 5.

587. Wursig, B., F. Cipriano and M. Wursig. 1990. Dolphin movement patterns: information from radio and theodolite tracking studies. In Dolphin Societies: Discoveries and Puzzles. University of California Press, Berkeley, California.

588. Zurowski, K.L. & R.M. Brigham. 1994. Does use of doubly labeled water in metabolic studies alter activity levels of Common Poorwills? Wilson Bulletin 106:412-415.

11. APPENDIX

Appendix A. References by Topic.

(Numbers correspond to entries in the bibliography).

GENERAL

10 12 31 37 87 96 125 142
180 230 264 276 300 318 326 335 369
376 382 405 414 423 452 456 457 458
466 501 506 540 547 569 570

EQUIPMENT/TECHNIQUES

57 88 101 106 108 117 127 128
146 151 161 162 170 194 195 229 263
267 279 315 443 526

IMPLANTED TRANSMITTERS/BIOTELEMETRY

38 85 92 100 141 152 204 210
216 219 234 257 280 282 284 288 296
302 321 323 324 360 372 396 404 409
410 415 428 439 450 453 496 497 498
500 508 509 514 532 536 538 571 579

SATELLITE TRANSMITTERS

86 113 153 169 197 204 221 254
255 270 271 272 273 277 293 339 343
345 347 348 349 350 351 355 356 357
358 399 479 510 511 524 565 576

SOFTWARE

1 133 201 269 310 466 503

HOME RANGE

1 11 21 22 45 71 89 90
91 99 109 114 133 134 136 137 139
144 167 175 178 181 185 205 222 224
245 251 252 256 258 269 286 287 298

MORTALITY

ACTIVITY/BEHAVIOUR

DEMOGRAPHICS

HABITAT SELECTION

DISPERSAL, MIGRATION

HERPTILES

77 78 91 95 102 133 161 162 163
170 173 175 188 213 231 241 242 245
269 280 281 303 321 324 332 360 364
371 377 378 391 393 397 410 416 417
418 424 432 433 435 441 442 448 450
454 476 477 480 488 494 500 508 513
515 519 530 533 534 535 573 574

UNGULATES

29 32 39 100 113 126 130 143
144 151 153 179 193 220 225 247 272
274 275 289 294 295 313 318 323 361
451 481 483 484 485 509 532

LARGE CARNIVORES

33 174 217 251 257 295 415 478
516

MEDIUM-SIZED MAMMALS

9 17 21 40 46 55 141 210
216 249 265 296 439 453 471 482 531
537 580

SMALL MAMMALS

27 71 101 131 138 158 165 185
206 218 288 298 316 329 330 331 367
370 379 384 396 401 426 436 463 494
497 498 512 563

BATS

4 5 59 60 61 62 63 68
104 108 155 156 290 299 362 541 542
543 544 545

MARINE MAMMALS

8 13 15 20 23 24 25 26
34 35 36 38 43 44 47 48 49
50 51 52 53 54 56 70 79 93

WEB-FOOTED BIRDS

CRANES, HERONS

SHOREBIRDS

RAPTORS

GAME BIRDS

PASSERINES, PIGEONS, DOVES, GOATSUCKERS

	4	19	30	57	64	65	66	67
69	81	82	120	121	160	190	191	198
199	208	209	211	243	250	262	282	283
285	290	302	344	363	366	368	385	394
413	427	430	431	444	464	523	549	577
586								

Appendix B. Sample log form for radio-transmitter unit.

Make	***Model***	***Serial Number***	***Frequency***	***Date of Purchase***
Wildtrack	*CR-57*	*000398932983*	*179.45*	*Jan 20/1996*

Testing

Date	***Pulse?***	***Strength***	***Quality***	***Comment***
01/20/96	*Yes*	*Good*	*Good*	*Working fine.*
02/28/96	*Yes*	*Good*	*Good*	*Working fine.*
10/20/96	*Yes*	*Variable*	*Good*	*Pulse seems inconsistent.*
12/18/96	*Yes*	*Weak*	*Poor*	*Needs repair and servicing.*
01/15/97	*Yes*	*Good*	*Good*	*Working fine.*
02/12/97	*Yes*	*Good*	*Good*	*Working fine.*

Deployment

Spp	***Date Deploy***	***Date Last Transmit***	***Date Recover***	***Total # Relocate***	***Reason for Failure***
WOLV	*03/01/96*	*06/01/96*	*06/19/96*	*11*	*Torn off.*
Comment *Collar found in boulder field. Leather had been torn through next to clasp. Still transmitting fine.*					
WOLV	*03/03/97*				
Comment					

Repair/Service Record

Date Repaired/ Serviced	***Technician, Company***	***Description***
10/15/96	*Smith Shoe Repair*	*Repair torn leather collar.*
01/10/97	*Wildtrack, Vancouver*	*Servicing and new battery.*