ERDC TN-EMRRP-SI-34
July 2009

Mammalian Survey Techniques for Level II Natural Resource Inventories on Corps of Engineers Projects (Part I)

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PURPOSE: This technical note is a product of the Ecosystem Management and Restoration Research Program (EMRRP) work unit titled "Natural Resource Inventories for Special Status Species on Corps Operating Projects." The objective of this note is to provide information on methods for conducting inventories of mammalian species to satisfy the requirements of Level II Natural Resources Inventories for Corps of Engineers operating projects. General information is provided on survey methodologies for a variety of mammalian species, with emphasis on broad-based methods that can be used to obtain occurrence/non-occurrence data for multiple species within a community (Martin et al. 2006). Selected techniques used to survey ungulates (hoofed mammals), carnivores, lagomorphs (rabbits and hares), squirrels, large aquatic rodents (beavers, muskrats, nutria), ground-dwelling rodents, and insectivores (shrews and moles) are described. Methods to determine presence/absence and/or relative abundance are emphasized. Inventory methods for bats are addressed separately in Part II of Mammalian Survey Techniques (Martin et al., in preparation).

BACKGROUND: Conducting inventories of free-roaming animal populations is often a difficult task that requires careful planning, preparation, and execution (Figure 1). Techniques appropriate for Level II inventories on Corps projects generally provide presence/absence or trend data rather than census data. This is because estimating population size for most mammals is constrained by limitations imposed by the underlying assumptions of census techniques and/or the amount of data required for a reliable sample. Also, mammalian inventory methods used for rigorous scientific study are often prohibitively expensive and time-consuming for routine surveys on Corps lands, and usually can only be justified when there is special concern regarding sensitive species. The survey method selected for a species or species group will be influenced by (1) constraints of time and cost,

Figure 1. Surveys of free-roaming mammals require careful planning, preparation, and execution *(photo courtesy of Mike Watkins)*.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **JUL 2009**	2. REPORT TYPE	3. DATES COVERED **00-00-2009 to 00-00-2009**
4. TITLE AND SUBTITLE **Mammalian Survey Techniques for Level II Natural Resource Inventories on Corps of Engineers Projects (Part 1)**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Army Engineer Research and Development Center,Environmental Laboratory,3909 Halls Ferry Road,Vicksburg,MS,39180-6199**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**27**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

(2) objectives of the survey, (3) desired level of accuracy and precision, (4) reliability and repeatability, (5) time of year, (6) and terrain and habitat features. Although presence-absence surveys are limited in their ability to provide reliable population size data, they are often the only feasible alternative for monitoring large areas when funds are limited (Pollock 2006). Issues and innovations associated with presence-absence sampling are discussed in several recent studies (Vojta 2005, Pollock 2006, Rhodes et al. 2006, Marsh and Trenham 2008).

Mammal surveys on Corps projects have historically been conducted primarily for game and furbearing species. However, the current emphasis on biodiversity and ecosystem management requires districts to have a better understanding of nongame species and their importance to ecosystem diversity on project lands. The following sections provide general guidelines for surveying a variety of mammals that may be present on Corps projects. Emphasis is placed on small mammal and carnivore surveys because inventory methods used for game species are generally conducted in accordance with procedures established through coordination with state wildlife agencies.

OMBIL SPECIES LIST: Mammalian special status species that potentially occur on Corps projects are listed in the Corps Operations and Management Business Information Link (OMBIL) species database. The current list includes six shrews and moles (Order Soricimorpha), 23 bats (Order Chiroptera), 21 carnivores (Order Carnivora), four hares and rabbits (Order Lagomorpha), 13 rodents (Order Rodentia), two ungulates (Order Artiodactyla), one manatee (Order Sirenia), and three cetaceans (Order Cetacea). Although the current OMBIL list is incomplete, it is apparent that bats, carnivores, and small mammals (primarily rodents and shrews) are of greatest concern as special status species on most projects. Therefore, these species groups will be emphasized.

PERMITS AND PRECAUTIONS: Permits are required before sampling mammals in any location. The appropriate state agency (usually the state Game and Fish office or Department of Natural Resources) should be contacted to procure the applicable permit well in advance of the sampling event. Federal permits will be required if there is a likelihood that a federally listed species will be captured. The applicant should be aware that obtaining permits can often take weeks or even months and may require a background check, proof of technical competence regarding knowledge of the species to be collected, and references from professional sources knowledgeable of the permitee's abilities. Some states even require completion of an extensive training program before granting a permit. Trapping and handling of mammals should be conducted in accordance with the Animal Care and Use Committee (1998) of the American Society of Mammalogy. Updated guidelines on marking, trapping, housing, and collecting mammals for research are provided in Gannon et al. (2007).

The project manager must take proper precautions to protect field and laboratory personnel from being exposed to zoonoses (diseases transmittable from animals to humans) that could potentially affect human health. Diseases of concern include lyme disease, hantavirus, and rabies, briefly described below. Other potential diseases and hazards are discussed in Constantine (1988), Kunz et al. (1996), and Cockrum (1997).

Lyme Disease. Lyme Disease (LD) is a tick-borne bacterial disease that has become a significant health problem in some regions of North America. The spiral-shaped bacterium that causes LD is known as *Borrelia burgdorferi*. The primary vector for LD in eastern and Midwestern states is the deer tick (*Ixodes dammini*) whereas the western black-legged tick (*I. pacificus*) is the major carrier in the West. Small mammals, particularly mice, are the more common hosts of the larval and nymphal stages of the tick's life cycle; deer (*Odocoileus* spp.) are the primary hosts for adults. Natural resources personnel should become aware of the potential for exposure to the disease in their area and take appropriate precautions to minimize contacts with ticks when handling wild animals. An overview of Lyme Disease is provided in Centers for Disease Control (CDC) (2007).

Hantivirus. Hantivirus pulmonary disease is an acute disease caused by viruses in the genus *Hantivirus*, which have been documented from several areas primarily in the Southwest (Mills et al. 1995, Dearing et al. 1998, Biggs et al. 2000); however, several eastern states have documented cases in recent years. The deer mouse (*Peromyscus maniculatus*) is the primary reservoir of Sin Nombre virus and related strains of hantivirus in the United States, but several other species of murid rodents have tested positive for the disease. Dried fecal material is the most likely route of transmission for the disease. Where hantivirus is a concern, personnel handling specimens should be required to wear air-purifying respirators (APRs) as a health and safety precaution. APRs typically worn during field surveys are the half-mask, twin-cartridge type (Andrews 1990). Also, leather gloves should be worn by personnel handling rodents in the field, and latex gloves should be worn when measuring and processing specimens. If traps are used to capture specimens, they should be thoroughly washed before storage or reuse.

Rabies. Rabies (*Lyssavirus*) is an acute viral infection of the central nervous system that occurs mostly in warm-blooded animals (Kunz et al. 1996). Contracting rabies from animal bites is a rare occurrence in the United States, but personnel handling mammals should be inoculated with a preventative rabies vaccine before conducting field work. The vaccine usually consists of three injections over several weeks. Animal handlers should have their titer (concentration of the vaccine in one's system) checked annually to ensure protection. This will require that blood be drawn and submitted to a qualified laboratory for testing. Booster doses are needed when the titer level drops below the acceptable level. If a person is bitten while handling any wild mammal, a physician should be consulted immediately. If possible, the specimen should be captured and submitted for testing.

PRE-SURVEY RECOMMENDATIONS: A variety of factors must be considered before conducting inventories. Objectives of the inventory must first be determined and appropriate techniques selected to provide the most useful information. It is also critical to determine how the data collected will be stored, analyzed, and used for management purposes. When designing a survey, managers must realize that it is seldom possible to meet all sampling criteria, and methods involving direct sightings often provide incomplete counts of individual animals occupying a study area (Rudran et al. 1996). Some important aspects of inventories are provided below.

Factors that Affect Inventories. A variety of factors affect the accuracy of field surveys and reliability of data collected. Major factors that must be taken into consideration are noted below:

- Time of year (there are often significant seasonal differences in movement patterns, thus detectability, of mammals)
- Time of day (most species are best surveyed during nocturnal or crepuscular periods)
- Weather (in most cases surveys should not be conducted during inclement weather)
- Human disturbance (anthropogenic disturbances on-site and adjacent to the survey area should be taken into consideration)
- Habitat conditions (habitat type and terrain features will influence the ability to conduct inventories for different species)
- Population levels of species being surveyed (species with low population levels in an area will generally be more difficult to survey than more common species)
- Behavioral characteristics (movement patterns will often vary according to sex and age)
- Detectability of species (some species are more easily observed than others)
- Skill and experience of observers/data collectors

Consistency in Sampling. Consistency in sampling procedures is extremely important when conducting mammal surveys because of the limitations of most methods to monitor population trends. The following guidelines should be followed by in-house and/or contract personnel for all field inventories:

- Use the same methods among sample sites from year to year
- Use the same transects/plots from year to year
- Conduct inventories at approximately the same time each year
- Start inventories at the same time each day
- Be consistent with data recording from year to year
- Use standard habitat codes for reporting
- Use standard codes or scientific names instead of common names on all data forms
- Identify sample sites using consistent Global Positioning System (GPS) equipment and methodology
- Ensure that all personnel collecting data are properly trained and have the necessary skills
- If possible, the same personnel should conduct surveys during the life of a study

Species Identification. Persons conducting surveys should be thoroughly familiar with species potentially occurring in the area. If surveys are to be conducted under contract, managers should ensure that contractors have experience working with species in the region. Regional guides and diagnostic keys are available for many areas, but descriptive information may be highly variable. Recent field guides for North American mammals include Kays and Wilson (2002) and Reid (2006). Area and state museums and universities should be checked for the availability of museum mounts that can be used to verify species identification.

TECHNIQUES FOR LARGE AND MEDIUM-SIZED MAMMALS: Methods for conducting inventories of large and medium-sized mammals are highly variable. Direct observation techniques may be used for some species, but the nocturnal and secretive nature of many species require the use of indirect techniques such as scent stations, track-plates, hair-traps, and remote cameras. Techniques commonly used to survey ungulates (hooved mammals) and carnivores are first discussed below. Selected techniques with high potential for use on Corps lands are then described in greater detail. Project managers should consult with local and regional state wildlife biologists before selecting a method for use on Corps projects, especially if game species are to be surveyed.

Deer, elk (*Cervus elaphus*), pronghorn (*Antilocapra americana*), Dall's sheep (*Ovis dalli dalli*), mountain goats (*Oreamnos americanus*) and other hoofed animals are often surveyed using aerial counts from fixed-wing aircraft (Pauley and Crenshaw 2006, Udevitz et al. 2006). Moose (*Alces alces*) counts are also generally made aerially, but their habitat preferences and frequent use of forest cover make them difficult to detect from aircraft, even helicopters. Collared peccary (*Tayassu tajacu*), also referred to as javelina, have been censused using aerial surveys, road censuses, and track counts, but these methods are often not feasible in dense brush country (Boyd et al. 1986). However, Langoria and Weckerly (2007) determined presence/absence of javelina from surveys of sign (tracks and feces) in southern Texas.

Javelina and feral swine (*Sus Scrofa*) (also referred to as wild hogs or European wild boars) were detected at scent stations baited with specially prepared attractants in southern Texas (Campbell and Long 2008). Populations of feral swine have expanded throughout the United States and can result in considerable damage to natural areas by their foraging and rooting behavior (Seward et al. 2004, Wilcox and Van Vuren 2009). Thus, it is especially important that managers conduct routine inventories of feral swine when they are present on project lands.

White-tailed deer (*O. virginianus*) and mule deer (*O. hemionus*) are the most common ungulates surveyed on Corps lands (Figure 2). Census methods available for deer include the Hahn deer cruise, drive count (method in which a crew of observers move methodically through an area and count all individuals of a species detected), spotlight census, track counts, aerial surveys, pellet group counts, mark recapture techniques, harvest surveys, and browse surveys. All of these techniques have been used extensively and each provide certain advantages for estimating deer populations. However, some methods are labor intensive, and several have limited regional application. Traditional methodologies such as drive counts and mark-recapture techniques can be costly, labor intensive, or limited to areas with high visibility (Lancia et al. 1994, Roberts et al. 2006). The spotlight census, a roadside survey in which deer are detected by shining spotlights on either side of the road from a slow-moving vehicle) is a commonly used technique for estimating white-tailed deer population size and distribution (McCullough 1982, Fafarman and DeYoung 1986, Collier et al. 2007) and has been applied to Corps lands in several regions (Mitchell 1986).

Figure 2. A variety of methods are available to inventory big-game populations *(photo courtesy of Mike Watkins)*.

Although not described in detail below, thermal infrared (TIR) imagery is being increasingly used to inventory and monitor populations of large animals. TIR imagers have shown broad potential for locating warm-blooded animals under a wide range of conditions (Boonstra et al. 1994, Garner et al. 1995, Melton et al. 2005). Collier et al. (2007) used a combination of traditional spotlight methods and thermal imagers to detect white-tailed deer in South Carolina. Roberts et al. (2006) experimented with infrared-triggered cameras in Florida and suggested that population estimates based on their data may provide an alternative to road surveys for estimating white-tailed deer densities. Drawbacks include the expense of TIR equipment and critical conditions that must be met for TIR imagery to be effective (Butler et al. 2006). For example, detection of target animals can be constrained by vegetative cover conditions and poor thermal contrast between biological objects and their background (Havens and Sharp 1998).

Carnivores are often difficult to survey because of their secretive nature, relatively low densities, nonrandom distribution, and the mobility and wariness of most species (Spowart and Samson 1986, Sargeant et al. 2003, Gompper et al. 2006) (Figure 3). Survey methods often used for carnivore inventories include mark-recapture techniques, aerial surveys, bounty and harvest records, road kills, predator calls, and counts of sign. Several mark-recapture procedures have been used, but all are expensive and labor intensive. Furthermore, the results are often biased by short retention times of marks, insufficient sample sizes, non-random sampling, and variability of an individual's susceptibility to capture and/or recapture. Aerial surveys, den surveys, and track counts are generally impractical in densely vegetated areas. Noninvasive methods such as remote cameras, hair snares, and scat surveys are being increasingly used to collect extensive data on carnivore occupancy, distribution, and abundance (Long et al. 2007).

Roadside Counts for Rabbits. Roadside counts are most often used to survey lagomorphs (hares and rabbits) and may be useful for detecting some ungulates and carnivores. When used to survey rabbits, the roadside count generally consists of driving along secondary roads in the evening or early morning and observing the eyes of animals that are reflected from the vehicle's beams or a spotlight. The "eye shine" resulting from the spotlight and subsequent "freeze" of the animal permits easy counting and species identification (Chapman and Willner 1986). The survey should be conducted during the daily peak of rabbit activity because small differences in rabbit numbers may be undetectable when populations are low (Chapman et al. 1982). The method can provide an index to relative abundance and may be used as long as factors such as time of day, time of year, and weather conditions remain constant. Rabbit density estimates can be obtained using mark-recapture techniques or drive counts (Davis and Winstead 1980); however, these methods are labor-intensive and not generally suitable for routine inventories on Corps projects.

Figure 3. Carnivores are difficult to survey for several reasons, including their secretive nature and wariness of humans *(photo courtesy of Mike Watkins)*.

Scat/Fecal Pellet Surveys. Counts of fecal material have traditionally been used in surveys of lagomorphs, carnivores, and some ungulates. Chapman and Willner (1986) found that pellet counts for lagomorphs were more useful for determining habitat preference than for estimating density. Fecal pellet-plot methods have been used extensively in snowshoe hare (*Lepus americanus*) studies, but pellets are subject to variable rates of decomposition (Murray et al. 2005), and snowshoe hare pellet-density relationships may not be constant over large distances and across ecoregions (Homyack et al. 2006). Mills et al. (2005) determined that pellet sampling was more suitable for areas with low hare densities. Also, rabbits and some carnivores often exhibit coprophagic behavior (consumption of feces). Livingston et al. (2005) cautioned that coprophagy and other animal behaviors that result in selective removal of feces may alter findings of population estimates based on fecal analysis. For example, feces may be an important source of food for opossums (*Didelphis virginianus*) and other species (Livingston et al. 2005).

The success of scat surveys to determine presence-absence of carnivores is highly variable dependent on species and habitat conditions. Detector dogs specially trained to locate scat have been used in studies of kit foxes (*Vulpes macrotis*), grizzly bears (*Ursus arctos*), black bears (*U. americanus*), and fishers (*Martes pennanti*) (Harrison 2006). Long et al. (2007) compared the use of cameras, hair snares, and scat detection dogs for detecting black bears, fishers, and bobcats in Vermont, and found that scat detection dogs yielded the highest raw detection rate and probability of detection for each of the target species. Gallant et al. (2007) advised extreme caution when interpreting data from scat surveys to monitor relative population size for certain species, such as river otters (*Lontra canadensis*) due to behavioral characteristics associated with use of latrine sites.

Scent Station Survey. The scent station survey is an indirect technique used to determine species presence and to obtain an index of relative abundance of carnivores and other furbearers (Johnson and Pelton 1981, Warrick and Harris 2001). The technique offers a standardized, repeatable, cost-effective method for inventorying predator populations on large tracts of land, and has been used in many areas to survey populations of bobcat (*Lynx rufus*), coyotes (*Canis latrans*), foxes, raccoons (*Procyon lotor*), opossums, and other mesocarnivores (Conner et al. 1983, Leberg et al. 1983, Leberg and Kennedy 1987). The method basically consists of a lure and tracking medium, usually composed of soft earth or sand (Linhart and Knowlton 1975) or a track plate (Zielinski and Kucera 1995, Zielinski and Stauffer 1996). Appendices A and B provide examples of a scent station survey form and a worksheet for calculating abundance indices. Measurements of relative abundance obtained through scent station surveys are based on the assumption that a consistent relationship exists between visitation rates at the station and actual population density. However, this relationship will vary from survey to survey due to a variety of factors. In most cases, changes in scent station indices must be documented with several years of data before one can reasonably assume that an increase or decrease in the population of a species has occurred. Sargeant et al. (2003) cautioned against the use of cluster sampling (systematic deployment of closely spaced scent stations in lines to reduce travel time and expedite data collection) because it tends to reduce the precision of estimated visitation rates. Also, all species will not be equally attracted to scent stations; for example, Harrison (2006) found that scent station surveys usually resulted in very low detection rates for bobcats. Crooks et al. (2008) used track and camera surveys (discussed below) to provide baseline information on distribution, activity, and habitat associations of mammalian carnivores in Arizona, and determined that the combination of track and camera data was effective in detecting a variety of species in a range of habitat types.

Remote Cameras and Track Plates. Automatically triggered cameras have been deployed to determine presence and estimate density for a variety of species (Cutler and Swann 1999). For example, Zielinski and Kucera (1995) used a combination of remote cameras and carbon-sooted aluminum track plates to monitor populations of American marten (*Martes americana*), fisher, lynx (*Lynx canadensis*), and wolverine (*Gulo gulo*). Hilty and Merenlender (2004) used unbaited, remotely triggered cameras to determine occurrence and compare habitat use of mammalian predators in northern California. Heilbrun et al. (2006) found that automatically triggered cameras provided reliable data on bobcat abundance not previously available without physical capture and radiotelemetry. However, human activity, scent, and the presence of equipment can potentially alter animal behavior and bias results of species photographed. Larrucea et al. (2007) found that the amount of human activity, location of cameras on roads versus trails, and habitat type influenced the number of photo-captures of coyotes at unbaited camera stations in California. Zielinski et al. (2006) concluded that although track plates (and cameras) are better at discriminating species that are readily detectable, neither method can achieve the goal of estimating the population size of target species. Thus, these methods are best used to determine the occurrence and distribution of species in an area. Examples of survey data forms for cameras, track plates, and snow tracking are provided in Appendices C and D (after Zielinski and Kucera 1995).

Hair-snares. Hair-snares (scented devices upon which animals deposit hair) are now commonly used to detect and obtain DNA information on a variety of carnivores such as black bears, brown bears, Canada lynx, bobcat, martens, fishers, coyotes, wolves (*Canis lupus*), and mountain lions (*Puma concolor*). Other mammals such as Woodrats (*Neotoma* spp.), red squirrels (*Tamiasciurus hudsonicus*), and beaver (*Castor canadensis*) have also been detected using hair snares (Zielinski et al. 2006). The method usually consists of stations where hair is snagged with barbed wire or glue in open baited sites or traps (Depue and Ben-David 2007). Zielinski et al. (2006) compared wire and glue hair snares for identifying mesocarnivores in California and found that glue snares were more effective at collecting hair from most species. Downey et al. (2007) stated that hair-snare sampling has become a common practice for assessing the distribution and abundance of felids, but reported that marking by gray foxes (*Urocyon cinereoargenteus*) may interfere with the tendency of felids to face-rub at sampling stations. Harrison (2006) reported that hair snares were not as effective as other methods for detecting bobcats. Depue and Ben-David (2007) found hair-snare traps to be more effective than traditional methods for sampling river otter populations. Zielinski et al. (2006) concluded that with future snare development, both glue and wire snares may prove useful for multi-species inventory. DNA obtained from hair snares has been used successfully to determine distribution patterns and estimate population size for many carnivores, especially bears (Boerson et al. 2003, DeYoung and Honeycutt 2005).

Time-Area Count for Squirrels. Squirrels are extremely difficult to survey, and no method has proven effective under all, or even most, conditions. Observational and trap-success methods have most often been used in squirrel surveys, but most techniques are best suited for intensive, local studies. A combination of techniques may be desirable to obtain the best information for a given area. Mark-recapture methods are frequently used for intensive studies, but they are labor-intensive and not practical for routine surveys (Teaford 1986). The squirrel time-area count is a direct time-lapse census method used to census both eastern gray squirrels (*Sciurus carolinensis*) and fox squirrels (*S. niger*). The technique basically consists of observers positioning themselves in forested habitat and recording the number of squirrels seen during a specific time period. The process is repeated at a series of plots located along a predetermined transect. Although time-area counts have been found to underestimate squirrel populations (Flyger 1959, Bouffard and Hein 1978), they do provide acceptable information for management purposes and have relatively low manpower requirements. Temporal differences in squirrel activity and observer bias can influence counts, and the user should be aware of the following limitations to the technique: (a) not all members of a population are active at the same time, (b) not all active individuals are visible to the observer, and (c) counts made in different cover types, by different observers, or during different seasons may not be comparable (Flyger 1959). Counts of squirrels inhabiting known den sites, artificial nest boxes, and leaf nests are often used to supplement time-area count data.

Surveys of Sign for Aquatic Rodents. Inventories of beaver, muskrats (*Ondatra zibethicus*), and nutria (*Myocaster coypus*) require specialized techniques. The presence of beavers along drainages is generally determined by recording beaver dams, lodges, or cuttings. Beavers that occur in western streams may live in bank dens and not build dams, but their presence should be evident from tree- and shrub-cutting activities. Call (1986) recommended making population estimates of beavers by cruising streams in October or November, counting active colonies (evidenced by food caches and repairs on dams and visible lodges), and multiplying the number by five. Aerial surveys of food caches and lodges may be required in backwater areas and relatively inaccessible drainages. Muskrat surveys often consist of counting the number of houses in a marsh, which can be used as an index to the population. However, muskrats construct different types of lodges (Dozier 1953, MacArthur and Aleksiuk 1979), and surveyors must be able to distinguish between active and inactive houses, and between feeding and dwelling lodges. Detecting the presence of muskrats that live along streams and use bank burrows is more difficult. Their occurrence in these areas is best detected by cuttings of vegetation on which they feed (Call 1986). Trapper surveys are often used to provide information that can help managers obtain a general estimate of beaver and muskrat populations.

The nutria or coypu is a large aquatic rodent native to South America that has been introduced throughout the United States and in many other countries (Carter and Leonard 2002, Bertolino et al. 2005). Nutria cause damage to water control structures, crops, and marshlands, and are considered a disease host (Carter et al. 1999, Carter and Leonard 2002), thus monitoring their populations and activity has become an important part of management and control programs in areas where the species is abundant. Mark-recapture, direct observation, tagging methods, and radiotelemetry have been used to monitor nutria activity (Nolfo and Hammond 2006, Myer 2006), but most monitoring practices are labor intensive and have met with limited success. Nevertheless, project managers should arrange to have routine observations made in wetland areas to detect increases in nutria populations.

TECHNIQUES FOR SMALL MAMMALS: A variety of techniques are used to inventory small mammal populations as part of research projects, but some methods may be too costly and labor intensive for routine inventories on Corps projects. Call (1986) stated that there are few situations that require information other than species occurrence and relative abundance of rodents and insectivores for Federal land management programs. Exceptions include inventories needed for federal or state protected or sensitive species, surveys of species that serve as an important prey base for raptors or carnivores whose numbers are critical or declining in a region, and population estimates needed for species of economic or social value. Small mammal surveys may also be needed for mitigation purposes or when habitat enhancement is a project objective.

Investigators should use extreme caution when interpreting the results of mammal surveys. All individuals in a project area are rarely captured when surveying small mammals, thus estimates of population size based on capture data may not be reliable (Slade and Blair 2000, Hopkins and Kennedy 2004). Nichols and Conroy (1996) stated that trapping methods can provide satisfactory results for temporal and spatial comparisons of abundance for a single species but may not be reliable for providing comparative information about species richness. However, Hopkins and Kennedy (2004) reported that measures of relative abundance provided patterns of population trends proportional to those derived from estimates of absolute abundance. The manager should make every effort to select appropriate sampling techniques and ensure adequate replication through time to help eliminate bias and provide results that can be used for management decisions.

Trapline Transects. Surveys of most rodents and some insectivores can be accomplished by systematic trapping along transects. Occurrence of species within different vegetative communities can be determined by setting an appropriate number of traps within the interior of each community and along edges. Trapping results will provide information on species presence and relative abundance of species within each habitat type. An estimate of population density may also be possible if certain designs are used and appropriate statistical analyses are factored into the sampling effort. The following guidelines apply generally to small mammal surveys where trapping methods are used.

- Describe vegetation communities and soil types at sample locations. If habitat types are to be compared, an appropriate number of traps should be set in each community.

- Establish transects within each vegetation community. Each transect usually consists of trap stations that are 15 m apart but this may vary with terrain features and target species. The transect length can vary, but 15 stations are usually adequate. Call (1986) recommended establishing a series of grids for sampling; however, this would not be necessary if the objective of the survey is to simply obtain presence/absence information. Figure 4 shows trapline transects established to compare rodent use of upland and riparian habitats on White Sands Missile Range, New Mexico (Martin et al. 2004). Trap placement will depend on a variety of factors, including sample objectives, terrain features, and habitat conditions. For example, Manley et al. (2005) placed extra-long traps 15 m apart and down the center of a sample hexagon for presence-absence monitoring in the central Sierra Nevada region.

- Set traps at each station. It is best to set at least two traps at each station because different species will be active at different times of the night. "Sherman live-traps" are recommended if specimens are to be released after capture (Jones et al. 1996), but some species are difficult to catch with live traps. Therefore, depending on the objectives of the survey, there may also be a need to use snap traps, such as “museum specials” or “Victor rat traps.” Extra large live-traps can be used to increase capture rates of larger-bodied squirrels (Slade et al. 1993).

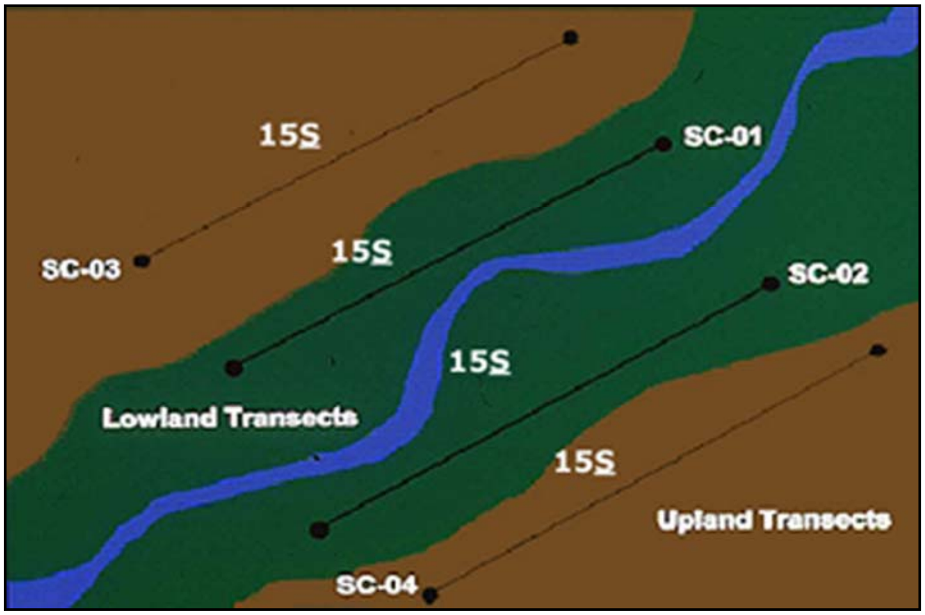


Figure 4. Trapline transects designed to compare rodent use of riparian and adjacent upland habitats.

- Trap baits are variable and some experimentation may be required to determine what works best. Common baits often include rolled oats and peanut butter or grains and seed mixtures. Cotton can be placed in traps to insulate captured animals from cooler temperatures. This is necessary in some areas to prevent mortality.

- Set the traps in early evening and check them every hour until midnight, if possible. This will allow removal of most of the easily caught animals and increase the chance of catching less abundant or more trap-shy animals for the rest of the night. Set the traps again at midnight and leave them until morning. Timing may need to be modified if trap lines are set at remote locations or if they are located far apart. Often it is only possible to open and bait traps in the early evening and check them the following morning. Traps should always be closed during the day unless a survey objective is to trap diurnal rodents.

- Trap-lines should be run for at least two consecutive nights, and preferably three consecutive nights, if possible.

- Tabulate all captures by species, sex, and age (sub-adult or adult). If needed, standard measurements (including total length, tail length, hind foot length, ear length, and weight) can also be obtained and information can be recorded on reproductive conditions. Catches will usually be expressed as numbers of each species per number of trap nights. If the same trapping design is used in different communities, species and relative density can be compared among different community types.

The field biologist should be aware that the above recommendations will often have to be modified because of costs, manpower constraints, and logistical problems. For example, although sampling for three consecutive nights is desirable, it may be more important to sample a greater number of sites than to obtain a third replicate. Extreme care should be taken when interpreting the results of small mammal surveys. The best results will be obtained when surveys can be conducted during several seasons for at least three consecutive years using the same crew. However, this may not be feasible for routine natural resource inventories. Surveys conducted with less intensity are best used only to provide a general estimate of species presence or non-presence within broad habitat types, but it should be realized that absence cannot be absolutely determined without a considerable amount of effort. Mackenzie (2006) and Strickland and McDonald (2006) emphasized that a major concern with using presence-absence data is that an animal may be declared absent from an area because the animal is not detected, not because it is actually absent, and hence could result in erroneous management decisions. Jones et al. (1996) recommended 500 trap nights/habitat as a minimum for determining presence-absence for inventory purposes, but this may vary according to region.

Factors that can affect conclusions drawn from sampling small mammal communities include trap type, trap arrangement and location, trapping method, and type of bait used (Osbourne et al. 2005). There is considerable disagreement in the literature regarding the success of transect versus grid trapping for sampling rodent communities. Pearson and Ruggiero (2003) found that transects resulted in more total captures of small mammals, more individuals of abundant species, and greater species richness compared to grids. Although grids provide better spatial resolution for estimating population density, home ranges, and dispersion, transects provide better information on community composition and habitat relationships (Pearson and Ruggiero 2003). Jones et al. (1996) stated that the easiest way to array traps is along a transect and recommended this procedure for inventory of small terrestrial mammals. However, transect sampling is not suitable for density estimation under most circumstances (Jones et al. 1996).

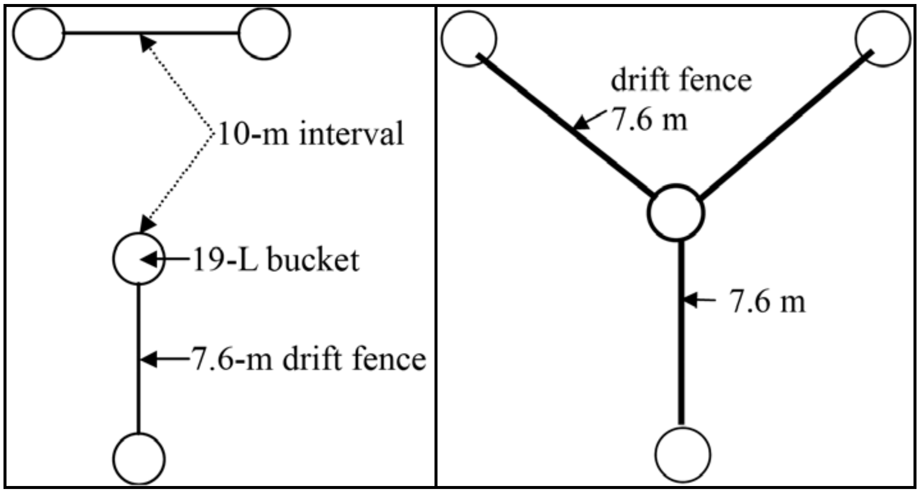
The Sherman live trap and the Longworth trap are probably the most widely used commercial traps for sampling small mammals (Anthony et al. 2005). The Longworth trap is a two-piece model consisting of a nesting-chamber box attached to a tunnel with a treadle. The Sherman live trap is a simple folding box trap that operates on a door-and-treadle system and is available in several sizes (Figure 5). Trap type and arrangement will depend on specific objectives of the survey. For example, Moore and Swihart (2005) used a combination of Sherman, Fitch, and

Tomahawk live traps set in grid patterns to assess habitat occupancy in forest patches in modified landscapes in Indiana. Tomahawk live traps set in a grid with 50-m spacing between points were installed 1.5 m high on trunks of large trees to sample northern flying squirrels (*Glaucomys sabrinus*) in California (Meyer et al. 2005). Guilfoyle (2006) established grid points and trap lines on Corps project lands to obtain estimates of relative abundance and diversity of small mammals in Habitat Management Units (HMUs) in eastern Washington. Trap lines consisted of four trap stations with five traps set per station. Each HMU was sampled for at least three nights so that a minimum of 500 trap nights per habitat was obtained (Guilfoyle 2006).

Figure 5. Sherman live traps are commonly used to sample small mammals *(photo courtesy of Mandy Like)*.

Pitfall Traps. In some areas shrews and moles are difficult to capture with snap traps or live traps baited with rolled oats or grain. One of the most effective methods for collecting shrews and some rodents is through the use of pitfall traps, commonly used to sample reptile and amphibian populations. The technique basically consists of sinking a series of buckets in the ground in strategic locations, and often includes placement of plastic or metal flashing (referred to as a drift fence) to funnel animals into the buckets. For best results, buckets used for collecting insectivores should hold more than 1 gallon and have a round aperture in the center, which will help reduce the possibility of escape. Setting up a trapping array with either three or four arms (extensions of flashing material, Figure 6) will capture shrews and some other small mammals in most areas. Trapping arrays should be set so that each bucket is connected by a drift fence of wire mesh or tin about 25.4 cm high and set 3-4 cm into the substrate (Call 1986). Various pitfall designs for sampling small mammals are described in Bury and Corn (1987) and Mengak and Guynn (1987).

Bury and Corn (1987) determined that pitfall trapping had several advantages over traditional traplines and that data obtained from pitfalls could be used to assess species presence and relative abundance among forest stands. Osbourne et al. (2005) collected 20 species of mammals in West Virginia using pitfall traps set in upland, edge, and riparian habitats; they concluded that sampling for inventory and monitoring purposes should be stratified by edge and interior locations to provide the best representation of diversity and abundance of small-mammal populations. A major disadvantage of pitfall trapping is that it is labor intensive and some species are not easily captured in pitfall traps; however, once installed they can be run with minimal effort. Another concern is that animals held in pits may become easy meals for snakes and other



Split-T array configuration **Y array configuration**

Figure 6. Trapping arrays used for pitfall traps.

predators, but this can be minimized by checking traps frequently during the evening. Ferguson et al. (2008) detected 10 predator species visiting pitfall arrays in south-central Texas, with the raccoon being the most frequently recorded species.

SUMMARY AND CONCLUSIONS: Thorough Level II inventories of mammals on Corps project lands will generally require the application of a variety of methods. As much as possible, techniques should be selected that obtain data for a variety of species (e.g., scent stations, track plates, hair snares, den surveys, transect surveys) rather than single species. Unless there is a need to obtain population data, methods that are most efficient at determining presence/non-presence should be selected. Level II mammal surveys will often need to be contracted out because conducting the surveys will require a commitment of time and labor that may be beyond the capability of project personnel.

Game species are generally surveyed annually by state wildlife biologists, and any method used to inventory these species should be coordinated with the appropriate state agency. Big game animals are often surveyed by state biologists using aerial counts from fixed-wing aircraft. Other traditional methods for large and medium-sized mammals include drive counts, spotlight counts, pellet group counts, mark-recapture techniques, harvest data, and browse surveys. However, many techniques designed to obtain census data are beyond the capability of project personnel and may only be needed for specific situations. Radio-telemetry and TIR imagery are increasingly being used to monitor populations of large mammals. Infrared-triggered cameras (ITCs) are a rapidly developing technology that may provide a viable alternative to wildlife managers because they can be economically used within a random or systematic sampling design (Roberts et al. 2006).

Carnivores are often difficult to inventory because of their secretive nature, relatively low densities, nonrandom distribution of populations, mobility, and wariness of human activity. Survey methods often used for carnivores include mark-recapture techniques, aerial surveys, bounty and harvest records, road kills, predator calls, and counts of sign. Noninvasive methods (e.g., remote cameras, hair snares, track plates, scat surveys) are being increasingly used for carnivore surveys. Each of these methods offers certain advantages, but results may vary from survey to survey due to a variety of factors. Automatically triggered cameras have been used to determine presence and estimate density for a variety of species, but human activity, scent, and the presence of equipment can alter animal behavior and bias results.

Surveys of small mammals can generally be accomplished by systematic trapping along transects. Occurrence of species within different habitat types can be determined by setting an appropriate number of traps within the interior of each community and along edges. Transects usually consist of trap stations 15 m apart, but this may vary with terrain features; transect length can vary, but 15 stations per transect is usually adequate. Sherman live traps are recommended unless there is a need to collect voucher specimens. Trap-lines should be run for at least two consecutive nights, and preferably three consecutive nights, if possible. However, it may be more important to sample a greater number of sights than to obtain a third replicate. The best results will be obtained when surveys can be conducted during several seasons for at least three consecutive years by the same crew. Pitfall traps are necessary for capturing some species, especially shrews. Thus, it may be best to use a combination of standard trap stations and pitfall traps to obtain complete information on the occurrence of small mammals on an area.

ACKNOWLEDGEMENTS: Thanks are extended to the Ecosystem Management and Restoration Research Program and the Stewardship Advisory Team for supporting this work. Manuscript review was provided by Drs. Michael P. Guilfoyle, Richard A. Fischer, Richard F. Lance, and Eric R. Britzke, Environmental Laboratory (EL), ERDC. Mandy E. Like, Sphere 3 Environmental, assisted with figures and graphics. Michael Watkins, Kansas City District, provided selected photographs.

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> Martin, C. O. 2009. "Mammalian survey techniques for Level II natural resource inventories on Corps of Engineers projects (Part I)," *EMMRP Technical Notes Collection* (ERDC TN-EMRRP-SI-34), U.S. Army Engineer Research and Development Center, Vicksburg, MS.

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Appendix A
Scent Station Survey Form

Observer(s):____ Date: _________________________

Route/Transect:_________________ Compartment:__________________ Stand: __________________

Name of Area (if any): ____

Weather on Night of Operation: ____

Species Identified at Scent Station							
	Red Fox	Gray Fox	Fox sp.	Coyote	Bobcat	Other(s)	Habitat
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

Instructions: Place an X in the box of each species that can be positively identified at the scent station. If red and gray fox tracks cannot be differentiated, place an X in the Fox sp. column. Write the names of other species in the space provided. Record only species whose tracks you can positively identify. If the station is disturbed by weather or other causes, consider it inoperable and record “IN” next to the station number. Record the dominant habitat types(s) where the scent station is located in the last column. Use the following habitat codes: LS = pine; OGC = bottomland hardwoods; OH = upland hardwoods; OP = mixed pine-hardwoods; TBH = shrub flats; AG = cropland; PA = pasture; OF = old field. More than one habitat type may apply. For example, if the station is on the edge of an old field next to a stand of bottomland hardwoods, record OF/OGC. The first abbreviation should be the habitat type in which the station is actually located.

Appendix B
Worksheet for Calculating Annual Abundance Indices Using Scent Station Data

Project:____ Date:________________________________

Compartment:___________________________________ Transect: ____________________________

Prepared by: ____

Species	Total Number of Stations Visited by Species	Total Number of Operable Stations	Total Number of Stations Visited/Total Number of Operable Stations	Abund. Index TNSVx1000 TNOS
Red Fox				
Gray Fox				
Coyote				
Bobcat				
Raccoon				
Opossum				
Rabbit				
Dog				
Armadillo				
Skunk				
Deer				
Other				

Appendix C
Survey Record Form for Camera, Track Plate, and Snow Track Sampling

Survey Type:

CAMERA__________________ TRACK PLATE_____________ SNOW TRACKING _____________

Line Trigger_____________ Enclosed_____________________ Searching for tracks_________

Single Sensor____________ Unenclosed___________________ Tracking at bait ____________

Dual Sensor_____________

Other__________________

SAMPLE UNIT NUMBER_________________

Number of Stations________________ or Distance searching for tracks ______________________

State_____________________ County______________________ Landowner_____________________

Location____ USGS Quad _________________________

Legal: T__________ R__________ S__________ , __________ , __________ , __________________ .

STATION LOCATIONS: UTM Zone ______________________________________

Station ID	UTM N/S	UTM E/W	Elevation (ft/m)

Vegetation type (s) ____

Date installed (or run)_______________________ Date Terminated _____________________________

Type of bait or scent ____

Name, address, and phone of investigator ____

____

____

* After Zielinski and Kucera (1995)

Appendix D
Track Plate Data Worksheet*

Observer________________ Weather[a]________________ Date_______________ Page_____ of______

Location ____

General Comments ____

Station Number	Visit Number	Nights since last visit	Target Species[b]	Other tracks of interest	Comments[c]

[a] Use the following codes: 1 = No precipitation since last visit; 2 = rain, snow, or heavy fog since last visit.

[b] Record the four-letter species code in pencil (e.g. MAAM, for marten) until identity is confirmed.

[c] E.g. box rolled, feces collected, bait removed, bait desiccated

* After Zielinski and Kucera (1995)