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**Pacific Southwest
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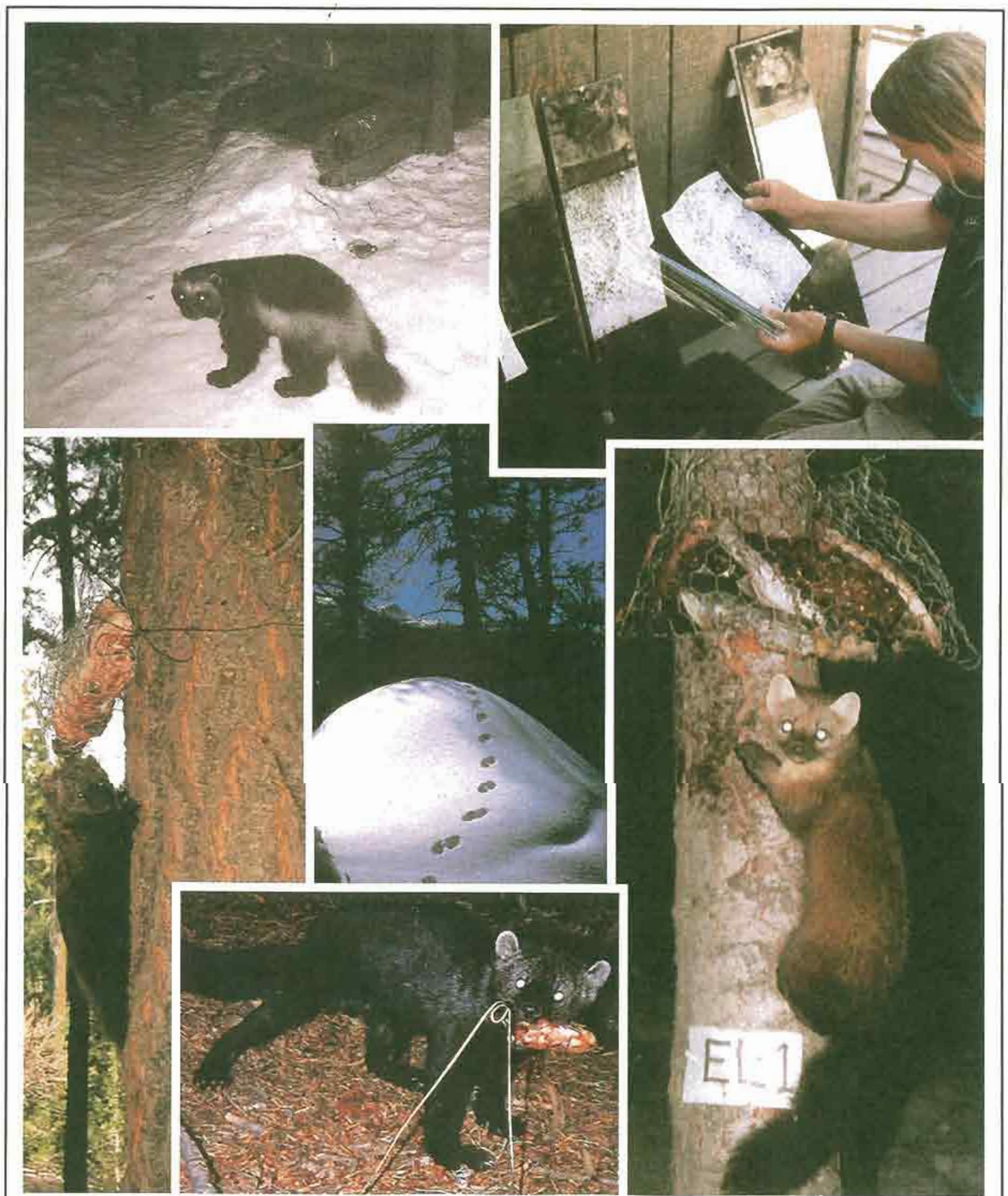
PSW-GTR-157

American Marten, Fisher, Lynx, and Wolverine: Survey Methods for Their Detection

William J. Zielinski **Thomas E. Kucera**



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Abstract

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The status of the American marten (*Martes americana*), fisher (*Martes pennanti*), lynx (*Lynx canadensis*), and wolverine (*Gulo gulo*) is of increasing concern to managers and conservationists in much of the western United States. Because these species are protected throughout much of their range in the west, information on population status and trends is unavailable from trapping records. This report describes methods to detect the four species using either remote photography, track plates, or snow tracking. A strategy for systematic sampling and advice on the number of devices used, their deployment, and the minimum sampling duration for each sampling unit are provided. A method for the disposition of survey data is recommended such that the collective results of multiple surveys can describe regional distribution patterns over time. The report describes survey methods for detection only but also provides some considerations for their use to monitor population change.

Retrieval Terms: furbearers, forest carnivores, survey methods, monitoring, inventory, western United States

Technical Editors

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Cover: photos by **Jeff Copeland** (upper left, wolverine); **Bill Zielinski** (upper right, technician with track plates; and bottom center, fisher with chicken and wire); **Tom Kucera** (lower right, marten on tree); **Sue Anderson** (lower left, fisher on side of tree); and **Christina Hargis** (middle center, snow tracks).

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Contents

Preface

The American marten (*Martes americana*), fisher (*Martes pennanti*), lynx (*Lynx canadensis*), and wolverine (*Gulo gulo*) are forest carnivores that are indicators of healthy forest ecosystems. Like the wolf (*Canis lupus*) and the grizzly bear (*Ursus arctos*), they are mammals that are associated with wild places. In this century the distributions of these species have contracted considerably and they no longer occur throughout much of their historic range in the western United States. Habitat loss through timber harvest and residential development, increased roading of forests, and these species' susceptibility to trapping and general sensitivity to human disturbance have been implicated in the decline of one or more of them. One of the most sensitive measures of the integrity of natural ecosystems is whether populations of tertiary consumers, like the four species considered in this publication, occur in an area and can be sustained there. Therefore, assessing the presence of these species is an essential part of determining the health of forest ecosystems.

Recently, petitions have been submitted to list three of these four species as threatened or endangered in the western United States, under the Federal Endangered Species Act. Various State and Federal agencies have designated them as "management indicator," "sensitive," and "species of special concern." In addition, increased public awareness of the ecological roles of lynx, wolverines, fishers, and martens has highlighted the need to understand their ecology and biogeography. The presence of these animals has been difficult to verify where they are not commercially harvested. Until recently most of the information about their presence came from commercial trapping records and compilations of sightings. However, since the mid-1980's a number of non-lethal detection methods have been developed (or refined) that reliably detect the presence of each of these uncommon species. Unlike data from sporadic, unverified sightings, these methods produce evidence that can be independently corroborated by specialists. We recommend and describe the use of three methods: photographic bait stations, track-plate stations, and snow tracking. We provide protocols for the use of each method. These protocols enable local biologists to choose among these methods, based on their objectives, funding, personnel, previous experience, and the reliability of snowfall. A minimum amount of effort is recommended for each method. We assume this effort is equivalent among methods and is sufficient to determine the presence of target species in a survey area during the survey period. In addition, we suggest a method for allocating survey effort across large geographic areas so that results can be aggregated into general maps of each species' distribution in an area of interest. Although we do not describe methods for monitoring the status or trend in population abundance, we provide background for those who would attempt to do so using the detection methods described here.

We thank the Western Forest Carnivore Committee, and especially Bill Ruediger, for recognizing the need for and securing much of the funding for the writing of this manual. Funds or staff were contributed by Regions 1, 5, and 6, and the Pacific Southwest Research Station of the USDA Forest Service; the USDI Bureau of Land Management - Idaho; Washington Department of Fish and Game; Montana Department of Fish, Wildlife, and Parks; Colorado Division of Wildlife; and the Department of Environmental Science, Policy and Management of the University of California, Berkeley. These funds were made available with the assistance of Bill Ruediger, Bob Naney, Gary Will, Brian Giddings, Diane Macfarlane, Linda Parker, Jim and Judy Oterman, Judy Sheppard, Allen Thomas, Dave Ware, and Reginald Barrett. Many of the photographic methods were refined during work funded by the California Department of Fish and Game, and Region 5 of the USDA Forest Service, with the assistance of Ron

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Many reviewers contributed their thoughtful evaluations to various chapters. Diane Macfarlane read the entire manuscript and we are grateful for her editorial assistance. Howard Golden, Kerry Murphy, Lee Fitzhugh, Louise Forrest, Harley Shaw, and Jay Tischendorf reviewed Chapters 1 and 2, and the snow tracking chapter (Chapter 5). Jeff Copeland, Leslie Chow, and Lawrence Jones reviewed Chapters 1 and 2, and the camera chapter (Chapter 3). Kristin Schmidt, Diane Macfarlane, and Keith Aubry reviewed Chapters 1 and 2, and the track plate chapter (Chapter 4). Kerry Foresman also contributed comments on various portions of the manual. Norm Bishop, Jeff Copeland, Greg Gordon, Nan Lederer, and Bruce Thompson contributed either slides or unpublished data to the snow tracking chapter. Biologists from the Klamath National Forest, in California, were helpful in their willingness to test the recommended survey methods and use our draft data forms. Each chapter was significantly improved by including what they learned. We especially thank Sue Anderson and Kathy Nickell for their cooperation. We gratefully acknowledge the time and careful thought that all these individuals contributed.

We extend a special thanks to Annette Albert for providing primary editorial assistance during all phases of the project. Annette, with the help of Garth Hodgson, also created many of the illustrations. Finally, we wish to acknowledge the persistence and creativity of the field biologists from Federal, State, and private organizations who have contributed to the evolution and refinement of the methods we chose to describe. We expect that their efforts will lead to even better survey methods in the future.

Introduction to Detection and Survey Methods

William J. Zielinski[1] and Thomás E. Kucera[2]

Background

The integrity of an ecosystem may be measured by the health of its vertebrate carnivore populations. Carnivores influence the structure and reflect the vigor of trophic levels on which they depend, and are sensitive to the abundance and behavior of the human populations with which they coexist (Eisenberg 1989). Concern for the conservation of mammalian carnivores in the western United States has centered on two large species, the gray wolf (*Canis lupus*) and the grizzly bear (*Ursus arctos*). The public is well acquainted with the plight of these species; a wealth of popular literature on their natural history and a long tradition of folk knowledge have built a foundation of awareness. In contrast, the four species that we address in this manual, the American marten (*Martes americana*), fisher (*Martes pennanti*), lynx (*Lynx canadensis*), and wolverine (*Gulo gulo*) (henceforth collectively referred to as MFLW), are no less important constituents of their biological communities than the wolf or grizzly bear, but much less familiar.

Fortunately, MFLW have begun to emerge from the shadows of public and scientific awareness (Kucera and Zielinski 1995). In the past 7 years in the Pacific Southwest Region of the USDA Forest Service, 58 actions such as timber sale appeals, lawsuits, and Freedom of Information Act requests were filed concerning the marten, 54 concerning the fisher, and 20 concerning the wolverine (lynx do not occur in California). Each species is receiving increased levels of administrative and legal protection. The wolverine is a "candidate" for Federal listing under the Endangered Species Act (Category 2 [C2]) in nine States, and listed as either "State Endangered" (SE) or "State Threatened" (ST) in three of them. A C2 designation indicates that more information is necessary to support a listing decision by the Fish and Wildlife Service (USFWS), U.S. Department of Interior. The lynx is a C2 species in nine states and either SE or ST in two states. The fisher is a C2 species in three states and SE or ST in two. The marten has no Federal status, but is SE in New Mexico. Each species is also listed as either "Sensitive" or as a "Management Indicator Species," as provided for in the National Forest Management Act, on most National Forests throughout its range (Macfarlane 1994). Sensitive species are those whose population viability is a concern because of significant current or predicted downward trend in abundance or habitat capability (Forest Service Manual 2670.32). Management Indicator Species are used by National Forests to reflect how particular habitats or habitat elements respond to management activities (Forest Service Manual 2670.5).

In the early 1990's the Fish and Wildlife Service (USFWS) was petitioned to list the fisher as "Endangered" in California, Oregon, and Washington under the Endangered Species Act (Central Sierra Audubon Society and others 1990), and the lynx was petitioned to be listed in Washington (Greater Ecosystem Alliance and others 1991). Both petitions were denied on the basis of inadequate information (U.S. Department of Interior, Fish and Wildlife Service 1991, 1992). Recently the USFWS was again petitioned to list both species, this time throughout their ranges in the western United

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States (Biodiversity Legal Foundation 1994a, 1994b). The lynx petition was denied again (U.S. Department of Interior, Fish and Wildlife Service 1994), and the fisher decision is pending. A petition to list the wolverine as "Endangered" in the contiguous 48 United States (Biodiversity Legal Foundation 1994c) also was denied (U.S. Department of Interior, Fish and Wildlife Service 1995). The Natural Resources Defense Council challenged the USDA Forest Service in California to suspend logging of late-successional forests until a plan to ensure the viability of forest carnivore populations is in place (Yassa and Edelson 1994). The first major conference on the biology of martens and fishers occurred in 1991 (Buskirk and others 1994), and in the same year the Western Forest Carnivore Committee, an interagency group of managers and scientists, was created to address the conservation needs of MFLW. Recently, a conservation assessment was conducted for the four species considered here to evaluate the state of our knowledge on their ecology and to consider the management implications of this information (Ruggiero and others 1994). The second conference on the biology of martens and fishers occurred in 1995.

The list above indicates that managers, administrators, and citizens of many western states are concerned about the status of MFLW. This concern stems from the possible deleterious effect of trapping and from habitat loss. Several investigators suspect that the accelerated harvest of old-growth forest has reduced, in particular, the populations of fisher and marten (Buskirk and Ruggiero 1994, Powell and Zielinski 1994) and that human encroachment on the range of the wolverine has reduced its numbers (Banci 1994). There is growing consensus that the southern portions of these species' historic ranges in the western United States have recently contracted (Douglas and Strickland 1987, Gibilisco 1994, Maj and Garton 1994, Nead and Halfpenny 1985, Ruggiero and others 1994, Weaver 1993).

The relative obscurity of MFLW and the logistical and financial difficulty of studying them may explain why so little is known about their biology and the effect of land-use changes on their populations. These species occur at low densities, are primarily nocturnal, have inconspicuous mating behavior, leave little sign, and shun human activity. Unless they are commercially harvested by trapping, their presence will often go unnoticed. In addition, managers may have assumed that carefully regulated trapping programs would monitor the distribution of each species and detect declining populations. Whether this was ever possible is now moot; collectively, MFLW are no longer a significant part of the fur harvest in the conterminous western United States. Changing public attitudes regarding trapping, poorly regulated harvests, and suspicions about excessive mortality from commercial harvest have contributed to the closure or restriction of trapping seasons. MFLW are legally trapped in only a few (one, lynx; two, wolverines; two, fisher; six, marten) of the seven western States, excluding Alaska, and quotas have been as low as two per State (Ruggiero and others 1994). It is likely that none of these species, with the possible exception of marten, will continue to be commercially harvested in the western conterminous United States for long.

Historically, MFLW occurred throughout northern North America including mountainous regions of the western United States (Gibilisco 1994, Grinnell and others 1937, Hagmeier 1956, Koehler and Aubry 1994), but none occupies all of its recent historical range (Banci 1994, Douglas and Strickland 1987, Gibilisco 1994, Koehler and Aubry 1994, Kucera and others 1995, Nead and Halfpenny 1985, Zielinski and others 1995). In the western United States, most of the range of MFLW occurs within the Rocky Mountains, the Cascade Range, the Coast Range, and the Sierra Nevada. Within these regions all four species are associated with coniferous forest ecosystems. Marten and fisher occur primarily in late-successional forests (Buskirk and Powell 1994), lynx are associated with a variety of seral stages (Koehler and Aubry 1994), and the wolverine inhabits areas with a mixture of forested and non-forested habitats (Banci 1994, Hash 1987, Hatler 1989). All are primarily carnivorous. Marten and fisher eat predominantly small- to medium-sized mammals (e.g., rodents and lagomorphs) (Douglas and Strickland 1987, Martin 1994, Strickland and Douglas 1987). Lynx prey largely on snowshoe hares (*Lepus americanus*) (Koehler and Aubry 1994), and wolverines depend mostly on carrion, especially that of ungulates (Hornocker and Hash 1981).

In sum, these species have similar habitat associations, are sympatric over much of their range, often occur at low densities, have relatively low reproductive potentials, occupy somewhat similar niches in their respective communities, and may be affected in similar ways by human land-use practices. Range-wide, the densities of martens, fishers, lynx, and wolverines have been reported as low as one individual for every 2.5, 20.0, 200.0, and 700 km^2, respectively (Arthur and others 1989, Banci 1987, Nellis and others 1972, Thompson and Colgan 1987). In addition, each frequently occurs in small, scattered subpopulations, making them especially vulnerable to extirpation (Gilpin and Hanski 1991, Weaver 1993). For these reasons, it is appropriate to consider detection and survey methods collectively for these four species. Moreover, we recognize the need to focus whenever possible on collective components of ecosystems rather than individual species.

Recent developments in the field of conservation biology suggest that we can no longer assume that the existing distribution of National Parks, and the prevailing management on National Forests, will guarantee the long-term persistence of large vertebrate populations (Newmark 1985, 1987; Salwasser and others 1987). Reserves cannot be created that are large enough to permit the persistence of MFLW populations; the multiple-use lands between reserves must also be managed with the conservation of these species in mind. Moreover, populations of lynx and wolverine in particular may depend on source populations in Canada; thus, conservation efforts must consider connectivity of habitat between the United States and southern Canada (Hatler 1989, Ruggiero and others 1994, Weaver 1993). Eventually, a spatially explicit conservation strategy should be developed for these species. This must include all land management agencies in western North America and model the viability of each species and population throughout the region. An initial step taken by the USDA Forest Service was a conservation assessment for MFLW that summarizes existing information and suggests research needs (Ruggiero and others 1994). In addition, general hierarchical guidelines for the conservation of fisher have been proposed for the western United States (Heinemeyer and Jones 1994). One of the key information needs identified in these documents is knowledge of the present geographic distribution of each species. Because commercial trapping is no longer a source of data on the distribution of these species, a new approach to the acquisition of distributional data must be developed.

Developing new methods to collect distributional data is a logistically and financially challenging problem, but it must be addressed and it must begin now. It is essential for several purposes: (1) to develop a contemporary benchmark for the geographic distribution of each species, (2) to generate data for habitat-relations models, (3) to evaluate the effects of land-use changes (e.g., timber harvest, mining, recreation) on populations, (4) to evaluate the effects of human density and disturbance on distribution, (5) to relate species occurrence to landscape physiognomy and composition (Fahrig 1988, Pulliam and others 1992), (6) to collect information that will assist the development of spatially explicit population viability models (e.g., Thomas and others 1990), (7) as an essential step in the development of a population-monitoring program, and (8) to assist in determining the necessity of protecting any of the species under the Endangered Species Act.

Others have addressed the issues of inventory and surveying populations of the carnivores considered here (Jones and Raphael 1993, Raphael 1994, Spowart and Samson 1986). However, they either address a particular technique or species or describe the issues in a general fashion. We hope that the present manual will facilitate the collection of distribution data for all four species in a standardized fashion, using methods that can be tailored to the local environment and particular target species. For this reason we expect it to be an important step toward addressing all of the objectives described above.

Species Detection

This publication is designed to help resource managers detect the *presence* of lynx, wolverines, fishers, and martens by using standardized, non-lethal methods. It should allow a biologist to conduct a search for MFLW that will provide reasonable assurance that the species are not present if they are not detected. However, until additional research is conducted on the probabilities of detecting individuals known to occur in an area, "failing to detect" should not be the same as concluding "absent" (see section on "Interpretation," below).

If the target species is detected, the location of the detection and the habitat features associated with it should become part of a larger database that includes all sites where each species was detected. Thus, detection efforts, if conducted in a standardized fashion, can describe the distribution of a species throughout a region of interest (see Chapter 2, "Definition and Distribution of Sample Units").

We describe three methods: cameras, sooted track plates, and snow tracking. Each offers ease of use, effectiveness, and economy. For each method we provide, in "cookbook" fashion, information about how to acquire or build the components and a protocol for using the method and recording the data collected. We do not recommend a particular method for a particular circumstance or geographic region. Instead, we describe the contexts in which each method works best, estimate the costs, and allow the biologist planning the survey to choose among the three techniques.

We considered other techniques such as habitat surveys, live trapping, and hair snares but decided not to include them in this manual. Habitat surveys are based on the assumption that habitat suitability is sufficiently well known that we can create a model that relates habitat attributes to species' presence. Unfortunately, existing models have had little testing, and factors other than habitat quality frequently affect distribution (Raphael 1994). Live trapping is uneconomical, given the low capture rates per unit effort for the species considered here. Snares that collect a sample of hair from individuals that visit a bait (e.g., Barrett 1983, Scotts and Craig 1988) are relatively inefficient, and species are not always readily identifiable by individual hairs (Fowler and Golightly 1993, Raphael 1994). However, DNA fingerprinting, which can determine the identity of species and individuals from DNA in cells at the base of the hair (e.g., Morin and others 1994), may soon resolve this issue. Individual marten have been identified using DNA extracted from hair collected from wooden "cubbies" lined with a sticky snaring medium (Minta and Heinemeyer 1995). Consequently, hair collected at station locations or encountered while snow tracking should be saved for future analysis.

It is important to emphasize that we recommend the use of the three methods for *detection only*. We assume here that the primary objective of a biologist responsible for the management of these species is to determine *whether* they occur in a particular locale and *where* they occur within the area. We refer to these as "Regional Surveys." Beyond this, biologists often are called upon to determine whether MFLW occur within a proposed management activity area ("Project Surveys"). This manual provides information on how to use standard methods to conduct both types of survey. Two of the chapters introduce detection methods that depend on "devices" (track plates and cameras); the final chapter describes snow tracking, which does not require a detection device.

Differences Among Survey Methods

No study has compared all of the methods and types of devices described in this manual, and therefore we cannot contrast their relative efficiencies. However, the methods differ in the following respects: the seasons during which they can be used, difficulty of identifying sign, amount of training necessary, labor and material costs, and whether they have successfully detected each species (*table 1*). No single method is better than the others in all categories (Raphael 1994).

Snow tracking and cameras have successfully detected all four species. Track plates have detected only fisher and marten. This is probably because track-plate boxes have not been enlarged to accommodate the larger species, and neither enclosed or unenclosed plates have received as widespread use in the western United States as the other methods. Because bobcats (*Lynx rufus*) have been detected at track plates, we know that felids can be attracted to the baits and will enter the boxes. Snow tracking, track plates, and line-triggered camera systems have the disadvantage of being limited to specific seasons. In addition, the difficulty of identifying the sign of the four species is greater for track-based methods than camera methods because images of the entire animal are almost always easier to identify than tracks. The extent of training necessary to use snow tracking and cameras successfully is greater than that required for track plates. Moreover, any method used in winter requires more training (for safety and travel) than methods used during other seasons.

Although cameras are technically challenging and snow tracking requires extensive experience to conduct properly, track-plate surveys are simple by comparison. A record of the sign from enclosed track plates is easier to retrieve from the field and provide to another individual for identification than is the information provided in a snow track. The 35-mm cameras are the least labor intensive because, unlike the other methods,

Table 1—*Methods described in this publication and characteristics of their use for the detection of lynx, wolverines, fishers, and martens.*

Methods	Target species detected using the method[1]	Seasons of use	Difficulty of verifying identity	Amount of training necessary to use method	Labor intensity	Cost of materials
Cameras						
Line triggered	F, M	Summer primarily	Low	Moderate	Moderate	Low
Dual sensor	W, L, F, M	Summer and winter	Low	Moderate	Low	High
Single sensor	L, F, M	Summer and winter	Low	Moderate	Low	High
Track Plates						
Box-enclosed	F, M[2]	Summer primarily	Moderate	Low	Moderate	Low
Unenclosed	F, M[2]	Summer exclusively	Moderate	Low	Moderate	Low
Snow Tracking	W, L, F, M	Winter exclusively	Moderate–High	High	High	Very low

[1]L=lynx W=wolverines F=fishers M=martens.
[2]No lynx, but bobcats have been detected.

they can operate untended for weeks. However, the material costs for snow tracking are much less than for the 35-mm camera systems.

The benefits and limitations of each method should be evaluated for each location, budget, and the objectives of the survey. We will learn much more about the efficiency of each method when it can directly be compared to other methods. Therefore, we encourage users to take every opportunity to sample survey areas using more than one method, and to publish these results. The work of Jones and Raphael (1990), Bull and others (1992), Laymon and others (1993), Fowler and Golightly (1993), and Foresman and Pearson (1995) are a start toward this goal. In Washington State, unenclosed track plates detected somewhat fewer martens than did line-triggered cameras (Jones and Raphael 1990). However, because martens may have removed bait at track plates without detection and rain reduced the legibility of tracks, this difference is trivial. Bull and others (1992) compared snow tracking, enclosed track plates, and line-triggered cameras and concluded that when conditions permitted, snow tracking was the most effective method for detecting martens. Track plates were better than line-triggered cameras when snow was absent or of poor quality for tracking. However, only 16 sample locations along one 10-km transect were included in this study. Laymon and others (1993) found that more vertebrate species were detected at unenclosed track plates than at line-triggered cameras. In this study, unenclosed track plates and the single-sensor camera had equivalent efficiencies of detecting species, including martens. Fowler and Golightly (1993) compared enclosed track plates and line-triggered cameras at 76 stations and found that track plates were the more effective method to detect martens. This is consistent with the results of comparisons of marten detections in Yosemite National Park (L. Chow, pers. comm.). J. Copeland (pers. comm.) detected wolverines at photographic bait stations more frequently by tracks in the snow than by photographs. In a recently completed study comparing the Manley dual sensor camera, open and enclosed track plates, and snow-tracking methods, Foresman and Pearson (1995) favored the use of 35-mm cameras to detect marten, fisher, and wolverine. Cameras and track plates detected martens and fishers at the same survey units, but snow tracking failed to detect marten at some units, and fishers at all the units, where they were detected by another method. A wolverine was photographed at one survey unit but was undetected there by track plate or snow tracking methods. Snow tracking was considered the least effective method given its dependence on ideal snow conditions and well-trained technicians (Foresman and Pearson 1995). Additional experimentation is necessary before the effectiveness of each method for each of the four species can be properly evaluated.

Survey Durations

It is important to emphasize that surveys conducted only to determine presence should be terminated when the intended species is detected, or if undetected, after some reasonable amount of effort (a combination of duration and spatial extent of survey). Terminating surveys when the target species is detected is the most economical way to survey large areas. The amount and schedule of maximum effort (if target species are not detected) are necessarily different for the device-dependent methods and the snow-tracking methods, and are outlined in detail in Chapters 3, 4, and 5. General considerations of the distribution of survey sample units are provided in Chapter 2.

For the purposes of this publication we refer to the use of more than one device at a time, and running more than a trivial distance of snow-track transects, as a *Survey* (see Chapter 2: Definition and Distribution of Sample Units). We accept the definition that a survey is "an exercise in which a set of qualitative or quantitative observations are made, usually by means of a standardized procedure and within a restricted period of time and over a restricted area" (Hellawell 1991). A survey can be as superficial as using more than one device during a specified time period in the same general area, or traveling a significant distance searching for tracks. However, we dedicate much of this manual to recommending minimum survey durations and effort over specified areas. To restate this important point, we use detection methods to determine presence at a point location, either a camera or track-plate location or an intersection point on a snow transect. Our surveys are *not* methods for indexing population density, population size, or change in population size.

Population Monitoring

Censuses involve counts of individuals, *indices* are counts of some object related to the number of individuals (Caughley 1977), and *monitoring*, as we define it, is an attempt to detect change in population size over time, i.e., trend. Although we do not recommend particular monitoring methods here, we envision this publication as an important step in the development of monitoring schemes. The detection methods described herein are probably the same tools that will eventually be used to index changes in population size. Hiby and Jeffrey (1987) discussed photographic techniques for population studies of rare species, and Mace and others (1994) reported the first attempt that we are aware of to use photographic methods to estimate population size. Karanth (1995) used photographic methods to estimate the population size of tigers (*Panthera tigris*) in India. Camera stations, track-plate stations, and snow transects each could be the detection technique used as the basis for a monitoring program, in much the same way that the scent-station visit was used in an attempt to assess coyote (*Canis latrans*) population status (Roughton and Sweeny 1979, 1982) and scat transects were used to monitor change in bear (*Ursus americanus* and *U. arctos*) populations (Kendall and others 1992). In fact, plans for monitoring fisher population change using track plates (Zielinski and Stauffer, in press) and cameras (York and others 1995) recently have been proposed.

We recognize the urgent need to develop monitoring schemes for the species considered here. The populations of MFLW in the conterminous United States appear to have declined, and population safeguards could be instituted if we had solid evidence of declines. However, we caution that population monitoring efforts require considerable planning and statistical evaluation before implementation (de la Mare 1984, Diefenbach and others 1994, Gerrodette 1987, Kendall and others 1992, Peterman and Bradford 1987, Taylor and Gerrodette 1993, Verner and Kie 1988). The objective of such monitoring is usually to detect a change in an index of population abundance over time. Thus, the null hypothesis that there has been no change in the population size between two points in time must be tested against the alternative that the population has changed (either increased or decreased: two-tailed test), or has declined or has increased (one-tailed tests).

The possible outcomes of testing the null hypothesis include two familiar types of errors. A Type I error occurs, with probability α, when we mistakenly reject the null hypothesis if it is true. A Type II error occurs, with probability β, when we mistakenly do not reject (i.e., 'accept') the null hypothesis when the alternative hypothesis is true. If we detect no change in a population and consider minimizing only the Type I error rate, there are two possible interpretations. Either there has been no change in the population and we are correct in our decision, or there has been a change in the population and we have insufficient information to detect this change. Small sample size and large variance reduce the ability to detect change (Cohen 1988). We must therefore ask the important question: if a significant population decline has occurred, what is the probability that we will detect it with our survey? The answer is critical to a monitoring program. However, the probability of detecting a change if it has occurred, i.e., rejecting the null hypothesis when the alternative hypothesis is true, called statistical power (1-β), is rarely determined. In developing a sampling design to monitor population change, it is essential to determine *a priori* the probability of detecting significant changes for varying sample sizes; this allows the investigator to choose an adequate sample size to detect population change with an acceptably high probability.

The literature is replete with examples of hastily implemented monitoring schemes that, after the expenditure of many of thousands of dollars, were determined to be insufficient to detect even catastrophic declines in populations over short periods. To embark on a monitoring scheme without complete familiarity with the detection method, without consultation with a competent statistician, and without simulating possible monitoring scenarios is a waste of time and money. For example, an established monitoring scheme thought to be sufficient to detect declines in whale stocks was found to be inadequate to detect a 50 percent change over a 10-year period (de la Mare 1984). Other examples of ill-fated monitoring schemes are documented in the fisheries literature (e.g., Peterman and Routledge 1983), and we cannot overemphasize the importance of conducting pre-monitoring evaluations of statistical power (Gerrodette 1987, Millard 1987, Peterman 1990, Taylor and Gerrodette 1993). Even the long-standing coyote monitoring program instituted by the U.S. Fish and Wildlife Service (Roughton and Sweeney 1979) suffered from poor planning that resulted in major changes years after the first data were collected (Roughton and Sweeney 1982).

The recent examples of monitoring schemes to track changes in bear (Kendall and others 1992) and bobcat (Diefenbach and others 1994) populations demonstrate the level of planning necessary before one considers population-level monitoring using sign surveys. Detection of even relatively large changes in population size (e.g., 25 percent) may require prohibitively large sample sizes to achieve sufficient power (Diefenbach and others 1994). Finally, one must realize that the conclusion from evaluating proposed monitoring schemes may be that it is not statistically valid or economically feasible to conduct population monitoring via inventory; demographic studies to estimate population growth rate may be preferable (Taylor and Gerrodette 1993).

Although much of the planning that goes into developing a monitoring scheme involves simulation modeling, the process also requires empirical data. For example, the probabilities of detecting (POD) animals that are known to occur in the survey area, after varying survey durations, need to be estimated. These can be estimated by determining how many radio-marked animals in the vicinity of the detection effort are actually detected (provided that previous capture does not affect subsequent detection), an approach taken by Fowler and Golightly (1993) for marten, or by using the data from multiple surveys where POD is a function of the distribution of "number-of-days-to-first-detection" (Azuma and others 1990, Zielinski and Stauffer in press). Regardless of method, POD should be estimated in a variety of habitats and physiographic provinces to determine whether regional differences exist.

A simple form of population monitoring may be possible using the system recommended in this publication. If detection surveys are conducted over a relatively short period of time, the collective information in a region can provide a "snapshot" of the local distribution of each species. A good example of this approach is represented by North American Breeding Bird Atlases (Smith 1990) and the Atlas of Mammals of the British Isles (Arnold 1978). Zielinski and others (in press) and Kucera and others (in press) describe the current distributions of fishers and American martens in California, based on techniques described in this document. Insofar as these distribution maps can be compared over time, the method can be interpreted as a way to monitor changes in species distribution.

This publication represents a significant first step toward the development of regional monitoring programs. They are urgently needed. If we are successful, and the methods described in this manual receive widespread use, biologists from private organizations and public land-management agencies will become familiar with the standard nse of detection methods. They will be prepared to implement cooperative population monitoring schemes when the necessary research and planning have been done *and* when the results suggest that the effort is statistically and economically feasible.

Alaska and Canada

We expect that the methods described herein will be valuable to biologists throughout the range of each species. However, we recognize that in Alaska and Canada, where MFLW are most common, the emphasis will be less on their detection and more on the management of commercial harvest. Trapping still provides information on distribution and abundance of populations in the north, and the more open forests make aerial surveys for some species feasihle (e.g., Becker 1991, Golden and others 1992). Thus, some of the methods described here may currently be less useful in Alaska and Canada. However, if the abundance of MFLW decreases and commercial trapping is reduced or prohibited, the methods described here for the conterminous western United States may have equal utility farther north.

Habitat Assessments

Ideally, a standardized survey protocol should be integrated with a standardized method for describing the habitat of both the area surveyed and the locations of detections. However, for a number of reasons, we do not propose standardized vegetation sampling methods in this publication. First, to develop a habitat sampling protocol sufficient to encompass the myriad habitat types included within the ranges of the four species considered here would be an enormous task. Second, a variety of methods already are used by different agencies or states to describe habitat (Anderson and Gutzwiller 1994), some with the goal of achieving statewide standards (e.g., California Wildlife Habitat Relationships System; Mayer and Laudenslayer 1988). We are not prepared to propose methods that would have universal appeal nor do we wish to distract from ongoing efforts. Finally, although it may be possible to standardize the type of information collected at point locations (e.g., detection stations), the scales that are most appropriate for the species treated herein are the watershed and the landscape. Field and computer methods for characterizing the biological and physical attributes at these scales are just developing and will require the coordinated effort of wildlife biologists, landscape ecologists, geomorphologists, and plant ecologists, among others. Geographic Information Systems will be an essential element of this process. The approach to characterizing habitat at this scale is far beyond the scope of our objectives here.

Even though we do not recommend a particular scheme to characterize habitat, we believe habitat information is important. We strongly recommend that some habitat assessment be included in every survey. Track plates, in particular, have been used to assess habitat use by fishers (e.g., Raphael 1988, R. Golightly, pers. comm.; M. Higley, pers. comm.; R. Klug, pers. comm.). However, the number of stations visited and the frequency of detection at individual stations can be influenced by factors other than habitat quality (e.g., hunger, learning, age, sex, population density, weather, season), so this measure should be interpreted with caution. Habitat sampling should be standardized across the largest scale possible and designed to be compatible with protocols created for other purposes. Statewide standards are best, but standardization within agency boundaries (e.g., National Forest) is preferable to none at all. The recent assessment of the conservation status of MFLW (Ruggiero and others 1994) discusses stand and landscape features associated with the occurrence of each of the four species and combinations of species (Lyon and others 1994). Consult this and other published information when deciding how to characterize landscapes surveyed and vegetation at sampling points.

Interpretation of Results

Failure to detect a species has several implications. For the species considered here, additional research on probability of detection must be conducted before we will know whether failure to detect is equivalent to "absent." And, even when the failure to detect indicates a high probability of absence, the dynamic nature of populations suggests that areas of suitable habitat that are currently uninhabited could be occupied in the future. Because most management activities occur in small areas relative to the home ranges of the largest species considered here, communication with the managers of adjacent lands is essential. The existence of a nearby population (e.g., in an adjacent Ranger District) indicates the potential for recolonization of currently unoccupied but suitable habitat. Thus, management activities planned for the area being evaluated could indirectly or cumulatively affect the species even if it is not detected in the project area.

Cautions

The central concern in the management of MFLW is to determine if any occur in a region of interest. This publication is intended to provide the technical background to begin a search for each of the four species. However, the detection of these species requires specialized skills that are acquired only after specific training. The publication is designed for biologists inexperienced with the techniques and is a necessary element in preparation for detection work. However, we emphasize that reading this manual is no substitute for practice using the methods in the field. We recommend that those interested in conducting a survey assist in work being conducted by more experienced technicians before beginning their own studies.

We encourage readers, regardless of experience level, to submit their questions and comments about the information provided herein. The publication will be improved with the addition of experience from other practitioners and by evaluating data collected using the procedures described here. This feedback, and the development of new methodologies, may necessitate an improved second edition.

Disposition of Data

The Western Forest Carnivore Committee has recommended that a data clearinghouse be established for the storage and analysis of information on the distribution of lynx, wolverines, fishers, and martens (B. Ruediger pers. comm.). Although a structure for data input has been drafted (E. Burkett pers. comm.), a process for the transmittal of information to a central repository (or repositories) has not been established. We realize, however, that this publication may stimulate the implementation of numerous detection surveys. This will provide us the tools to standardize the process by which the data are collected and managed thereafter.

We recommend that whenever a target species is detected, a copy of the Species Detection form (sample form included in the appendix of each method chapter and in the pocket on the inside back cover) be submitted to the Natural Heritage program in the state where the species are detected. A list of the addresses of the Natural Heritage program offices for each state is provided in *appendix A*. A duplicate of the Species Detection form should also be archived in a local administrative office of the agency sponsoring the survey (e.g., Forest Supervisor's Office, USDA Forest Service). This assumes that the Natural Heritage program in the state maintains a database for the target species detected. Currently this will be a problem for marten because many states do not maintain records for this species. Until they do, copies of the form should at least be forwarded to a designated administrative office, perhaps at the regional level.

Because most state Natural Heritage databases record information only on positive results from surveys, we also recommend that a Survey Record form (sample form also included in the appendix of each chapter and in the pocket on the inside back cover) be completed and filed at the appropriate administrative office. These forms become an official record of where surveys have been conducted, regardless of results, and are just as important as the record of detections.

Finally, we encourage coordination, communication, and sharing of data among the individuals, agencies, and organizations conducting detection surveys to maximize our understanding of this poorly known group of species.

References

Anderson, S. H.; Gutzwiller, K. J. 1994. **Habitat evaluation methods**. In: Bookhout, T. A., ed. Research and management techniques for wildlife and habitats. 5th ed. Bethesda, MD: The Wildlife Society; 592-606

Arnold, H. R. 1978. **Provisional atlas of the mammals of the British Isles**. Abbots Ripton, Huntingdon, England: Institute of Terrestrial Ecology; 144 p.

Arthur, S. W.; Krohn, W. B.; Gilbert, J. R. 1989. **Home range characteristics of adult fishers**. Journal of Wildlife Management 53: 674-679.

Azuma, D. L.; Baldwin, J. A.; Noon, B. R. 1990. **Estimating the occupancy of spotted owl habitat areas by sampling and adjusting for bias**. Gen. Tech. Rep. PSW-124. Berkeley, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 9 p.

Banci, V. 1987. **Ecology and behavior of wolverine in Yukon**. Burnaby, BC: Simon Fraser University; 178 p; Thesis.

Banci, V. 1994. **Wolverine**. In: Ruggiero, L. F.; Aubry, K. B.; Buskirk, S. W.; Lyon, L. J.; Zielinski, W. J., tech. eds. The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the western United States. Gen. Tech. Rep. RM-254. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 99-127.

Barrett, R. H. 1983. **Smoked aluminum track plots for determining furbearer distribution and relative abundance**. California Fish and Game 69: 188-190.

Becker, E. F. 1991. **A terrestrial furbearer estimator based on probability sampling**. Journal of Wildlife Management 55: 730-737.

Biodiversity Legal Foundation. 1994a. **Petition to list the North American fisher (*Martes pennanti*)**. Boulder, CO: Biodiversity Legal Foundation.

Biodiversity Legal Foundation. 1994b. **Petition to list the North American lynx (*Felis lynx canadensis*)**. Boulder, CO: Biodiversity Legal Foundation.

Biodiversity Legal Foundation. 1994c. **Petition to list the North American wolverine (*Gulo gulo luscus*)**. Boulder, CO: Biodiversity Legal Foundation.

Bull, E. L.; Holthausen, R. S.; Bright, L. R. 1992. **Comparison of three techniques to monitor marten**. Wildlife Society Bulletin 20: 406-410.

Burkett, E., Wildlife Biologist, California Department of Fish and Game. Sacramento, CA. [Personal communication]. 1994

Buskirk, S. W.; Harestad, A.; Raphael, M.; Powell, R. A., eds. 1994. **Martens, sables, and fishers: biology and conservation**. Ithaca, NY: Cornell University Press; 484 p.

Buskirk, S. W.; Powell, R. A. 1994. **Habitat ecology of fishers and American martens**. In: Buskirk, S. W., Harestand, A.; Raphael, M., comps. eds. Biology and conservation of martens, sables and fishers. Ithaca, NY: Cornell University Press; 283-296.

Buskirk, S. W.; Ruggiero, L. F. 1994. **American marten**. In: Ruggiero, L.F.; Aubry, K.B.; Buskirk, S.W.; Lyon, L.J.; Zielinski, W.J., tech. eds. The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the western United States. Gen. Tech. Rep. RM-254. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 38-73

Caughley, G. 1977. **Analysis of vertebrate populations**. New York: John Wiley and Sons; 232 p.

Central Sierra Audubon Society and others. 1990. **Petition for a rule to list the fisher as endangered**. North San Juan, CA: Central Sierra Audubon Society; 26 p.

Chow, L., Wildlife Biologist, U.S. Department of the Interior, National Biological Service, Yosemite Research Center. El Portal, CA. [Personal communication]. 1994

Cohen, J. 1988. **Statistical power for the behavioral sciences**. 2nd ed. Hillsdale, NJ: Lawrence Erlbaum Assoc., 567 p.

Copeland, J. P., Wildlife Biologist, Idaho Department of Fish and Game. Stanley, ID. [Personal communication]. 1994.

de la Mare, W. K. 1984. **On the power of catch per unit effort series to detect declines in whale stocks.** Report of the International Whaling Commission 34: 657-661.

Diefenbach, D. R.; Conroy, M. J.; Warren, R. J.; James, W. E.; Baker, L. A.; Hon, T. 1994. **A test of the scent-station survey technique for bobcats**. Journal of Wildlife Management 58: 10-17.

Douglas, C. W.; Strickland, M. A. 1987. **Fisher.** In: Novak, M.; Baker, J. A.; Obbard, J. A., comps., eds. Wild furbearer management and conservation in North America. Toronto, Ontario: Ontario Ministry of Natural Resources; 511-529.

Eisenberg, J. F. 1989. **An introduction to the Carnivora.** In: Gittleman, J. L., ed. Carnivore behavior, ecology, and evolution. Ithaca, NY: Cornell University Press; 1-10.

Fahrig, L. 1988. **A general model of populations in patchy habitats**. Applied Mathematics and Computation 27: 53-66.

Foresman, K.R.; Pearson, D.E. 1995. **Testing of proposed survey methods for the detection of wolverine, lynx, fisher, and American marten in Bitterroot National Forest**. Final report. Unpublished draft supplied by authors.

Forest Service Manual 2670.32. **Definitions. Chapter 2670 - Threatened, endangered, and sensitive plants and animals**. Washington, DC: Forest Service; U.S. Department of Agriculture.

Forest Service Manual 2670.5. **Definitions. Chapter 2670 - Threatened, endangered, and sensitive plants and animals**. Washington, DC: Forest Service; U.S. Department of Agriculture.

Fowler, C. H.; Golightly, R. T. 1993. **Fisher and marten survey techniques on the Tahoe National Forest.** Final Report. Unpublished draft supplied by authors.

Gerrodette, T. 1987. **A power analysis for detecting trends**. Ecology 68: 1364-1372.

Gibilisco, C. J. 1994. **Distributional dynamics of martens and fishers in North America**. In: Buskirk, S. W.; Harestad, A. S.; Raphael, M. G., comps., eds. Martens, sables, and fishers: biology and conservation. Ithaca, NY: Cornell University Press; 59-71.

Gilpin, M.; Hanski, I., eds. 1991. **Metapopulation dynamics: empirical and theoretical investigation**. London: Biological Journal of the Linnean Society 42(1-2) and Academic Press; 336 p.

Golden, H. N.; Route, W.; Jenkins, K.; Johnson, W. N.; Paragi, T.; Doyle, T.; Shults, B.; Adams, L. 1992. **Furbearer track count index testing and development**. Wildlife Research Study Plan. Cooperating Agencies: Alaska Department of Fish and Game, National Park Service, U.S. Fish and Wildlife Service. Unpublished draft supplied by authors.

Golightly, R., Wildlife Faculty, Department of Wildlife, Humboldt State University. Arcata, CA. [Personal communication]. 1992.

Greater Ecosystem Alliance and others. 1991. **Petition for a rule listing the Canadian lynx (*Felis lynx canadensis*), of the North Cascades Ecosystem of Washington, as an Endangered Species**. Bellingham, WA: Greater Ecosystem Alliance; 82 p.

Grinnell, J.; Dixon, J. S.; Linsdale, J. M. 1937. **Furbearing mammals of California**. Vol. 1. Berkeley, CA: University of California Press; 372 p.

Hagmeier, E.M. 1956. **Distribution of marten and fisher in North America**. Canadian Field-Naturalist 70: 149-168.

Hash, H. S. 1987. **Wolverine.** In: Novak, M.; Baker, J. A.; Obbard, M. E., comps., eds. Wild furbearer management and conservation in North America. Toronto, Ontario: Ontario Ministry of Natural Resources; 575-585.

Hatler, D. F. 1989. **A wolverine management strategy for British Columbia**. Wildlife Bulletin B-60. Victoria, BC: British Columbia Ministry of Environment, 124 p.

Heinemeyer, K.; Jones, J. L. 1994. **Fisher biology and management in the western United States: a literature review and adaptive management strategy**. Missoula, MT: Northern Region and Interagency Forest Carnivore Working Group, Forest Service, U.S. Department of Agriculture; 120 p.

Hellawell, J. M. 1991. **Development of a rationale for monitoring.** In: Goldsmith, B., ed. Monitoring for conservation and ecology. London: Chapman and Hall; 1-14.

Hiby, A. R.; Jeffrey, J. S. 1987. **Census techniques for small populations, with special reference to the Mediterranean monk seal.** Symposium of the Zoology Society (London) 58: 193-210.

Higley, M., Wildlife Biologist, Hoopa Tribal Forestry. Hoopa, CA. [Personal communication]. 1994.

Hornocker, M. G.; Hash, H. S. 1981. **Ecology of the wolverine in northwestern Montana**. Canadian Journal of Zoology 59: 1286-1301.

Jones, L. L. C.; Raphael, M. G. 1990. **Ecology and management of marten in fragmented habitats of the Pacific Northwest.** Progress Report FY90. Portland, OR: Pacific Northwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 60 p.

Jones, L. L. C.; Raphael, M. G. 1993. **Inexpensive camera systems for detecting martens, fishers and other animals: guidelines for use and standardization**. Gen. Tech. Rep. PNW-306. Portland, OR: Pacific Northwest Research Station, Forest Service, U.S. Department of Agriculture; 22 p.

Karanth, K. U. 1995. **Estimating tiger *Panthera tigris* populations from camera-trap data using capture-recapture models**. Biological Conservation 71: 333-338.

Kendall, K. C.; Metzgar, L. H.; Patterson, D. A.; Steele, B. M. 1992. **Power of sign surveys to monitor population trends**. Ecological Applications 2: 422-430.

Klug, R., Wildlife Biologist, Simpson Timber Company, Arcata, CA. [Personal communication]. 1994.

Koehler, G. M.; Aubry, K. B. 1994. **Lynx**. In: Ruggiero, L. F.; Aubry, K. B.; Buskirk, S. W.; Lyon, L. J.; Zielinski, W. J., tech. eds. The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the western United States. Gen. Tech. Rep. RM-254. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 74-98.

Kucera, T. E.; Zielinski, W. J. 1995. **The case of forest carnivores: small packages, big worries**. Endangered Species Update 12: 1-7.

Kucera, T. E.; Zielinski, W. J.; Barrett, R. H. 1995. **The current distribution of American martens in California**. California Fish and Game [In press].

Laymon, S. A.; Holterman, M. D.; Barrett, R. H. 1993. **Distribution of marten, fisher, wolverine, and Sierra Nevada red fox in portions of the Sierra National Forest**. Unpublished draft supplied by authors.

Lyon, L. J.; Aubry, K. B.; Zielinski, W. J., Buskirk, S. W.; Ruggiero, L. F. 1994. **The scientific basis for conserving forest carnivores: considerations for management**. In: Ruggiero, L. F.; Aubry, K. B.; Buskirk, S. W.; Lyon, L. J.; Zielinski, W. J., eds. The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the western United States. Gen. Tech. Rep. RM-254. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 128-137.

Mace, R. D.; Minta, S. C.; Manley, T.; Aune, K. E. 1994. **Estimating grizzly bear population size using camera sightings**. Wildlife Society Bulletin 22: 74-83.

Macfarlane, D. 1994. **National forest system status information**. In: Ruggiero, L. F.; Aubry, K. B.; Buskirk, S. W.; Lyon, L. J.; Zielinski, W. J., eds. The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the western United States. Gen. Tech. Rep. RM-254. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, 176-184.

Maj, M.; Garton, E. O. 1994. **Fisher, lynx, wolverine: summary of distribution information**. In: Ruggiero, L. F.; Aubry, K. B., Buskirk, S. W.; Lyon, L. J.; Zielinski, W. J., eds. The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the western United States. Gen. Tech. Rep. RM-254. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 169-175.

Martin, S. 1994. **Feeding ecology of American martens and fishers**. In: Buskirk, S.; Harestad, A. S.; Raphael, M. G.; Powell, R. A., eds. Martens, sables, and fishers: biology and conservation. Ithaca, NY: Cornell University Press; 297-315.

Mayer, K. E., Laudenslayer, Jr., W. F. 1988. **A guide to wildlife habitat of California**. Sacramento, CA: California Department of Forestry and Fire Protection; 166 p.

Millard, S. P. 1987. **Environmental monitoring, statistics, and the law: room for improvement**. American Statistician 41: 249-259.

Minta, S.C.; Heinemeyer, K.S. 1995. **Yellowstone hairsnares**. Unpublished draft supplied by authors.

Morin, P. A.; Moore, J. J.; Chakraborty, R.; Jin, Li; Goodall, J.; Woodruff, D. S. 1994. **Kin selection, social structure, gene flow, and the evolution of chimpanzees**. Science 265: 1193-1200.

Nead, D. M.; Halfpenny, J. C. 1985. **The status of wolverines in Colorado**. Northwest Science 8(4): 286-289.

Nellis, C. H.; Wetmore, S. P.; Keith, L. B. 1972. **Lynx-prey interactions in Central Alberta**. Journal of Wildlife Management 36: 320-329.

Newmark, W. O. 1985. **Legal and biotic boundaries of western North American national parks: a problem of congruence**. Biological Conservation 33: 197-208.

Newmark, W. O. 1987. **A land-bridge island perspective on mammalian extinctions in western North American parks**. Nature 325: 430-432.

Peterman, R. M. 1990. **Statistical power analysis can improve fisheries research and management**. Canadian Journal of Fisheries and Aquatic Sciences 47: 2-15.

Peterman, R. M.; Bradford, M. J. 1987. **Statistical power of trends in fish abundance**. Canadian Journal of Fisheries and Aquatic Sciences 44: 1879-1889.

Peterman, R. M.; Routledge, R. D. 1983. **Experimental management of Oregon coho salmon (*Oncorhynchus kisutch*): designing for yield of information**. Canadian Journal of Fisheries and Aquatic Sciences 40: 1212-1223.

Powell, R. A.; Zielinski, W. J. 1994. **Fisher.** In: Ruggiero, L. F.; Aubry, K. B., Buskirk, S. W.; Lyon, L. J.; Zielinski, W. J., eds. The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the western United States. Gen. Tech. Rep. RM-254. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 38-73.

Pulliam, H. R.; Dunning, J.B., Jr.; Liu, J. 1992. **Population dynamics in complex landscapes: a case study.** Ecological Applications 2: 165-177.

Raphael, M. G. 1988. **Long-term trends in abundance of amphibians, reptiles, and mammals in Douglas-fir forests of northwestern California.** In: Szaro, R. C., Severson, K. E.; Patton, D., tech. coords. Management of amphibians, reptiles and small mammals in North America. Gen. Tech. Rep. RM-166. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 23-31.

Raphael, M. G. 1994. **Techniques for monitoring populations of fishers and American martens.** In: Buskirk, S. W.; Harestad, A. S.; Raphael, M. G.; Powell, R. A., eds. Martens, sables, and fishers: biology and conservation. Ithaca, NY: Cornell University Press; 224-240.

Roughton, R. D.; Sweeny, M. W. 1979. **Indices of predator abundance in the western United States, 1978.** Denver, CO: Fish and Wildlife Service, Denver Wildlife Research Center, U.S. Department of Interior; 119 p.

Roughton, R. D.; Sweeny, M. W. 1982. **Refinements in scent-station methodology for assessing trends in carnivore populations.** Journal of Wildlife Management 46: 217-229

Ruediger, W., Wildlife Biologist, USDA Forest Service, Region 1, Missoula, MT. [Personal communication]. 1992.

Ruggiero, L. F.; Aubry, K. B.; Buskirk, S. W.; Lyon, L. J.; Zielinski, W. J. 1994. **The scientific basis for conserving forest carnivores: American marten, fisher, lynx and wolverine in the Western United States.** Gen. Tech. Rep. RM-254. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 183 p.

Salwasser, H.; Schonewald-Cox, C.; Baker, R. 1987. **The role of interagency cooperation in managing for viable populations.** In: Soule, M., ed. Viable populations for conservation. Cambridge University Press; 159-173.

Scotts, D. J.; Craig, S. A. 1988. **Improved hair-sampling tube for the detection of rare mammals.** Australia Wildlife Research 15: 469-472.

Smith, C. R. 1990. **Handbook for atlasing North American breeding birds.** North American Breeding Bird Atlas Committee. Richmond, VT: Vermont Institute of Natural Science; 78 p.

Spowart, R. A.; Samson, F. B. 1986. **Carnivores.** In: Cooperrider, A. Y.; Boyd, R. J.; Stuart, H. R., eds. **Inventory and monitoring of wildlife habitat.** Denver, CO: Bureau of Land Management Service Center, U.S. Department of Interior; 475-496.

Strickland, M. A., Douglas, C. W. 1987. **Marten.** In: Novak, M.; Baker, J. A.; Obbard, M. E., comps., eds. Wild furbearer management and conservation in North America. North Bay, Ontario: Ontario Trappers Association; 530-546.

Taylor, B. L.; Gerrodette, T. 1993. **The uses of statistical power in conservation biology: the vaquita and northern spotted owl.** Conservation Biology 7: 489-500.

Thomas, J. W.; Forsman, E. D., Lint, J. B.; Meslow, E. C.; Noon, B. R.; Verner, J. 1990. **A conservation strategy for the northern spotted owl: Interagency Scientific Committee to Address the Conservation of the Northern Spotted Owl.** Forest Service, U.S. Department of Agriculture; Bureau of Land Management, U.S. Department of Interior; Fish and Wildlife Service, U.S. Department of Interior; National Park Service, U.S. Department of Interior. Washington, DC: Government Printing Office; 427 p.

Thompson, I. D.; Colgan, P. W. 1987. **Numerical responses of martens to a food shortage in northcentral Ontario.** Journal of Wildlife Management 51: 824-835.

U.S. Department of Interior, Fish and Wildlife Service. 1991. **Notice of petition finding: 90-day petition finding for the Pacific fisher.** Federal Register 58: 1159-1161.

U.S. Department of Interior, Fish and Wildlife Service. 1992. **Notice of petition finding: 90-day petition finding for the North American lynx.** Federal Register 57: 46007.

U.S. Department of Interior, Fish and Wildlife Service. 1994. **Endangered and threatened wildlife and plants; 12-month finding for a petition to list as endangered or threatened the contiguous United States population of the Canada lynx.** Federal Register 59: 66507-66509.

U.S. Department of Interior, Fish and Wildlife Service. 1995. **Endangered and threatened wildlife and plants; 90-day finding for a petition to list as endangered or threatened the contiguous United States population of the North American wolverine.** Federal Register 60: 19567-19568.

Verner, J.; Kie, J. 1988. **Population monitoring: an essential link between theoretical and applied conservation biology.** 1988 Transactions of the Western Section of the Wildlife Society 24: 18-25

Weaver, J. 1993. **Lynx, wolverine, and fisher in the western United States.** Research assessment and agenda for the Interagency Lynx-Wolverine-Fisher Working Group. Intermountain Research Station Contract No. 43-0353-2-0598. Missoula, MT: Northern Rockies Conservation Cooperative, Forest Service, U.S. Department of Agriculture.

Yassa, S.; Edelson, D. B. 1994. **Petition to USDA Forest Service for amendments to the regional guide and forest plans for sensitive furbearers and other old growth-associated wildlife in the Sierra Nevada National Forests.** National Resource Defense Council and others. San Francisco, CA: National Resource Defense Council; 82 p.

York, E.C.; Fuller, T.K.; Powell, S.M.; DeGraaf, R.M. 1995. **A description and comparison of techniques to estimate and index fisher density.** Unpublished draft supplied by authors.

Zielinski, W.J.; Stauffer, H.B. In press. **Monitoring *Martes* populations in California: survey design and power analysis.** Ecological Applications.

Zielinski, W. J.; Kucera, T. E.; Barrett, R. H. 1995. **The current distribution of fishers in California.** California Fish and Game [In press]

Appendix A—*Addresses of State Natural Heritage Programs*

Alaska Natural Heritage Program
707 A Street, Suite 208
Anchorage, AK 99501
PHONE: (907) 279-4549
FAX: (907) 258-9139

California Natural Heritage Division
Department of Fish and Game
1220 S Street
Sacramento, CA 95814
PHONE: (916) 322-2493
FAX: (916) 324-0475

Colorado Natural Heritage Program
College of Natural Resources CSU
103 Natural Resources Building
Ft. Collins, CO 80523
PHONE: (303) 491-1309
FAX: (303) 491-0279

Idaho Conservation Data Center
Department of Fish and Game
600 S. Walnut Street, Box 25
Boise, ID 83707
PHONE: (208) 334-3402
FAX: (208) 334-2114

Montana Natural Heritage Program
State Library Building
1515 E. 6th Ave.
Helena, MT 59620
PHONE: (406) 444-3009
FAX: (406) 444-0581

Nevada Natural Heritage Program
Dept. of Conserv. & Natural Resources
123 West Nye
Carson City, NV 89710
PHONE: (702) 687-4245
FAX: (702) 885-0868

New Mexico Natural Heritage Program
University of New Mexico
2500 Yale Blvd. SE, Suite 100
Albuquerque, NM 87131
PHONE: (505) 277-1991
FAX: (505) 277-7587

Oregon Natural Heritage Program
Oregon Field Office
1205 NW 25th Ave.
Portland, OR 97210
PHONE: (503) 229-5078
FAX: (503) 228-3153

Utah Natural Heritage Program
3 Triad Center, Suite 450
355 W North Temple
Salt Lake City, UT 84180-1204
PHONE: (801) 538-4759
FAX: (801) 538-4709

Washington Natural Heritage Program
Department of Natural Resources
P.O. Box 47016
Olympia, WA 98504-7016
PHONE: (206) 902-1450
FAX: (206) 902-1783

Wyoming Natural Diversity Database
1604 Grand Ave., Suite 2
Laramie, WY 82070
PHONE: (307) 745-5026
FAX: (307) 745-5026

Definition and Distribution of Sample Units

William J. Zielinski,[1] Thomas E. Kucera,[2] James C. Halfpenny[3]

Introduction

Objectives

We assume that a land manager may wish to conduct detection surveys for one of two reasons. The first is to determine the distribution of each species within a management or administrative area (Regional Surveys). For example, a biologist may want to know whether wolverines occupy any of the watersheds in the northern half of a ranger district or whether marten occur throughout the true fir (*Abies* spp.) forest types on the district. The second reason to conduct detection surveys is to determine whether any of the target species occur in an area where some management activity is proposed (Project Surveys). We will present general sampling schemes that address both needs.

Background

The theoretically "ideal" survey is to place only one detection device (a camera or track plate) or a short snow-transect in a frequently used portion of each potential home range for only as long as it takes to detect the resident. However, this manner of sampling is unrealistic for several reasons. First, we will never have *a priori* knowledge of the home ranges of target individuals. Second, even if we knew the locations of home ranges, we do not understand enough about home range use to know exactly where to place our station or snow transect so that we could detect the resident in a reasonable period of time. Although a single detection device or transect would not maximize the possibility of detecting a resident, dozens of stations (or many kilometers of snow transects) per home range would probably be more than necessary; the optimum of this trade-off lies somewhere between.

Detection surveys should be designed to maximize the probability of detecting target species while simultaneously minimizing multiple detections of the same individuals. A single detection is all that is necessary to document the presence of a species in a survey area. Multiple detections, especially when individuals cannot be distinguished, provide no new information in this regard. However, with animals as rare as those considered here we believe that survey effort must be somewhat redundant; the density of detection devices and snow transects within the sample unit should exceed some minimum effort. Likewise, the distance between sample units should minimize the possibility of overlooking an occupied area within the region. This approach will probably result in some situations where the same individual is detected at more than one device or on more than one sample unit (especially with wolverines and lynx). We prefer this potential redundancy because it reduces the chance that occupied areas will be overlooked.

We explain the characteristics of survey protocols (e.g., duration of survey, frequency of visits to sample units) for cameras, track plates, and snow tracking in Chapters 3, 4, and 5, respectively. This chapter provides suggestions for allocating effort to the sample

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unit and for distributing sample units. We have modeled our approach on the American Breeding Bird Atlas (Smith 1990) and the Atlas of Mammals of the British Isles (Arnold 1978). These surveys provide a "snapshot" of the distribution of target taxa by recommending minimum survey effort within cells created by a grid overlaid on the geographic area of interest. The resulting distribution of cells with and without evidence of occurrence is a database of distribution. Here, we suggest a sample unit size (analogous to the grid cells in atlas methods) and recommend minimum effort to detect MFLW. This is an unprecedented survey approach for these species; we solicit alternative ideas if they can be demonstrated to be more useful or efficient.

The Sample Unit

The sample unit is the smallest division of a detection survey. It is the same size regardless of the target species, and is scaled to be large enough to include the entire home-range size of the smallest species, American marten. The sample unit we propose is a 4-mi^2 area that is aligned with section boundaries (*figs. 1-3*) and is the basis for all detection methods (camera, track plate, and snow tracking). This standard unit is recommended for simplicity, comparability, and ease of application using available maps. In those locations in the western United States where township and range designations are not used (e.g., National Parks), sampling units will need to be identified using the Universal Transverse Mercator (UTM) projection. In these locations, create sample units that are 3.2 km (3200 m) on a side.

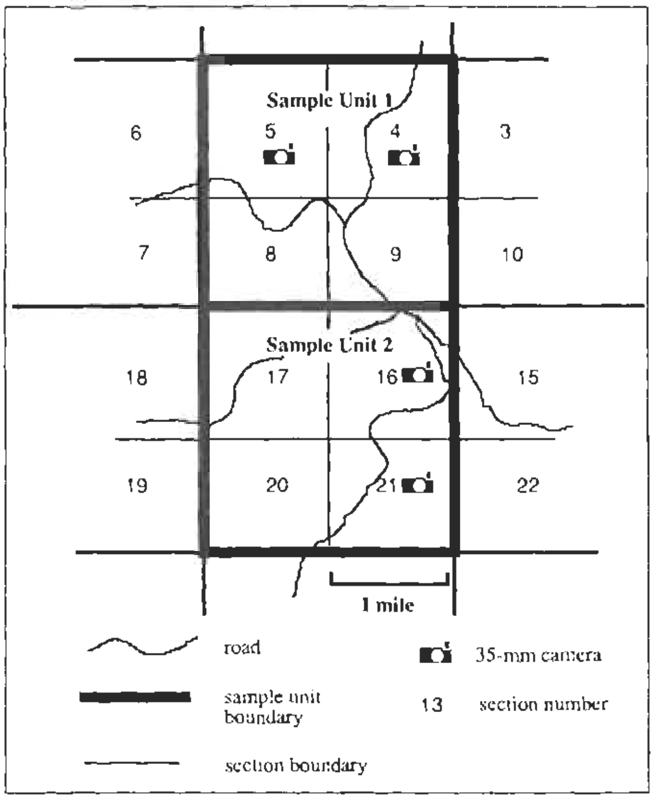


Figure 1—Schematic representation of two adjacent sample units surveyed using 35-mm cameras. The cameras are located one mile apart. The location of the cameras within each sample unit is assumed to coincide with either the most appropriate habitat or a site of an unconfirmed observation (Sections 4 and 5 of Sample Unit 1 and Sections 16 and 21 of Sample Unit 2).

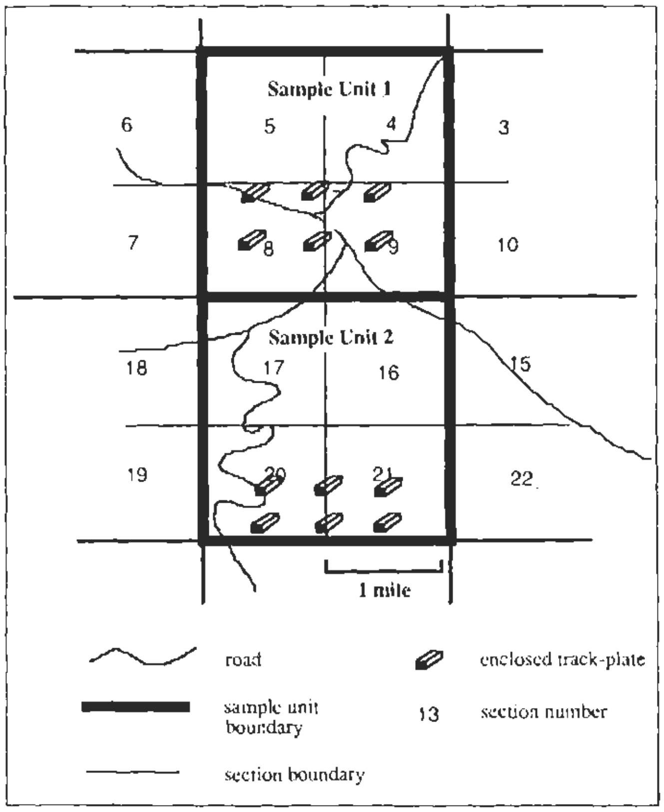


Figure 2—Schematic representation of two adjacent sample units surveyed using a grid of track-plate stations or line-triggered cameras with the objective of detecting marten or fisher. The stations are located 0.5 mile apart. The location of the grid within each sample unit is assumed to coincide with either the most appropriate habitat or a site of an unconfirmed observation (central portion of Sample Unit 1 and southern portion of Sample Unit 2).

The fact that the sample-unit size is *not* scaled to the density of particular target species, but is relatively small and invariant, assures that the rarer species with the largest home ranges (i.e., wolverine and lynx) will have the least chance of being overlooked in a survey area. However, if wolverine is the sole species of interest, larger sample units could be considered given that a detection in one 4-mi^2 area would guarantee that large adjacent areas are probably used as well. In this case, sampling immediately adjacent 4-mi^2 units for wolverines may not be the most cost effective. We encourage the use of 4-mi^2 sample units so that as data accumulate throughout the west they can be mapped using the same scale. Should one wish to create a distribution map with larger scale units at some later date, the information from the 4-mi^2 units can readily be aggregated.

Use of Detection Devices: Cameras and Track Plates

We describe camera and track-plate procedures in detail in Chapters 3 and 4; here we describe the number and distribution of the devices in general. The minimum number of devices per sample unit differs with the type of device. If 35-mm cameras are used, there should be *at least* two per 4-mi^2 sample unit, spaced 1.0 mile apart (*fig. 1*). However, if track plates (either enclosed or open) or line-triggered cameras are used, we recommend a *minimum* of six devices per sample unit (*fig. 2*). Because 35-mm cameras may be checked less frequently and larger, more attractive baits can be used

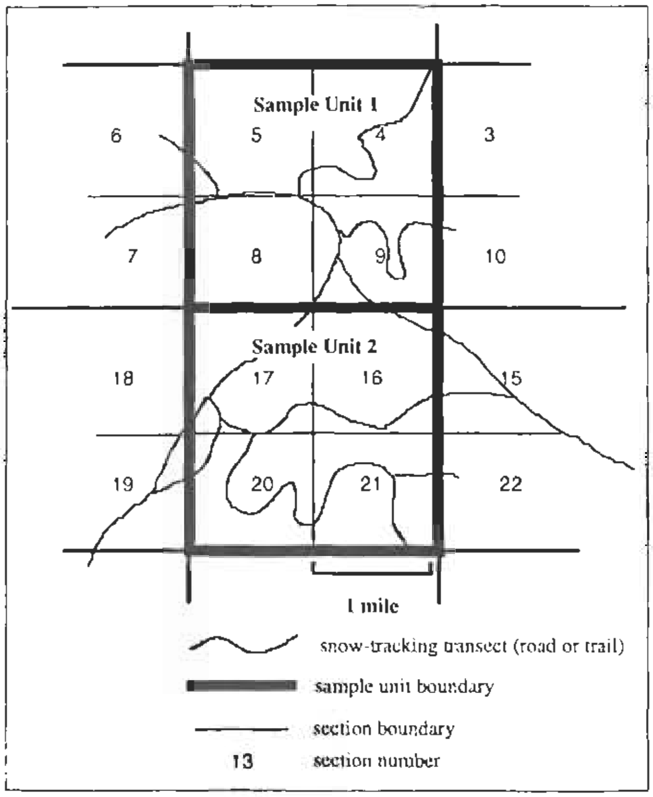


Figure 3—Schematic representation of two adjacent sample units surveyed using snow-tracking transects. Transects follow every road and trail. The route should begin at the access point to the sample unit that is nearest the most appropriate habitat for the target species, or nearest the site of an unconfirmed observation.

with them, fewer cameras are needed per sample unit. Fewer 35-mm cameras per sample unit may also be a financial necessity as they are considerably more expensive than the other devices.

Using more than one device is essential for several reasons. First, the distances from which target species are attracted to baits or lures at the devices are unknown, and a single station has a lower probability of being within the detection distance of a target species than two devices. Second, devices can be rendered ineffective from vandalism (by humans and bears) and mechanical failure. Therefore, it is better to have more than one detection device when their failure is influenced by unpredictable events.

Placement of Detection Stations

Place the array of devices (at least two 35-mm cameras or at least six track-plate boxes or line-triggered cameras) in the sample unit at a site where detections are most likely. This will be either where the habitat suitability appears highest (see Ruggiero and others 1994 for habitat descriptions) or where unconfirmed sightings are concentrated. This method approximates the "expert sampling" approach (Kish 1965) where professional judgment is used to select sample strata from a heterogeneous population. If habitat appears equally suitable throughout the sample unit, choose an area closest to the center of the sample unit with acceptable access.

Snow-Tracking Methods

We describe snow-tracking protocols in detail in Chapter 5; here we describe the essence of the procedures. We assume that snow tracking is conducted on foot using skis or snowshoes, or from a snowmobile; we expect that aerial surveys (e.g., Golden and others 1992, Stephenson 1986) will be difficult in the forested areas that comprise most of the habitat of MFLW in the conterminous western United States.

We discuss two methods for detecting the presence of the target species: "Searching for Tracks" and "Tracking at Bait Stations." The former and historically more common method involves traversing trails and roads in an area in search for tracks. The latter method involves the detection of tracks in the snow at bait stations.

When conducting a survey by searching for tracks, all roads and trails within the 4-mi^2 sample unit comprise the population of routes to be surveyed (*fig. 3*). An attempt should be made to travel all routes in the sample unit during the course of one day. If that is not possible, at least 10 km of trail should be traversed. If there are no roads, cover the area on skis as thoroughly as possible. Start the survey at the portion of the sample unit with the most likely habitat for the target species or where there have been unconfirmed sightings. If on skis, cover the sample unit proceeding from the most suitable to least suitable habitat and conclude the search after one day, regardless of distance traveled provided it exceeds 10 km. Traveling all roads in the sample unit in one day should not be difficult if snowmobile(s) are used. When tracking at bait stations is the chosen method, a protocol similar to that for 35-mm cameras should be used. A minimum of two bait sites, at least 1.0 mile apart, should be chosen per 4-mi^2 square sample unit.

Survey Duration

Searching for rare carnivores is expensive. While some duplication of effort is necessary to minimize the possibility of overlooking an occupied area, detection surveys should be designed to reduce the costs of collecting more information than is necessary. To minimize these costs we advocate that surveys be conducted in each sample unit until either the target species is detected *or* a reasonable amount of effort is expended (see

Chapters 3, 4, and 5 for minimum survey durations). The survey of a sample unit is terminated when the intended target species is (are) detected. Although multiple detections can be of value in some circumstances (e.g., when detection sites are used to assess habitat use), they are of little use when individuals cannot be reliably identified and when the objective is to determine the distribution of a species within an administrative area.

Sample Unit Distribution

Regional Surveys

Regional Surveys are designed to determine the distribution of MFLW within an administrative area and are not motivated by the need to verify the presence of a species on a project area. For this reason, the objectives of the survey are determined by the information needs of the land manager. The region within which information on the distribution of target species is desired should be delineated and divided into 4-mi^2 sample units. All sample units should eventually be surveyed, and the number that can be surveyed each year will depend on funding and the detection method chosen. Many different schedules can be envisioned; we suggest one of the three following options (*fig. 4a-c*):

(1) *Stratify by expectation of success.* Use the same logic for determining where to allocate survey effort within the region that is applied to the sample unit: choose the areas to survey first where the expectation of success is greatest (northeast and southwest regions in *fig. 4a*).

(2) *Proceed in a single direction.* Proceed across the administrative area in a consistent pattern or direction, surveying as many sample units as possible each year.

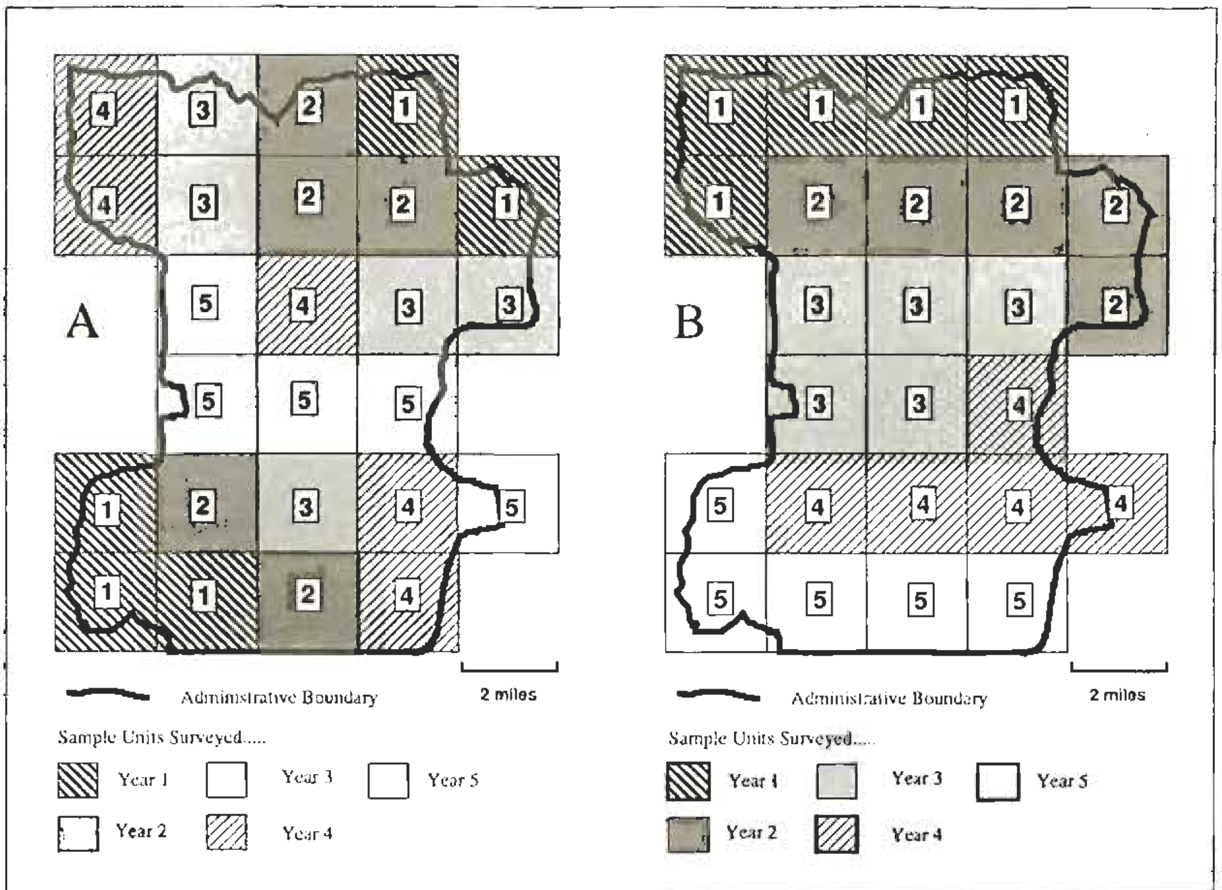
(3) *Systematic surveys.* Each year, distribute the number of sample units for which you have funding or personnel to survey evenly across the administrative area. Survey the same number of new sample units each successive year until all the sample units have been surveyed.

Hypothetical results of surveys conducted in any one of these ways is presented in *fig. 5.*

Project Surveys

A Project Survey is conducted prior to a proposed management activity (e.g., timber harvest, recreational development). Projects vary in size, but are typically small relative to the size of the home ranges of the species considered here (with the possible exception of marten). With small projects, surveys conducted only within the boundaries of the project have a poorer chance of detecting a member of a resident population than surveys in larger areas. If a target species is not detected during a survey, that should not be interpreted to mean that the species does not use the area at some other time or that it does not occur immediately adjacent to the project. As good as our detection methods appear, their efficiencies have not been adequately tested. This uncertainty demands a conservative approach. It is important to determine use on adjacent areas because this should be considered in evaluating a project's indirect and cumulative effects on habitat suitability. For these reasons we recommend that every project be centered on a *minimum* survey area equivalent to the size of a township (36 mi^2) (e.g., *fig. 6*).

The 36-mi^2 area should be delineated and divided into nine, 4-mi^2 sample units. Each 4-mi^2 sample unit should be surveyed as described above for Regional Surveys until either the maximum effort recommended for the method has been expended or the target species has been detected. It is important to emphasize, however, that a detection



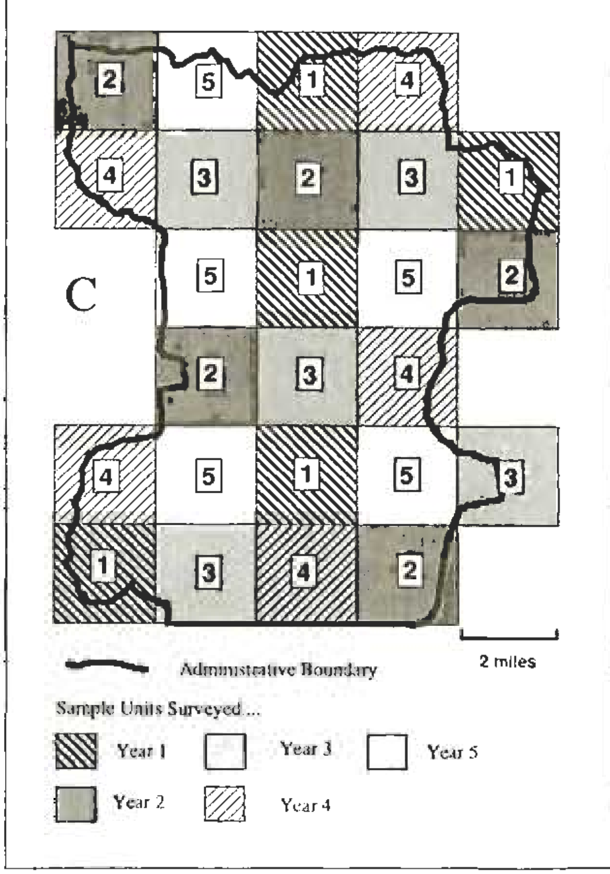


Figure 4—Three hypothetical options for scheduling a Regional Survey of a 100-mi² administrative area that includes 25 sample units. Stratification by (A) expectation of success, (B) directional coverage, and (C) systematic coverage.

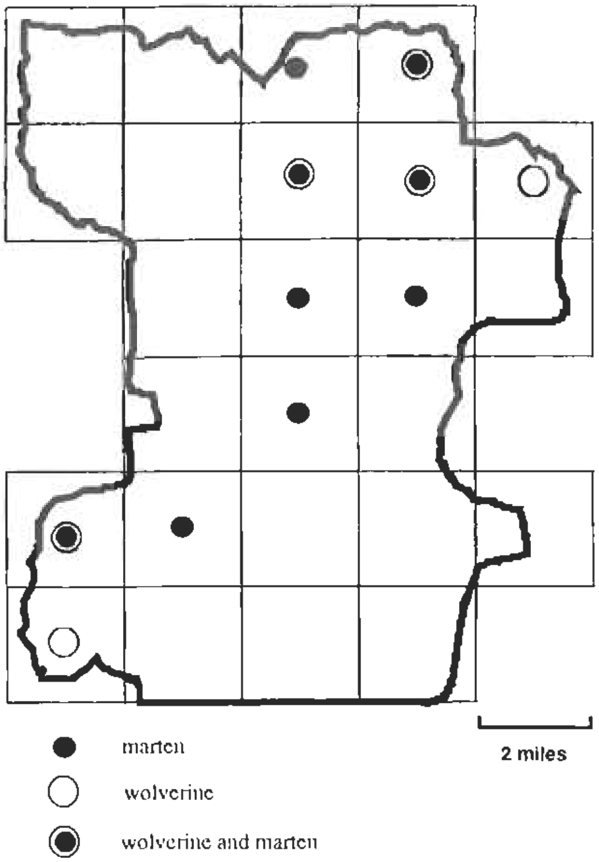


Figure 5—Hypothetical results of the completed surveys on a 100-mi² study area. Each sample unit is reported as either occupied or not occupied after the survey is complete, regardless of the number of detections that have occurred.

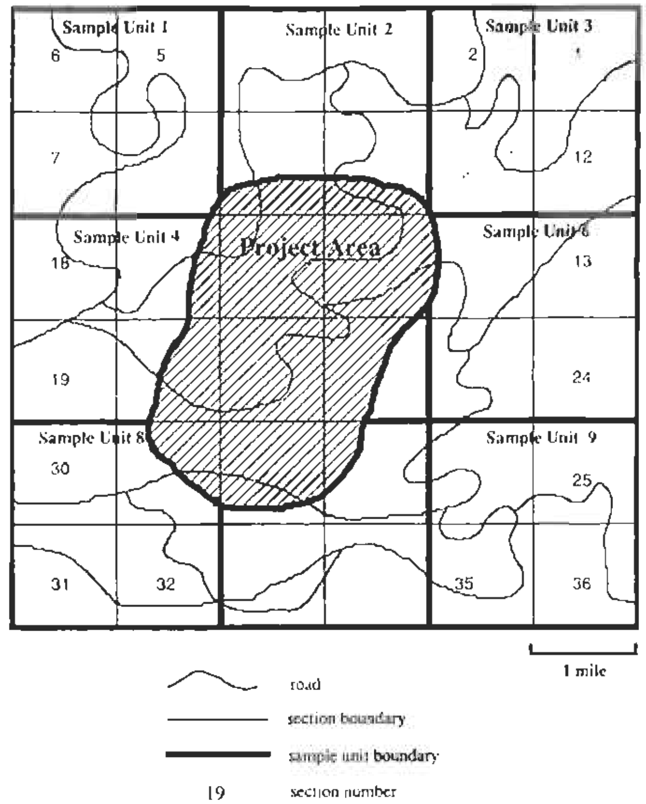


Figure 6—Schematic representation of a simulated survey area for a proposed project (e.g., timber sale, recreational development). The approximately 4,000-acre project area is centered on a township-sized (36-mi²) area that is composed of nine, 4-mi² sample units (see also *figs. 1-3*).

in one of the nine sample units should not trigger the termination of survey efforts on all nine sample units. Each of the nine sample units should be surveyed until either a species is detected or the maximum effort is expended.

Several options for survey schedules exist, but we suggest that the sample units that include the project area be surveyed first and, based on resources available, the sampling sequence thereafter proceed from sample units nearest the project to those furthest from the project boundary.

References

Arnold, H. R. 1978. **Provisional atlas of the mammals of the British Isles**. Abbots Ripton, Huntingdon, England: Institute of Terrestrial Ecology.

Golden, H. N.; Route, W.; Jenkins, K.; Johnson, W. N.; Paragi, T.; Doyle, T.; Shults, B.; Adams, L. 1992. **Furbearer track count index testing and development**. Wildlife Research Study Plan Cooperating Agencies: Alaska Department of Fish and Game, National Park Service, U.S. Fish and Wildlife Service. Unpublished draft supplied by authors.

Kish, L. 1965. **Survey sampling**. New York: John Wiley and Sons.

Ruggiero, L. F.; Aubry, K. B.; Buskirk, S. W.; Lyon, L. J.; Zielinski, W. J. 1994. **The scientific basis for conserving forest carnivores: American marten, fisher, lynx and wolverine in the western United States**. Gen. Tech. Rep. RM-254. Ft. Collins, CO: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, 183 p.

Smith, C. R. 1990. **Handbook for atlasing North American breeding birds**. North American Breeding Bird Atlas Committee. Richmond, VT: Vermont Institute of Natural Science.

Stephenson, R. O. 1986. **Development of lynx population estimation techniques**. Alaska Department of Fish and Game, Federal Aid in Wildlife Restoration, Research Final Report, Project W-22-2, W-23-3, W-22-4, and W-22-5, Job 7.12R. Unpublished draft supplied by authors.

Photographic Bait Stations

Thomas E. Kucera,[1] Art M. Soukkala,[2] and William J. Zielinski[3]

Introduction

There are a variety of systems in use that employ a camera at a bait station to detect wildlife. We will describe three that are widely used and with which we are most familiar. They can be divided into two major categories according to the type of camera used. The first employs automatic, 35-mm cameras and can be further divided into two types that differ by the mechanism that triggers them. We will refer to these types as "single sensor" (Kucera and Barrett 1993, 1995) and "dual sensor" (Mace and others 1994). The second major category is a line-triggered system that uses a manual, 110-size camera (e.g., Jones and Raphael 1993). We provide data on equipment costs and discuss the relative merits of the various systems in a later section of this chapter.

Remote-camera systems are currently available from several manufacturers (e.g., Cam-Trakker, 1050 Industrial Drive, Watkinsville, GA 30677; Compu-Tech Systems, P.O. Box 6615, Bend, OR 97708-6615; Deerfinder, 1706 Western Ave., Green Bay, WI 54303; also see Bull and others 1992, Laurance and Grant 1994, Major and Gowing 1994, Danielson and others 1995).[4] All employ somewhat different configurations and have different advantages and disadvantages. The cameras used in these systems also change as camera models are discontinued by manufacturers and new ones are introduced. Thus, the systems we describe in this document may differ from what is available in the future, and the reader who wishes to use remote photography to detect wildlife may need to modify specific procedures as appropriate for the equipment in hand. As remote-camera technology advances, it is likely that additional designs will continue to be developed.

Description of Devices

Single-Sensor Camera System

The single-sensor system that we will describe here is the Trailmaster TM1500 (Goodson and Associates, Inc., 10614 Widmer, Lenexa, KS, 66215, 1-800-544-5415), which consists of an infrared transmitter and receiver, used with the TM35-1, an automatic, 35-mm camera (*fig. 1*). The camera is triggered when an infrared beam is broken; such an occurrence is termed an "event." The transmitter emits a cone of infrared pulses. Because the receiver has an area of sensitivity of about 1 cm in diameter, the effective beam diameter is about 1 cm, thus requiring precise placement to intercept the target animal. The transmitter and receiver may be placed as far as 30 m apart. Their alignment is facilitated by a sighting groove on the receiver and a red light that flashes during the setup procedure to indicate that the beam is being received; this light stops flashing when the system is in data-collection mode.

The receiver also is an event recorder that stores the date, time, event number, and whether a picture is taken each time the beam is broken. A maximum of 1000 events can be stored. The sensitivity of the trigger—that is, the length of time the beam must be broken or, more accurately, the number of infrared pulses that must be blocked to register as an event—can be adjusted by the user from 0.05 to 1.5 seconds. The time

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[4] The use of trade or firm names in this publication is for reader information and does not imply endorsement of any product or service by the U.S. Department of Agriculture.

after a photograph is taken until the next can be taken (the "camera delay") also is set by the user, from 0.1 to 98 minutes. If the beam is broken during the camera delay, events are still recorded and stored. The transmitter and receiver are each powered by four alkaline C-cells, which last approximately 30 days of continuous field operation. Both units come with nylon straps about 70 cm long for attachment to trees.

The most recent (November 1995) Trailmaster configuration employs an Olympus Infinity Mini DLX camera; earlier models used a Yashica AW Mini or an Olympus Infinity Twin. These camera changes were dictated by the availability of the models from the manufacturer; users of the equipment must become familiar with the operations of the particular camera they have. The components of the different systems, such as receivers and cables, are not interchangeable and should not be mixed up. The camera is modified to be triggered by an electrical pulse from the Trailmaster receiver. A quartz clock in the camera allows display of date and time on the photograph. The camera connects to the receiver with an 8-m wire, providing flexibility in the placement of the camera. Several cameras can be triggered simultaneously with the use of an optional multi-camera trigger. The flash can be operated automatically as required by available light, in fill-in flash mode so that the flash operates with every frame, or the flash can be turned off. With 100-ASA film, the flash illuminates to about 3.5–6 m, depending on the camera model; with 400-ASA film, this distance is doubled. Infrared film also may be used with an infrared filter over the flash. Slave flashes, triggered by the flash of the camera, can be used to extend the area illuminated.

Figure 1—Single-sensor equipment. From left to right: transmitter, receiver, and camera. Above the camera is the metal shield that protects it. Immediately below the camera is a ball-and-socket head bolted to a metal L-bracket for attachment to a tree; below that is the "tree-pod" that comes with the system. The camera is attached to the receiver with an 8-m wire.

The Olympus Infinity Mini DLX in the newest Trailmaster configuration can use either one 3-v lithium or two AA alkaline batteries. In normal use, the lithium battery will operate through about 14 rolls of 36-exposure film, and the alkaline batteries about 10, assuming flash on half the exposures. At a bait station, because the camera is constantly on and the flash is charged, the battery may last only 30 days. The quartz clock is operated by the camera battery. The capacitor that charges the flash in the Olympus Infinity Twin camera used in earlier models drains after 2-4 days if no photograph is taken. Thus, if the camera is not triggered, or is not reset by closing and opening the lens hood during this time, the flash may fail to operate the first time the camera is triggered. This does not happen with the Yashica, which keeps the flash charged at all times. However, the batteries in the Yashica must be changed more frequently. The Olympus Infinity Twin uses two 3-v lithium batteries, which will last through approximately 20 rolls of 36-exposure film, assuming the flash operates on half the frames. The Yashica camera uses 2 AA batteries, which last approximately 2 weeks. The quartz clock is operated by a separate 3-v lithium battery that will last 3 years.

The system comes with a 10-cm, collapsible, plastic tripod with a threaded ball-and-socket head that screws into the bottom of the camera. A metal bracket shields the top and back of the camera and prevents birds from pecking the controls while allowing access to the viewfinder; the metal bracket also provides some protection for the lens from rain or snow if the camera is operated in landscape format. The tripod is designed to be placed on a flat surface, or when collapsed, attached to a small tree or branch by a Velcro strap. The attachment of the camera to a tree or other support can be greatly improved by using a more substantial ball-and-socket head purchased at a photographic supply store (the Bogen model 3009 works well), attaching this to a metal "L"-bracket with a bolt, and fixing the bracket to a tree with lag bolts (*fig. 1*). This is a much more secure and convenient alternative.

The entire system weighs about 2 kg with batteries, and can be transported in a 25- × 20- × 10-cm box. It is weatherproof and operates in rain and snow. We tested low-temperature operation of an early model using the Olympus Infinity Twin in a freezer, and it performed consistently at −17 °C for 2 weeks and at −7 °C for 2 more weeks.

Also available from the manufacturer (Goodson and Associates) is a device that allows electronic collection of data (date and time of all events, and which events triggered the camera) in the field for later transfer to a personal computer; the data can also be transferred directly from the receiver to a personal computer. The collector is particularly useful when you check several stations in a day by reducing the time you spend recording data at each station. The software package required for downloading from either the receiver or collector provides output in the form of text (event number, date, time, and frame number) and a graph showing events by day and time in a 3-dimensional bar chart. Trailmaster also makes a battery-operated printer that produces a hard copy of the event data in the field.

Dual-Sensor Camera System

The dual-sensor remote camera system consists of an automatic 35-mm camera modified to be triggered by a microwave motion and a passive infrared heat sensor (Mace and others 1994; *figs. 2A, 2B*). Dual-sensor systems are made by Compu-Tech, Trailmaster, and Tim Manley (524 Eckleberry, Columbia Falls, MT, 59912, 406-892-0802). Although the Trailmaster TM500 dual sensor (*fig. 3*) has recently been field-tested and proved reliable and lightweight (K. Foresman, pers. comm.), we will describe the use of the equipment from the last source, sometimes referred to as the "Manley" camera. These three systems share many similarities. If you are using a dual-sensor system from another manufacturer, the procedures described below will need to be altered as required by the

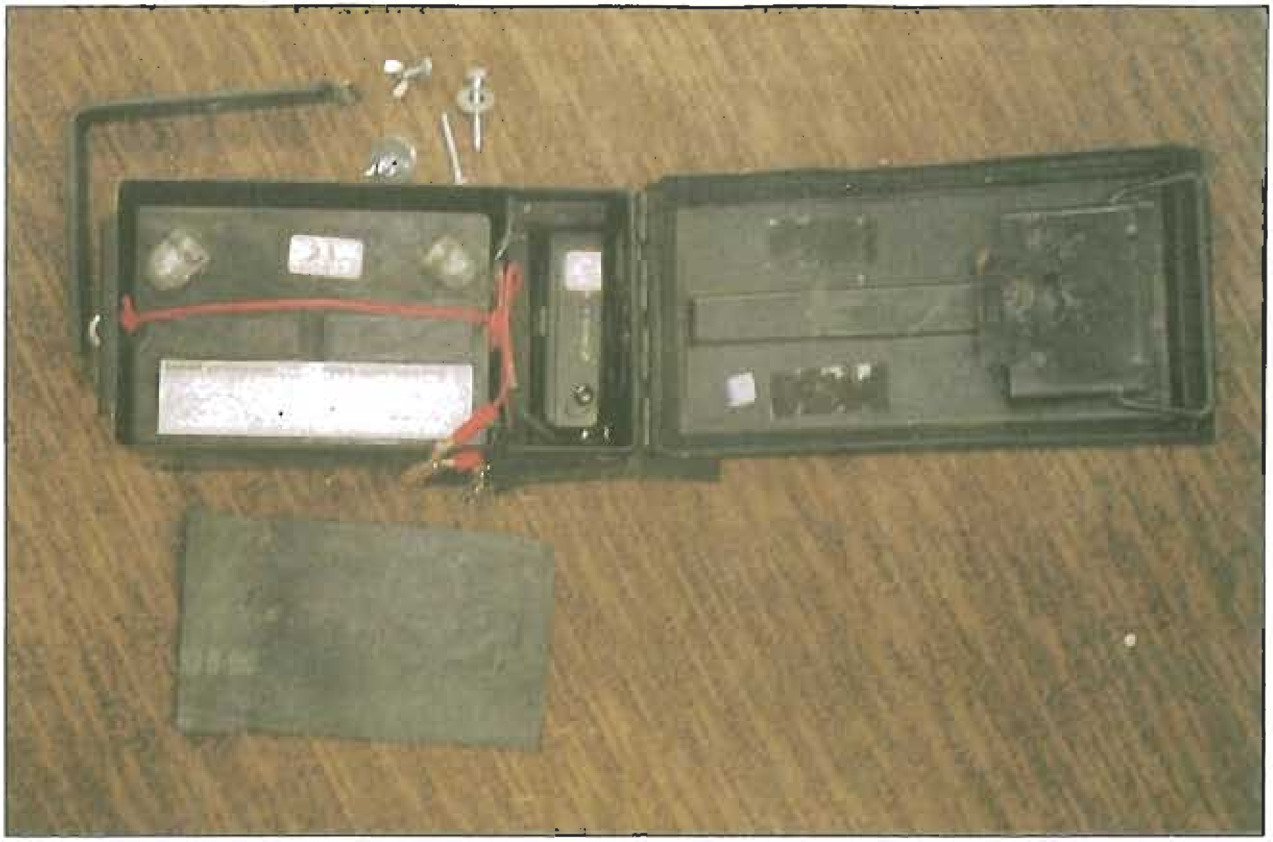

Figure 2A—Manley dual-sensor equipment (from above). Battery on left and camera on right.

Figure 2B—Manley dual-sensor equipment (from the front).

Figure 3—The Trailmaster TM500 dual-sensor camera system. From left to right: dual-sensor unit, camera, and metal camera shield. Immediately below the camera is a ball-and-socket head bolted to a metal L-bracket for attachment to a tree; below that is the "tree-pod" that comes with the system. The camera is attached to the receiver with an 8-m wire.

particular system employed. Again, because of the availability of particular camera models from the manufacturers, specific designs of the system are likely to change.

In normal operations, both the microwave sensor that detects motion and the passive infrared (PIR) sensor that detects changes in ambient temperature are triggered simultaneously and operate the camera. If either sensor malfunctions (e.g., the microwave sensor loses its signal, or if ambient temperature approaches the body temperature of a target animal), the other sensor will take priority and will work like a single-sensor system. Both sensors send out a field to approximately 11 m. The camera is triggered when an animal enters the field, which can be restricted to several meters wide by obstructing the PIR sensor window. The sensors draw 35 mA from the 12-v gel cell (golf-cart type), deep-cycle battery used to power the system. This rechargeable battery should last for 20 days between charges.

Early versions of this system used an Olympus Infinity Jr. camera, modified to be triggered by an electrical pulse from the sensor. The camera focuses from 0.7 m to infinity; the flash illuminates to 4.5 m with 100-ASA film and 9 m with 400-ASA film. The flash can be operated automatically as required by available light, continuously on every picture in fill-in mode, or the flash can be turned off. The capacitor that charges the flash drains after 3-4 days if no picture is taken. Thus, if the camera is not triggered or is not reset by closing and opening the lens hood, the flash may fail to operate the first time the camera is triggered. The camera is powered by a 3-v lithium battery that will last through 20 rolls of 36-exposure film, assuming the flash operates on approximately half the pictures. However, because the light meter is on continuously while the remote camera is operating, the camera battery may last only 1-2 weeks depending on how many rolls of film are exposed, how many flash pictures were taken, and the ambient temperature. The camera is equipped with a quartz clock that allows displays of date and time on each photograph; the clock is powered by a 3-v lithium battery that will last several years.

The entire system is housed in a weatherproof 15- × 30- × 19-cm metal ammunition box that will withstand moderate abuse (e.g., from a bear) without being damaged. An external switch allows the system to be turned on and off without opening the box. The box can be modified to allow it to be locked shut and cabled to a tree to discourage theft and vandalism. The system comes with a mounting bracket and lag bolts for attachment to a tree. Total weight is approximately 13.6 kg including the 12-v battery.

Line-Triggered Camera System

This is an inexpensive, remotely triggered system, assembled by the user, that employs a 110-size camera (*fig. 4*). We have the most experience with the Concord 110 EF and CEF with internal, electronic flash (a distributor can be contacted by calling 908-499-8280), but similar models may be satisfactory. It is essential that the camera have an internal flash; "flash bars" and "flash cubes" have a high failure rate in the field. Each camera should be identified with a unique number engraved or written on the body with permanent marker.

The system is composed of the camera, a wooden mounting stake, a cover from a plastic gallon milk jug, an external battery pack, and the trigger mechanism. The mounting stake is a 1- × 3- × 36-inch post topped with a 0.05- × 2.75- × 5.0-inch wooden platform (*figs. 5, 6*). The platform should be firmly screwed to the top of the post because this is the surface on which the camera is attached. Avoid using plywood for the platform.

The camera can be adequately weather-sealed for most conditions by putting a strip of electrical tape over the trigger release and a second strip over the flash switch area (*be sure the switch is ON*). However, in rainy conditions, the camera should be covered with

Figure 4—110 camera, raised from platform to view Velcro attachment.

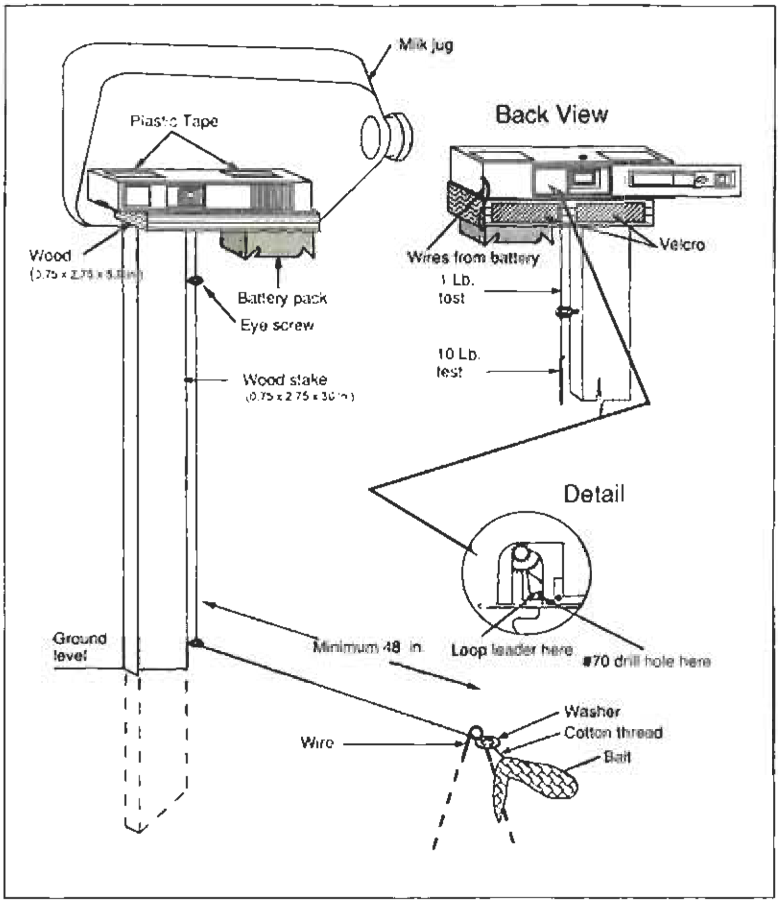

Figure 5—Schematic configuration of a line-triggered camera station.

Figure 6—Line-triggered camera station. Protective milk jug in place.

half of a 1-gallon milk jug (*fig. 5*). Staple Velcro to the milk jug and to the vertical surface of the platform board to hold the jug in place. Position the Velcro pads to avoid obstructing the nylon leader that comprises the trigger mechanism (see below) as it exits the camera. Camouflage the jug with dark green or brown spray paint to reduce the chance of its discovery by passers-by.

Unlike previous versions in which a coat-hanger-wire mechanism triggered the shutter (Fowler and Golightly 1993, Jones and Raphael 1993), the design presented here employs a line from the bait that connects directly with the shutter mechanism *inside* the camera (L. Chow, pers. comm.). Familiarize yourself with how the 110 camera works by opening the rear of the camera and watching inside while tripping the shutter and operating the film-advance mechanism several times. Look for a flat, triangular lever that snaps backwards when you trip the shutter. This is the internal shutter release. Trip the shutter to disengage the internal shutter release from the toothed gear. Drill a small hole (using a #68 or #70 gauge drill bit) in the underside of the camera, approximately 2 mm from the rear edge of the camera. Position and angle the hole so it is just behind the internal shutter release. Make a loop in a 12- to 15-inch length of a 2-lb test nylon fishing leader. Fold and pass the loop through the hole and, using forceps, hook it over the internal shutter release. Secure the loop by knotting it outside the camera an inch or two from the hole; a knot inside the camera may prevent the shutter release from operating properly.

Because the factory-suggested batteries for the camera are insufficient to provide energy for more than a few days, additional power must be provided. Build an auxiliary battery unit that will house two size D batteries (*fig. 6*). House the batteries in a standard, open, plastic battery pack, available at electronics stores. The D-cell unit should be connected to the battery terminals in the camera by stereo wire that is soldered from the battery pack to the contacts in the camera battery compartment; if wires are provided with the battery pack, use them. The Concord 110 requires very little modification to solder the wires to the battery terminals in the camera's battery compartment. After soldering the wires, cut a small hole in the camera's battery compartment door to allow entry of the wire from the auxiliary battery unit. Seal this hole with silicone. The battery compartments of other camera brands (e.g., Vivitar and Focal) require that some of the plastic body be cut away to access the internal battery terminals. Attach the battery pack to the bottom of the platform board with short screws or rubber bands; Velcro is inadequate to support the weight of the batteries.

Baits and Lures

Recommendations:

With the 35-mm systems, we recommend using road-killed deer, fish, or a combination of the two. The amount used should be as large as possible, up to a whole deer carcass, but at least 5 kg. With the line-triggered system, chicken wings are the recommended bait. Also use a commercial lure and, especially for surveys for lynx, a visual attractant (e.g., hanging bird wing, large feather, or piece of aluminum).

Mustelids

Wolverines, fishers, and martens are opportunistic hunters, and the great diversity in their diets reflects this (Banci 1989, Hash 1987, Martin 1994). In addition to taking live prey, they frequently scavenge in winter and can be attracted to carcasses of ungulates (Hornocker and Hash 1981; Pittaway 1978, 1983). Thus, road-killed deer (*Odocoileus* sp.) are probably one of the most readily available baits to attract these species to 35-

mm camera stations. However, because it is illegal to handle or transport road-killed deer without appropriate permission, coordination with the state game agency is necessary before handling and transporting them.

In many areas, road-killed deer are available seasonally; this may require planning in order to have bait for the field season. Storing deer can be a challenge; a large freezer such as at fish hatcheries or cold box at some National Forest System ranger districts often is necessary. The bigger the bait the better, but handling whole deer carcasses can be difficult. An important requirement is that the bait be large enough to remain attractive until it is scheduled to be replaced. We recommend a piece of road-killed deer weighing at least 5 kg. One approach to increase the convenience of storage and transport of bait is to quarter deer when fresh and freeze the pieces in individual plastic bags. The frozen packages can be transported when needed, eliminating the need to cut up frozen carcasses. Another attractant being experimented with is cow blood, frozen in gallon milk jugs, from a slaughterhouse. Putting an anticoagulant in the blood will keep it in a liquid state. At the camera station, perforate the jug to allow the scent to escape and suspend the jug from a cable, approximately 3.5 m above the ground.

Commercially available trapper lures such as skunk scent may be valuable to attract the mustelids, and we recommend that they be tried and evaluated in conjunction with the bait. Two sources of such lures are the M & M Fur Company, P.O. Box 15, Bridgewater, SD 57319 (605-729-2535) and Minnesota Trapline Products, 6699 156th Ave. NW, Pennock, MN 56279 (612-599-4176). Standard predator-survey disks containing fatty acids can be obtained from the Pocatello Supply Depot, 238 East Dillon St., Pocatello, ID 83201. In several areas of California, fish emulsion sold as fertilizer in garden-supply stores and used in conjunction with deer carrion has been used to attract fishers and martens. Brands vary in the strength of their odor. Mixing vegetable oil or glycerin with the fish emulsion may retard evaporation and thus extend the attractiveness of the scent.

Lynx

Lynx rely heavily on a single prey species, the snowshoe hare (*Lepus americanus*), although they do take other small mammals, birds, and carrion, particularly when hares are rare (Hatler 1989). This requires somewhat different strategies in attempts to detect them. The typical set used to trap lynx employs a scented lure (e.g., commercially available skunk scent and some catnip) in addition to a visual attractant or "flasher" such as a grouse wing, a turkey primary feather, or an aluminum pie plate on a string above the trap (Baker and Dwyer 1987, Geary 1984, Young 1958). Once attracted to the general area by the scent, the animal sees the object moving in the wind and comes to investigate it. A similar arrangement could be used to attract lynx into the beam of the single-sensor, or within the range of the dual-sensor camera. Scents are probably best purchased from a commercial supplier. A set employing carrion, a scent, and a bird wing conceivably could attract any of the four target species.

Survey Seasons

Recommendations:

35-mm systems: Conduct surveys in winter. Bears are least active during winter, and the dual-sensor cameras operate best in cool temperatures.

Line-triggered system: Conduct one survey in the spring, shortly after snowmelt, and if the target species is not detected, conduct another in the fall. The line-triggered camera system works best in snow-free conditions.

Single and Dual Sensor

There is evidence that wolverines are more attracted by carrion in the winter than at other seasons (Hornocker and Hash 1981), and this is likely true of the other mustelids. They also may be less likely to come to an attractant when natural foods are more common. In addition, bears are usually much more numerous than wolverines, fishers, and possibly martens, and are readily attracted to bait. Bears can exhaust the film, remove bait, and damage equipment. For these reasons, the best season to try to detect mustelids is winter. However, data on wolverines in Idaho suggest that females restrict their movements from near the time of parturition through weaning of offspring and thus may be effectively removed from the population in late February and March (J. Copeland, pers. comm.). Similar seasonal considerations may apply to fishers (Arthur and Krohn 1991, York and others 1995) and American martens (Strickland and others 1982).

Both 35-mm systems operate well in the snow; the dual-sensor system operates best in winter because warm temperatures during the summer can send erroneous signals to the sensor. If working in winter is not possible, or if bears are active year-round in a particular area, you may need to check and move the equipment more frequently. If a bear finds a station, it is likely to return, so the station may need to be moved or reconfigured to prevent the bear from taking the bait (see below, Checking the Stations).

Seasonal differences in vulnerability of lynx to trapping are unknown, so recommendations for seasonal guidelines will have to await additional data. Again, however, if bears are a problem in a study area, or if there is an ongoing program of snow tracking (see Chapter 5) to detect lynx that can incorporate the photographic bait stations, winter would be the most appropriate season.

Line Trigger

The line-triggered camera system recommended here is difficult to use in snow, especially if snow falls during the survey period (C. Fowler, pers. comm.). Snow can interfere with the trigger wire that runs along the ground, and cold temperatures can affect the mechanical trigger. Therefore, surveys using line-triggered cameras should be conducted when most snow is melted and the risk of new accumulation is low. However, the line-triggered camera has successfully been used during winter by attaching the camera and bait to the top of a downed log that is above the snow (T. Holden, pers. comm.).

Martens and fishers have been detected on numerous occasions at line-triggered camera and track-plate stations baited with chicken during the spring, summer, and fall (Fowler and Golightly 1993; Seglund and Golightly 1993; Zielinski and others, 1995), when alternative foods are assumed to be more abundant than in winter. Bull and others (1992) detected marten at more stations in winter than summer, but only 16 stations were used. There is no compelling evidence that spring and fall surveys that target marten and fisher are less effective than winter surveys, and surveys certainly are easier to conduct in spring and fall. Neither wolverines nor lynx have been detected at line-triggered cameras, so conclusions about seasonal effects on their detectability must await additional data. There is little evidence that bears will return as frequently to a line-triggered camera station as they do to 35-mm camera stations. There is no reason to believe that moving the station will result in less damage than replacing the unit at the same location. Because of its low cost, a line-triggered camera set damaged by bears does not result in significant expense.

Survey Duration

Recommendations:

35-mm systems: Operate each station until either the target species is detected *or* a minimum of 28 days have elapsed.

Line-triggered system: Stations should be set for a minimum of 12 nights and checked every other day for at least six visits (excluding setup) *or* until the target species is detected. If the target species is not detected during the first 12-day session, run a second session during the alternate season (either spring or fall) for at least 12 days *or* until the target species is detected.

Allow extra days to achieve the recommended duration if the camera becomes inoperative.

Because the objective of the survey is to determine whether the target species is present in a sample unit, effort need not be expended beyond the detection of the target species. The minimum duration that a 35-mm camera station should operate without detecting a target species is 28 days. We based this minimum effort on data on "latency to first detection" of wolverines and American martens. Using dual-sensor systems, J. Copeland (pers. comm.) detected wolverines at six stations with a mean latency of 38 days; the median latency was 17 days. Mean latency to first detection at dual sensor cameras in Montana was 13.5, 9.0, and 13.0 days for martens, fishers, and wolverines, respectively (Foresman and Pearson 1995). Kucera[5] detected American martens at 25 single-sensor stations after a mean of 7.9 days and a median of 5 days.

[5] Unpublished data on file at the Department of Environmental Science, Policy, and Management, University of California, Berkeley, CA.

We set the minimum effort when using line-triggered cameras at 12 nights in response to several sources of information on the latency to first detection for marten and fishers. In reviewing the results of 207 surveys that used either track plates or line-triggered cameras, Zielinski and others (1995) found that the mean (SD) latency to first detection for surveys that had from 6 to 12 stations was 4.2 (2.4) and 3.7 (2.6) days for fisher and marten, respectively. This estimate is biased downward, however, because it included only those surveys that detected a target species before the survey was concluded. Raphael and Barrett (1984) suggested that 8 days were sufficient to achieve high detection probabilities when measuring carnivore diversity at a site. Jones and Raphael (1991), however, discovered that 60 percent (3 of 5) of first detections during marten surveys occurred after day 8 but before day 11. They concluded that surveys should run more than 11 days. Fowler and Golightly (1993) suggested a 22-day survey duration, but this was with the intention of using track-plate visits to monitor population change. Because the objectives of detection surveys are different, and because the statistical merits of their approach have not been adequately addressed, 22 days is probably excessive for detection.

Because visits by lynx and wolverines to line-triggered camera stations have not yet been recorded, there are no data on which to base recommendations for survey duration. Until appropriate data are collected to suggest otherwise, we believe that the 12-day duration, twice per year if necessary, is sufficient effort.

Preparations for the Field

Defining the Survey Area

Recommendations:

Conduct surveys in 4-mi^2 sample units, as described in Chapter 2.

Chapter 2 discusses the two types of survey, Regional Distribution and Project Level. The investigator should decide which type is appropriate for the planned work and outline the survey area on a map. In both types of survey, we recommend the use of separate, 4-mi^2 sample units as the basis of the survey. For a Regional Distribution survey, the region of interest should be defined on a map, and the 4-mi^2 sample units located as suggested in Chapter 2. A Project Level survey will include a 36-mi² area, with nine sample units, centered on the project.

Station Number and Distribution

Recommendations:

35-mm systems: Use a minimum of two cameras in each sample unit, no closer than 1 mile apart, at the sites of the most appropriate habitat or where unconfirmed sightings have occurred.

Line-triggered system: Use a minimum of six camera stations in each sample unit. Arrange stations in a grid, distributed at intervals of about 0.5 mile, at the site in the sample unit with the most appropriate habitat or where unconfirmed sightings have occurred (see Chapter 2, *fig*. 2).

Within each sample unit, place the detection devices (minimum of two 35-mm or six line-trigger cameras) where a detection is most likely. This could be in an area thought to have the most suitable habitat or near an area of previous reports of occurrence or likely travel routes, as discussed in Chapter 2. However, in doing so, try to maintain the inter-station spacings recommended above.

Two 35-mm cameras are an adequate minimum density per sample unit because they can operate longer for the same personnel costs than the line-triggered cameras, and the larger baits used should attract target individuals from a greater distance. The number of line-triggered cameras in a survey can influence its success (Zielinski and others, 1995). Although the data are too few to estimate the optimum station number, it seems reasonable to have detection stations that sample at least 10 percent of the area in the sample unit for the survey duration. Six stations provide at least 12.5 percent coverage of the sample unit if they are arrayed as a rectangle and one assumes that a target individual will be detected if it travels within the area created by joining the perimeter stations. Of course more stations will provide a greater assurance in detecting occupants, but more than 12 stations (covering 1.5-mi²; 37.5 percent of the area) would probably be excessive.

If there is no reason to place the line-triggered camera stations either at the most suitable habitat or where previous sightings occurred, array the stations as a grid in the center of the sample unit. Wherever the grid is placed, adjust its shape to accommodate road access in the vicinity. If the sample unit is roadless, pack the materials into the area.

In the Field

Before you go out, become familiar with the operation of the device you are using. Practice with it so that you are comfortable with its operation. When using the single-sensor system we describe, understand its commands, know how to program it, read out the event data, clear it, change batteries, and know where in the manual to look for instructions for a particular topic you need help on. This is *much* more easily done in the warmth of home or office than in the field.

In the field, do not go alone, especially during winter. Tell someone where you are going and when you will return, and what to do if you do not return by a certain time. Be aware of the weather forecast, have appropriate gear, and expect the worst. Remember that ease of access can change drastically as snow conditions change. Be sure you have all the necessary equipment; a list is provided below (Equipment List).

The major considerations for establishing stations in the field are maximizing the probability that they will be found by the target animal species and minimizing the likelihood that the station will be found by people. Mark the station permanently with a metal tag or stake, and precisely describe its location. If possible, use a Global

Positioning System to determine the location. This will allow future study efforts to replicate your work.

Winter Safety

Surveys using 35-mm cameras will be conducted primarily during winter when potentially hazardous conditions frequently exist. It is the responsibility of the supervisor to evaluate potential hazards in the survey area and to obtain proper training for all personnel before they go into the field. Field biologists often assume they know how to get along in the outdoors. Surveying for rare species during winter may test those assumptions; being a field biologist does not guarantee competence to conduct fieldwork in winter.

Job descriptions and training for field technicians should stress winter field skills including skiing, snowshoeing, snowmobiling, camping, and avalanche training. Proper winter equipment must be provided to each field person. Employees should be trained by in-house experts or at one of several established winter training schools. Lists of winter camping and avalanche training schools are provided in Chapter 5 under Safety Concerns. Two excellent references on avalanches are by Armstrong and Williams (1986) and Daffern (1992). Selected references on winter outdoor skills include Forgey (1991), Gorman (1991), Halfpenny and Ozanne (1989), Pozos and Born (1982), Schimelpfenig and Lindsey (1991), Weiss (1988), Wilkerson and others (1986), Wilkerson (1992), and Wilkinson (1992).

Handling Bait

Uncooked meat baits are a potential source of *Salmonella* bacteria, so meat should be wrapped in plastic and frozen until the day it is used. Contact with either fresh or old bait should be minimized. Plastic bags can be used as gloves to reduce contact, and for smaller pieces of bait, kitchen tongs can be used. Carry soap, water, and disposable wipes so that you can wash your hands thoroughly after handling bait. Careful attention to cleanliness will make the risk of contamination from rotting meat, including chicken, negligible (J. Sheneman, pers. comm.). The risk of poisoning the target species with rotting meat baits is very low, as most target species regularly consume carrion.

Station Setup

Single Sensor

A soft-sided cooler bag is convenient for carrying the Trailmaster and provides some protection. Be sure that the receiver is programmed for the correct date and time, for pulses = 10 (**-P 10**), and for camera delay = 2.0 (**cd 2.0**). These are initial recommendations; change them if you have reason. For example, make the trigger more sensitive (fewer pulses) if bait is being taken but no events recorded, or increase the camera delay if a non-target animal such as a squirrel is shooting up a lot of film. Make sure that the receiver is programmed to activate the camera (see the Trailmaster manual, p. 12). A short summary of Trailmaster commands is presented in *appendix B*.

Load film into the camera. Print film of 100 ASA works well, is relatively inexpensive, and can produce enlargements of acceptable quality. Using a small, blunt tool, synchronize the date and time on the camera display with the receiver, and set the display to show the date (day number) and time, not month or year or other configuration. With the Olympus Infinity Twin, be sure that the horizontal bar over the minutes digits is showing, which indicates that the information will appear on the film.

For mustelids, an ideal site has three trees, 15-30 cm in diameter and 3-10 m apart, lined up in a north-south direction with the middle tree slightly (15 cm) offset, and a

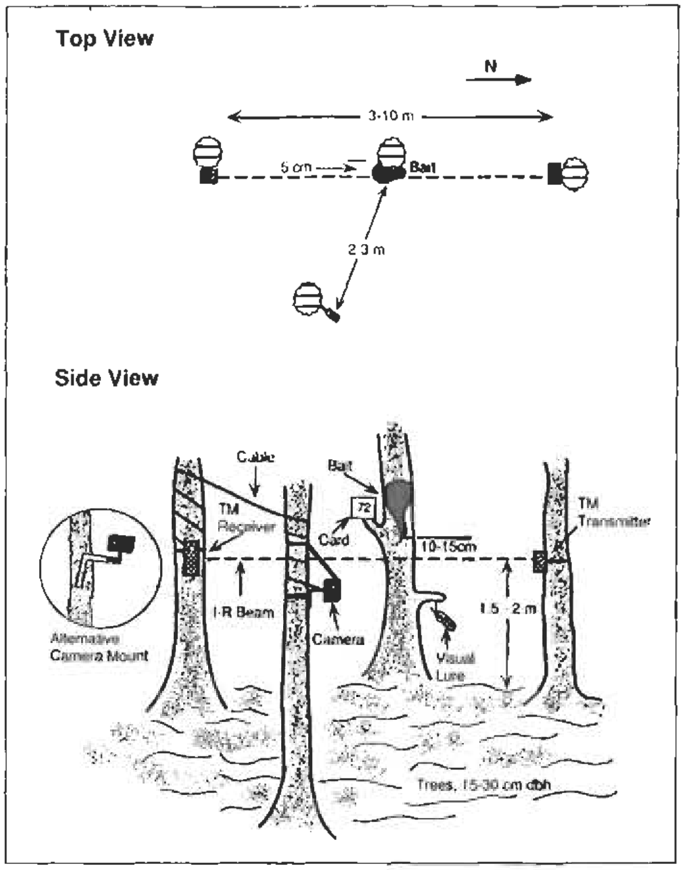

Figure 7—Schematic configuration of a single-sensor camera station.

fourth tree or a branch 2-3 m from the middle tree with a good view of it (*figs. 7, 8*). The transmitter will be in the middle of the trunk of the northernmost tree facing south, and the receiver will be on the east side of the trunk of the southernmost tree with the receiving window pointing north. This orientation is important to prevent solar infrared radiation from reaching the receiver and causing false events to be recorded. The bait will be on the middle tree, and the camera will be on the fourth tree. As an alternative, the camera can be above the receiver on the same tree. The beam should pass within 5 cm of the middle tree about 1.5-2 m above the ground. With some practice, you can easily identify the appropriate configuration of trees. Do not use trees that will move in the wind, and trim any branches that could blow into the beam or block the camera.

It is best to have one person handle the bait and another the equipment, so that no odors from the bait get on the equipment. Hang the bait along the trunk of the middle tree so that it is at least 2 m above the ground to prevent canids from reaching it. In areas of heavy snowfall, you may need to adjust the height of the bait to accommodate changing levels of snow. Attaching the bait to the tree with wire will prevent loss of the bait if the string or rope is chewed. Trim lower branches to guide animals to the bait through the beam and to eliminate perches for birds and squirrels in the beam. Add any scent as appropriate to attract animals to break the beam.

Position the transmitter on the northern tree and receiver on the southern tree so that the infrared beam passes 10-15 cm below the bait on the middle tree and about 5 cm from the tree, so that any animal climbing the tree to get the bait must pass through the beam. Look down the sighting groove on the receiver, and aim it *precisely* at the transmitter window; this is important for getting the best performance. When the approximate positions of the transmitter and receiver are established (using the receiver in setup mode with its flashing red light), tighten the receiver strap and check the alignment again.

Figure 8—Single-sensor station. Camera and receiver on tree on left, bait (deer leg) on central tree, and transmitter on tree on right.

Loosen the transmitter strap and tilt the transmitter up and down and side to side, watching when the red light on the receiver stops flashing. This is to determine where the central portion of the infrared beam is; fasten the transmitter so that this central portion of the beam hits the receiver. Check the position of the beam relative to the tree and bait by passing your hand through the beam to simulate an animal coming to the bait and watching when the red light on the receiver goes out, showing that the beam is broken. Remember, after 4 minutes the receiver automatically leaves the setup mode and the red light stops flashing. Again, sight down the groove in the receiver; adjust it so that it points directly at the transmitting window and tighten the strap, pushing the points on the back of the receiver into the tree so that the unit is firmly positioned. Visually check the transmitter to determine that the central portion of the beam is directed at the receiver, and adjust it if necessary.

If you are using the collapsible tripod supplied with the Trailmaster, attach the camera to it with the metal bracket shielding the top of the camera. Set the flash mode for **FILL-IN**, so that the flash operates on every exposure, and make sure that the self timer and continuous mode are off. Attach the camera and tree-pod to a tree or large branch about 2-3 m from the bait, with an unobstructed view centered on where you expect the animal to be. Position the camera so that the automatic focus frame in the viewfinder is on the target and not a distant background. The tree-pod should be collapsed; use duct tape to attach it to the tree. Tighten the attachment of the tree-pod to the camera, make a final alignment of the camera to the target, and tighten the ball and socket; this should be done with pliers to achieve a secure connection, but be careful not to strip the threads. A length of duct tape from the camera shield up to the tree helps prevent the camera from tipping down when weighted with snow. As a more secure alternative, attach an L-shaped metal bracket to the tree with lag bolts to provide an attachment for a more substantial ball-and-socket head such as the Bogen 3009 (*figs. 1, 7*).

Run the camera cable from the receiver to the camera, winding it several times around the trees on which the camera and receiver are placed, so that any tugging on the cable (from snow, animals, you falling down) pulls on the tree and not the equipment. Be aware that the cables are specific for the model camera used and are not interchangeable. Be sure you are using the correct one. Run the cable at least 2 m off the ground so that animals and most people pass below it. Do not plug the cable into the camera yet. Trim any branches that could be in the field of view or interrupt the beam when weighted with snow or that could lift into the field of view as snow melts. Attach a blue, 3 x 5 card with the station's identification number written in large letters with a waterproof, wide-tipped marking pen to the tree in the field of view. The card provides a scale for measurement of animals in photos and a record of location. Avoid white cards, which often are overexposed and difficult to read on the photo. Attach a laminated card with the following message to a nearby tree, positioning it out of view except when close to the set:

> This is part of an important wildlife study being conducted by ______________. Please do not touch. It is an automatic camera that will take a picture of an animal as it comes to the bait, and will not harm the animal. If you have any questions, please contact ______________________. Thank you.

Finally, when you think all is ready, plug the cable into the camera and receiver, being sure the cable is plugged in correctly. Reset the event recorder to zero, run your hand through the beam where you expect the animal to be, and be sure a picture is taken and an event recorded. If they are not, check the programming of the receiver (p. 12 in the Trailmaster manual), the camera cable, or the alignment of the beam. Make sure everything is right, and remember the 2-minute camera delay: a picture will not be taken for 2 minutes after the last picture is taken. If necessary, reset the receiver to zero and try again.

Record in your field notebook the number of photographs taken during set-up, the final event number on the receiver, and the date and time of your test photo departure. This will be important information when you return to check the camera. A sketch of the set on the Survey Record form (*appendix A* and in pocket inside back cover) will help identify what configuration works and what does not. Be generous in taking field notes; these will be used in the future to reconstruct what happened, and to analyze what went wrong and right. Use flagging tape to mark the way to the site if necessary, but do not flag the site itself, to lessen the chance of its being found by people.

Dual Sensor

We will describe a station configuration that we have used with the Manley system. If you are using the Trailmaster TM500 or another dual-sensor system, modify the station as the equipment and reason dictate. Before going out, familiarize yourself with the camera and the other components of the system and how they work. The camera will operate without film so the system can be assembled in the office to make sure all components are working properly. Set the camera so that the day, number, and time are displayed and will be printed on each picture. Make sure you have all the equipment on the list provided at the end of the chapter.

An ideal site for the dual-sensor station is the intersection of several game trails. However, if deer densities are high, setting over game trails may produce too many pictures of non-target animals. Choose a site in a sheltered area, if possible, that will be shaded for most of the day. The camera unit produces the best pictures if it faces north. An area along the trail with three trees in a triangle will work best (*figs. 9, 10, 11*). The tree at a southern point serves to support the camera and should be 3.5-5.5 m from the target point. The two other trees support the cable holding the bait and should allow the bait to be at least 3 m from any tree trunk and hang over the trail or target point. Because the Manley dual-sensor camera operates as long as a warm, moving object is in its sensor field, the bait must be inaccessible. An animal should be attracted to the station but leave shortly because it cannot reach and feed on the bait. The Trailmaster TM500 requires setting a camera delay, which avoids exposing all the film in a short time.

Suspend the bait on 1/8-inch cable between the bait trees at least 3.5 m off the ground. Use 10-m cable pieces with looped ends that will allow the cables to be hooked together to reach the appropriate length. Using a climbing belt and either removable tree steps or climbing spurs, attach one end of the cable to one tree. Then climb the other tree, wrap the cable around it as many times as needed, and anchor the cable with a nail through the looped end. Remember to place the cable high enough so the bottom of the bait will be at least 3.5 m off the ground. The bait can be suspended by attaching a rigid wire hook to the bait, roping it up to the cable, and using a pole to push it out along the cable until it hangs over the appropriate target point. If you are using heavy baits, they can be suspended using a pulley system. Attach a pulley to the cable so that when it is strung, the pulley will hang over the target point. Before suspending the cable, tie a rope to the bait (using burlap sacks to contain the bait will help) and put the rope through the pulley. Suspend the cable, keeping in mind that the pulley plus a short length of rope will cause the bait to hang lower. The bait can then be pulled up and the rope tied off to a tree. Attach a laminated card with the following message to a nearby tree, positioning it out of view except when close to the set:

> This is part of an important wildlife study being conducted by ____________________ . Please do not touch. It is an automatic camera that will take a picture of an animal as it comes to the bait, and will not harm the animal. If you have any questions, please contact ________________________ .
> Thank you.

Climb the camera tree and mount the camera at a location where it is no more than 3-4 m from the target point and sufficiently high in the tree to reduce its accessibility to people and animals (between 3-4 m). By pointing the camera slightly down to the target point, the sensor field will be shortened so that an animal will not trigger the camera before it is close enough to be illuminated by the flash. Secure the camera to the tree using the mounting bracket and lag bolts. Mount the bracket at the approximate angle and direction needed to have the camera point directly to the target point. The camera angle can be adjusted slightly after it is mounted in the tree.

To test that the sensor field is appropriate for the site, position the unit and turn it on without film in the camera. With one person in the camera tree, the other person should walk into the target area from different directions to determine where the sensors first trigger the camera. Adjust the sensor field by blocking part of the sensor with the magnetic strips provided so that the camera is triggered only when the person is near the target point and toward the center of the picture.

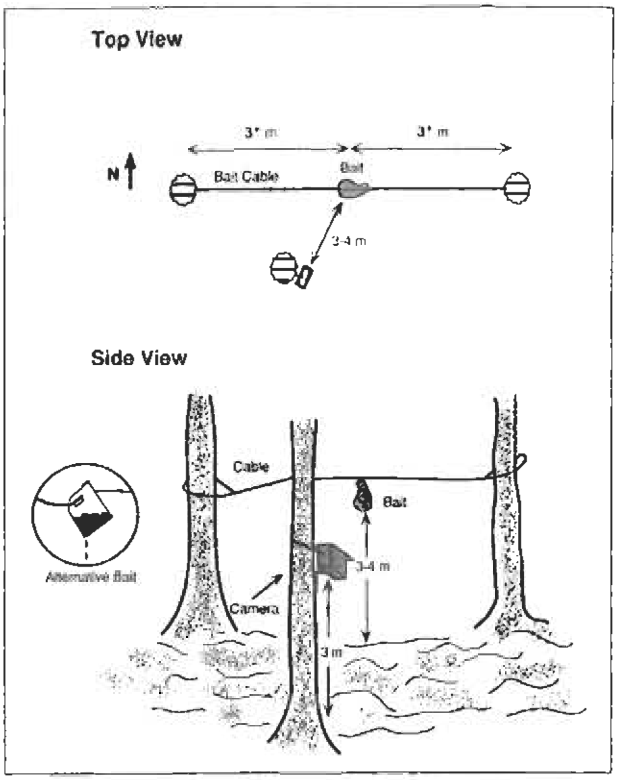

Figure 9—Schematic configuration of a dual-sensor camera station. Meat is used as an attractant, but blood baits can also be used.

Figure 10—Dual-sensor camera in position.

When the test is complete, load film in the camera and climb down the tree. With a black marker, write the station number on the back of a data sheet. Walk into the sensor field and trigger a single picture so that the station number will be identified in the photograph. Record in your field notebook the number of pictures taken during set-up, and the date and time of your departure from the site. A sketch of the site on the Survey Record form (*Appendix A* and in pocket inside back cover) including directions and approximate distances will help in evaluating the effectiveness of different configurations. Leave the site without walking through the sensor field. Write a short description of how to get to the site (a dot on an orthophoto-quad, topographic map, or aerial photo is extremely helpful), and flag the way to the site if necessary, but do not flag the site itself to lessen the chance of its being found by people.

Line Trigger

These stations are most easily established with two people, one setting up the mounting stake and camera and the other preparing the bait. If only one person is available, the camera portion should be assembled and in place before bait is handled to avoid transferring scent to the camera unit (Jones and Raphael 1993). Avoid putting stations in direct sunlight; light can penetrate these cameras. Remove vegetation so that the camera has an unobstructed view of the bait and the monofilament line is not obstructed (*figs. 5, 6*). Dig a hole about 6 inches deep for the mounting stake, put the bottom of the stake in it, and tap the soil around its base firmly to secure it. Rocks can be used for additional support or to help adjust the angle of the stake.

Load the camera with 12-exposure, 100-ASA, 110 print film, and advance it to exposure 1. Twenty- or 24-exposure film is also satisfactory but will leave more unexposed film. The date and station number should be identified on each film cartridge *before it is loaded into the camera* to avoid confusing the rolls when they are removed. This is important because there will probably be at least six cameras per sample unit. Attach the unit to the camera platform with Velcro, and if necessary, place the cut milk jug over it to protect it from rain.

Tie the monofilament line (> 20 lb test) to the 2-lb test trigger line, feed the former through the eye screws and ground wire to the washer on the "bait side" of the ground wire (*figs. 5, 12*). After attaching the line to the washer, move the ground wire away from the camera until the line is taut. The washer should be between 4 and 8 feet from the mounting stake. The second person should tie a strand of thread around the chicken and then tie the thread to the washer, leaving no more than 1 inch between the bait and the washer. Time can be saved by tying thread to all the chicken pieces you will use during the day before going into the field.

Do not rely only on the viewfinder to aim the camera. The aim will differ with the position of the observer's eye. Like all other aspects of setting up a camera, aiming should be practiced before the cameras are set up in the field. Some technicians find that the camera is properly aimed when, viewing from the bait, the operator can see neither the top of the camera nor the bottom of the platform. Others sight the bait so that it is in the lower third of the viewfinder. Still others use a length of line stretched from stake to bait to determine horizontal alignment, and straight up from the bait for vertical alignment. Placing the bait slightly uphill from the camera or angling the mounting stake slightly toward the bait will usually help center the bait in the photograph. Attach a laminated information slip with the following information to each camera stake:

Figure 11—Dual-sensor station. Camera (in box) on left and blood bait in jug suspended from line.

Figure 12—Bait attachment to ground wire, line-triggered camera system.

This is part of an important wildlife study being conducted by ____________ . Please do not touch. It is an automatic camera that will take a picture of an animal as it comes to the bait, and will not harm the animal. If you have any questions, please contact ________________.
Thank you.

When you consider the camera "set" in the field, take one or two test shots, holding a label card (a piece of 8 × 8-inch paper with the camera number, date, and station number indicated in large print) in view of the camera. Record in your field notes the number of test shots and the exposure number on which the camera is set when you leave, and then transfer this and other general information onto the Line-Triggered Camera Results form (*appendix A* and in pocket inside back cover).

Checking the Stations

Recommendations:

35-mm systems: Check the station four times at 7-day intervals so that it is operating 28 days *or* until the target species is detected. Allow extra days to achieve the minimum survey period if the station becomes inoperative. Pay particular attention to tracks in the snow near the station every time you check it.

Line-triggered system: Stations should be set for a minimum of 12 nights and checked every other day for at least six visits (excluding setup) *or* until the target species is detected. If the target species is not detected during the first 12-day session, run a second session during the alternate season (either spring or fall) for

12 days *or* until the target species is detected. Allow extra days to achieve the minimum survey period if the station becomes inoperative.

Single Sensor

The station should be checked at weekly intervals to ensure that it is working and that a non-target animal such as a squirrel has not immediately found it and used all the film. Weekly checks are also necessary to check the camera batteries which can discharge rapidly during cold winter conditions (Foresman and Pearson 1995). The station should be checked at least four times at weekly intervals, so that it is operating for 28 days.

Before you leave to check a station, be sure you have new bait and replacement film and batteries, Camera Results form (see *appendix A*, and in pocket inside back cover), contact cleaner and brush, and equipment for recording tracks in snow (see Chapter 5). Be familiar with the tracking material in Chapter 5. This is important. J. Copeland (pers. comm.) detected wolverine visits to photographic bait stations more frequently by tracks in snow than by photographs. Do not go alone, do check the weather, and bring appropriate gear. A list of equipment is provided below.

When you approach the set, look for and identify, describe, measure, photograph, and collect, as appropriate, tracks, scat, or any other sign of what may have been there. Note whether the bait is still present, whether it has been consumed, etc. Has the tree been scratched up, or have any string or wires been chewed or broken? Record these observations on the 35-mm Camera Results form (*appendix A*, and in pocket inside back cover).

Press R/O ADV to cycle through the "events" (i.e., interruptions of the beam). Record on the Camera Results form the date, event number, and time of only those events that caused a photograph to be taken (i.e., those that show a period between the first and second digit locations on the receiver's display; see "Displays" section of the Trailmaster manual). If you miss something, cycle through the data again.

After recording the event data you will know how many frames were exposed. Replace the film if half or more of the frames were shot, or if you suspect from tracks or other sign that a target species has been at the set. To rewind a roll of film before its end, press the rewind button on the bottom of the camera gently with a ball-point pen. Immediately upon removing the film, write the station code and date on it with a marking pen, and put it into a film canister to keep it dry. Check the three electrodes on the camera cable for corrosion, and clean them if necessary.

With the Yashica camera, replace the two AA batteries after 1–2 weeks in the field. Avoid getting moisture or any other contamination in the battery or film compartments, or on the rubber seals; remove any moisture with a cotton-tipped swab. The Olympus cameras have a battery display on the LCD panel when the lens cover is opened. A solid battery figure indicates that the batteries are good; an outline of a battery, either flashing or on continuously, means that the batteries must be changed. Replace them with one (Infinity Mini DLX) or two (Infinity Twin) "DL123A" or "CR123A" lithium batteries. With the Infinity Mini DLX, check the day and time display to be sure it is still correct after changing the battery.

The batteries in the Trailmaster transmitter and receiver will last for 30 days in the field. When the batteries in the transmitter are low, the red indicator light on its base will immediately come on and quickly turn off when the unit is turned off; the light will stay on, or will not flash, when the unit is turned on. The receiver has a **L o b** ("low on batteries") display and will not record events if the batteries are low. If the batteries have been in use more than 20 days, or if either the transmitter or receiver indicates low batteries, replace the batteries in both units with four new alkaline C-cells. Do this over a jacket or cloth to avoid losing the tiny hex screws or wrench when you drop them into the snow or forest litter. Always replace batteries in both units at the same time. Before replacing the backs of the transmitter and receiver, make sure the rubber-gasket seals are seated in the groove, and that there is no moisture or other contamination on them.

If you are going to keep the station in place, replace and align the transmitter, receiver, and camera as necessary. Clean the camera lens with lens tissue and fluid if it is dirty. Clear the events from the receiver. Take a test photo to determine that all is operating correctly, and record the frame and event numbers left on the units when you leave.

If you find that a bear, coyote, or gray fox (*Urocyon cinereoargenteus*) has found the station and has been frequently returning, move the station at least 0.5 miles from the first location. If smaller animals such as birds or squirrels are triggering the camera, move the beam farther below the bait or out from the tree so that smaller-bodied animals do not break it. Check to see that no branches that may serve as perches remain near the beam.

Dual Sensor

Stations should be checked 4 times at weekly intervals. When checking a station, have all the gear necessary to establish one, including extra film and batteries. A spare camera unit or two will allow you to replace faulty ones if necessary. Bring equipment for recording tracks (see Chapter 5). Be familiar with the tracking material in Chapter 5. This is important. J. Copeland (pers. comm.) detected wolverine visits to photographic bait stations more frequently by tracks in snow than by photographs.

When you approach the set, look for and identify, describe, measure, photograph and collect, as appropriate, any tracks, scat, or other sign of which animals may have been to the station. Has the bait or scent been disturbed? Has the bait tree or camera tree been climbed? Record these observations on the Camera Results form (*appendix A* and in pocket inside back cover).

Enter the sensor field with the station sign, and trigger a single picture. Climb the camera tree, turn the unit off, and open the box. Record the frame that the camera is on. If the roll is more than half exposed, or if you suspect that a target species has visited the station, remove the film. Using a digital pocket battery tester, test both the 12-v battery and camera battery, and change them if they are low (this will depend on how long the unit has been out and when you plan to visit the site again). Remember, new, fully charged batteries will probably need recharging after 20 days, so you will probably need to replace the batteries after 1–2 weeks. Put new film in the camera if needed, check the batteries, hook the unit up, and turn it on just before you climb down the tree. Enter the sensor field with a sign indicating the station number and date, and expose a single picture. Leave the site without again entering the sensor field.

Line Trigger

When checking the camera, first determine whether the film can be advanced. If so, a photograph has been taken since the last visit. Record this and other information on a copy of the Line-Triggered Camera Results form (*appendix A* and in pocket inside back cover). Examine the camera unit, and note whether the camera is functional. Reasons for non-functional cameras include the thread being chewed through, the monofilament line obstructed or broken, and misattachment of the trigger line. To verify that the unit is functional, take a test photograph at every visit. To save processing costs, take this test shot with your hand blocking the lens so that no print will be developed from this exposure. Replace the bait at every visit. Initially, replace the film after one or two exposures (excluding test shots). Once the crew is familiar with the operation of the camera and the area appears safe from vandalism and persistent bear damage, the film can be left in the camera longer. If the film is to be removed, make certain to advance it to the end of the roll before removing the cartridge. Failure to do so will result in the overexposure of the last few photographs and loss of data. Before leaving the station, make sure to advance film to the next exposure. If necessary, take additional test shots with the lens blocked to test the camera operation. Other general suggestions for checking line-triggered cameras are outlined in Jones and Raphael (1993).

Developing Film

When you remove exposed film from a camera, label it with the station number and date so that it will not be confused with other rolls. Fine-tipped, indelible markers work best. Often the least expensive developing is provided by large discount or drug stores, which typically make two prints of each exposure. Record the camera number, station number, and time period over which the film was exposed on the processing envelope *and* on the receipt. When using 110 film, if a custom-processing laboratory is available, have a contact sheet printed first. Review each frame on the sheet, and if possible, request that only those photographs that contain animal subjects be printed at full size. If custom processing is not available, and the budget is especially tight, have the negatives developed first and then select for printing only those frames that, when examined under a lens, contain an animal subject. However, there is a danger of missing something important if just the negatives are examined.

Label the back of each photograph with the species, date, and station. This same information should be entered on the Camera Results form. Archive all photographs in protective plastic covers. Examples of prints from 35-mm and 110 camera systems are presented in *appendix C*.

Data Management

We recommend three forms for data: Survey Record, Camera Results (different for 35-mm and line-triggered systems), and Species Detection form (*appendix A* and in pocket inside back cover). In wet areas or during snowy seasons, we strongly recommend using indelible ink and photocopies of the data sheets made on waterproof paper. All forms should be stored with photographs in a 3-ring binder as a permanent, complete record of what was done, where, when, by whom, and what the results were. Record all species detected. Your survey efforts can contribute to understanding the distributions of a variety of species in addition to MFLW.

Survey Record Form

This form contains information on each survey's location and details on its configuration. It is important to identify the legal description *and* the Universal Transverse Mercator (UTM) coordinates at each station. Collectively, these forms become a record of all the surveys conducted in the administrative area, regardless of their outcome.

Camera Results Form

Single and Dual Sensor

When checking stations using either the single-sensor system or the Trailmaster dual sensor, fill in the Date, Event, Number, and Time columns in the field as you cycle through the Readout/Advance mode. Record data only for those events associated with a picture, which is indicated by the decimal point between the first and second digits on the receiver's display. Fill in the Contents section after the film is developed, noting any species present.

When checking the stations using the dual-sensor system made by Manley, record in the comments section the number of frames exposed. When the film is developed, record the Date, Time, and Contents of each exposure by examining the prints. Ignore the Event column.

In a 3-ring binder, store the data sheets, negatives, and prints by sample unit and station. Put the negatives and prints in plastic sleeves made for storing film.

Line Trigger

Use this form when establishing and checking the line-triggered camera stations. Use a separate sheet for each day, and record information for each camera visit whether an exposure was taken or not. Record the station number, the camera number, and the exposure number (at both your arrival and your departure from the station) at each visit. Record the visit number (0 for setup, and 1-6 for station visits) and the number of nights since the last visit (should be two in most cases). Note also whether a photo was taken since the last visit and the number of test shots taken at each check. The species recorded will be determined after the film is processed, so that space will remain blank until later. Remember, do not terminate effort on the sample unit until the film is developed and you are certain the target species was photographed.

Species Detection Form

When a survey is successful at detecting marten, fisher, lynx, or wolverine, complete the Species Detection form, which characterizes successful surveys and is used for all methods (camera, track-plate, snow-track). Complete one form for each species detected. Submit one copy to the state Natural Heritage office (addresses provided in Chapter 1), and archive a copy at the office of the agency that manages the land where the survey was conducted. Most Natural Heritage databases record only positive results from detection surveys.

Comparisons of Camera Systems

The perfect remote camera system is yet to be developed. In this section we discuss some of the strengths and weaknesses of each of the camera systems described to allow investigators to decide which may be most appropriate for their circumstances.

The first major difference between 35-mm and line-triggered systems is in the cost of the equipment. The 35-mm systems cost $500-$600, and the line-triggered systems less than $25. This substantial difference in initial price, however, may be mitigated by differences in labor involved in the construction of the equipment and the frequency of checking the stations. The 35-mm systems require virtually no assembly upon receipt from the manufacturer. The line-triggered system must be built by the user. Because the 35-mm systems can shoot an entire 36-exposure roll of film, they may be left in the field longer without being checked than the line-triggered systems, which can take only one picture and then must be rebaited and reset. However, damage or loss from vandalism, theft, or bears is more serious with the 35-mm systems than with the line-triggered system. Both of the 35-mm systems can be more readily used in severe weather, especially winter, than the line-triggered cameras.

Another difference between the two types of camera system is the triggers. The 35-mm systems use infrared (single sensor) or infrared and microwave (dual sensor) triggers, which require only that an animal be near the bait to be photographed. In contrast, animals must physically pull the bait to be photographed by the line-triggered system. In addition, the sensitivity of the triggers on several of the 35-mm systems is adjustable, and the film displays the date and time. The line-triggered camera lacks these features. Jones and Raphael (1991) found that half of all photos taken by line-triggered cameras did not record a subject and that 65 percent of these problems were due to failure of the disposable ("flip") flash. However, the 110 camera recommended here has an internal flash that rarely fails.

Of the 35-mm systems we discussed, the Trailmaster TM1500 allows the user to specify the minimum length of time between photographs to lessen the probability that one animal will expose most of the film. Although this is not possible with the Manley dual-sensor model, the dual sensor made by Trailmaster (TM500) does have this feature. With the single-sensor camera system the animal must break a narrow infrared beam. The dual-sensor system requires only that an animal come into the field, up to 11 m from the camera. However, dual-sensor systems may be triggered when the sun heats up the background, so it is best to use them in cold conditions. The TM1500 uses eight alkaline "C" cells; the Manley dual sensor uses a heavier 12-volt battery, which is more difficult to transport. Some 12-volt batteries may leak; gel-cell batteries that do not leak can be used but at greater expense. The difference in batteries accounts for the approximately 10-kg difference in the weight of the two systems. Both Trailmaster models store the date and time of all "events." The Manley dual-sensor system is housed in a metal box, which affords some protection from weather and bear damage and can be modified to be locked shut and cabled to a tree to help prevent theft and vandalism.

Other commercially available products may resolve some of the problems with dual-sensor systems. The Trailmaster TM500 uses four alkaline C-cells, and the Deerfinder uses six D-cell and two AAA batteries, which results in much more portable systems. The TM500's batteries last several months in the field. These dual-sensor systems also allow the programming of a camera delay and store the date and time of up to 1000 (Trailmaster) or 495 (Deerfinder) events. We do not yet have extensive field experience with these systems, but preliminary results from simultaneous use of the Manley and TM500 dual-sensor systems indicate great advantages of the lighter weight, ability to program a camera delay, and storage of event data provided by the TM500 (K. R. Forseman, pers. comm.). The TM500 also allows adjusting of the sensitivity of its dual-sensor trigger, which may prevent small, non-target species from triggering the camera.

Remote video technology also is advancing, and video has several obvious advantages over still photography. Video tape does not require developing, and it may be used repeatedly. Video systems allow continuous photographic monitoring rather than a "snapshot," and can record several hundred "events," rather than the 36 events possible on a standard roll of film. Trailmaster offers a modified Sony Handycam camcorder to be used with the Trailmaster TM700v. A dual-sensor monitor turns the video camera on when it detects motion and heat, and turns the camera off when the animal moves out of range of the sensors. The tape lasts 2 hours, and the system stores the date and time of up to 1000 events. Other remote video systems are available from Compu-Tech Systems. Remote videography has been used to detect fishers in Oregon (S. Armentrout, pers. comm.; F. Wahl, pers. comm.). We have had no experience with these systems, however, and their cost (several thousand dollars) will probably prevent their common use in detection surveys.

In summary, the line-triggered system is inexpensive but requires more labor and is less versatile and rugged than the 35-mm systems. Once the bait is taken, the camera must be reset for another picture; date and time are not displayed on the film. The 35-mm systems are initially expensive, but require no assembly and because they can shoot an entire roll of film, they require less labor. The single-sensor's trigger requires precise placement of the system and can be adjusted for sensitivity. The Trailmaster allows the minimum interval between pictures to be set by the user and electronically stores the date and time of each event. Dual-sensor systems can detect animals over a broader field, the size of which is somewhat adjustable. The Manley dual sensor uses a heavy, 12-v battery, does not allow a minimum interval between photographs to be set, does not store the date and time of events, and is housed in a metal box that provides mechanical protection and may be locked. All Trailmasters operate with alkaline C-cells. The TM500 dual sensor allows specification of a minimum interval between photographs of 1 to 98 minutes, stores the date and time for up to 1000 events, and allows adjustment of the sensitivity of the trigger.

Costs

Assumptions for 35-mm systems:

- Five adjoining sample units, 4 mi^2 each, are surveyed.
- Five camera systems are available. Dual-sensor stations use Manley systems.
- There are two stations per sample unit for a total of 10 stations; stations will be established in two sessions of five stations each.
- There is one survey per year, in winter; each station operates for 30 days; the station is visited after 2 and 14 days and is removed after 30 days. No target species is detected.
- The work is conducted by a team of two federal employees paid at $75.00/ person/day. No contractors are used.
- All sample units have adequate road access.

Single Sensor

Session 1

1. Labor		
Planning	2 person-days (pd)	
	2 pd × $75 =	$150
Training	2 pd × $75 =	150
Establish stations, 1 station/pd	5 pd × $75 =	375
Station visits, 4 visits/station	0.5 pd/visit 5 stations	
	10 pd × $75 =	750
Data analysis	4 pd × $75 =	300
Subtotal for Session 1 Labor		1725
2. Vehicles and Gas		300
3. Materials and Supplies		
Trailmaster TM1500	5 @ $550 =	2750
Film and processing	10 rolls @ $15 =	150
Batteries, miscellaneous		200
Subtotal for Session 1 Materials		3100
Session 1 Total		*$5125*

Session 2

1. Labor - Same as for Session 1		1725
2. Vehicles and Gas - Same as for Session 1		300
3. Materials and Supplies		
Film and processing	10 rolls @ $15 =	150
Batteries, miscellaneous		200
Subtotal for Session 2 Materials		350
Session 2 Total		$2375
Grand Total - Single Sensor		***$7500***

Dual Sensor

Session 1

1. Labor - will be same as for single sensor $1725
2. Vehicles and Gas - same as for single sensor 300
3. Materials and Supplies
    - Dual-sensor remote cameras .... 5 @ $ 475 = ... 2375
    - 12-volt batteries .... 10 @ $ 40 = ... 400
    - Film/developing - same as single sensor 150
    - Camera batteries .... 8 @ $ 8 = ... 64
    - 12-volt battery charger 35
    - Pocket volt meter 30
    - Tree steps .... 10 @ $ 3 = ... 30
    - Climbing safety belt 15
    - Ratchet/sockets 15
    - Brush clipper or pruning saw 15
    - Equipment for bait set-up 5

Subtotal for Session 1 Materials 3134

Session 1 Total *$5159*

Session 2

1. Labor - same as for Session 1 1725
2. Vehicles and Gas - same as for Session 1 300
3. Materials and Supplies
    - Film and processing 150
    - Camera batteries .... 8 @ $ 8 = ... 64
    - Misc. replacement equipment 50

Subtotal for Session 2 Materials 264

Session 2 Total *$2289*

Grand Total - Dual Sensor ***$7448***

Line Trigger

Assumptions:

- Five adjoining sample units, 4 mi^2 each, are surveyed simultaneously for a total survey area of 20 mi^2.
- There are six stations per sample unit (a total of 30 stations) that are checked during the entire survey period, 12 nights.
- All sample units have adequate road access.
- It is assumed that no target species are detected during the survey. Because a survey is terminated when the target species is (are) detected, costs can be significantly less if the target species is detected early in the survey period.
- There are two surveys per year, during fall and spring.
- The work is conducted by a crew of federal employees paid about $75.00/person/day. No contractors are used.

Season 1

1. Labor

Planning	2 person days (pd)	
	2 pd × $75/ =	$150
Training	2 pd × $75 =	150
Materials acquisition and construction	5 stations/day	
	6 pd × $75 =	450
Establish stations 10 stations/pd	3 pds × $75 =	225
Stations visits	6 at 2-day frequency	
	6 × 30 =180 visits 20 stations/pd	
	= 9 pds (including ≥ 1 Sunday @ time + 1/2)	
	(8 × $75) + (1 × 112) =	712
Station removal, plate cleaning, data analysis	4 pds × $75 =	300
Subtotal, Season 1 Labor		1987
2. Vehicles and Gas		700
3. Materials and Supplies		
Camera stations	$15/station × 30	450
Extra cameras and miscellaneous supplies		250
Subtotal, Season 1 Materials		700
Season 1 Total		*$3387*

Season 2

1. Labor		
Plan, survey, establish, visit, and remove stations		1387
2. Vehicles and Gas		700
3. Materials and Supplies		
Cameras	replace 15 percent of first season's stations 5 stations × 15 =	75
Miscellaneous supplies		250
Subtotal, Season 2 Materials		325
Season 2 Total		$2412
Grand Total - Line Trigger		***$5799***

Equipment List

Single Sensor

- ☐ Trailmaster transmitter and receiver
- ☐ Tree pod, or ball-and socket head
- ☐ Bait and scent
- ☐ Data forms
- ☐ Maps and aerial photos
- ☐ Parachute cord/string
- ☐ 3×5 cards
- ☐ Flagging tape
- ☐ Spare batteries (eight alkaline C-cells, two 123A lithium camera)
- ☐ Cameras
- ☐ Spare allen screw
- ☐ Duct tape
- ☐ Push pins
- ☐ Wire
- ☐ Pliers
- ☐ Pruning saw
- ☐ Do-not-disturb signs
- ☐ Film
- ☐ L-bracket and lag bolts
- ☐ Allen wrench and spares
- ☐ Contact cleaner and brush
- ☐ Copies of Trailmaster manuals
- ☐ Waterproof pen
- ☐ Cotton-tipped swabs
- ☐ Spare camera cable(s)

Dual Sensor

- ☐ Cameras
- ☐ Camera batteries
- ☐ Flagging tape
- ☐ Pocket volt meter
- ☐ Nails
- ☐ Pruning saw
- ☐ Copies of camera and sensor manuals
- ☐ Sensors
- ☐ 12-volt batteries
- ☐ Wire
- ☐ Tree steps
- ☐ Bait and scent
- ☐ Station ID signs
- ☐ Waterproof pen
- ☐ Camera boxes
- ☐ Film
- ☐ Maps and aerial photos
- ☐ Rope and climbing belt
- ☐ 1/8-inch cable for suspending bait
- ☐ Data forms

Line Trigger

- ☐ Cameras
- ☐ Bait and scent
- ☐ Soap and water
- ☐ Coat hanger for ground wire
- ☐ Stereo wire
- ☐ Velcro
- ☐ Silicone sealant
- ☐ 2-lb and ≥ 20-lb monofilament line
- ☐ Film
- ☐ Data forms
- ☐ 3 × 5 cards
- ☐ Thread
- ☐ Soldering equipment
- ☐ Shovel
- ☐ Duct tape
- ☐ Auxiliary battery pack
- ☐ Mounting stake
- ☐ Milk jug
- ☐ Washers
- ☐ D-cell batteries
- ☐ Heavy rubber bands
- ☐ Fence staples or eye screws
- ☐ Electrical tape

References

Armentrout, S., Wildlife Biologist, Rogue River National Forest. Prospect, OR. [Personal communication]. 1994.

Armstrong, B.; Williams, K. 1986. **The avalanche book**. Golden, CO: Fulcrum, Inc.

Arthur, S.M.; Krohn, W.B. 1991. **Activity patterns, movement and reproductive ecology of fishers in south central Maine**. Journal of Mammalogy 72: 379–385.

Baker, J. A.; Dwyer, P. M. 1987. **Techniques for commercially harvesting furbearers**. Novak, M.; Baker, J. A.; Obbard, M. E.; Malloch, B., eds. Wild furbearer management and conservation in North America. North Bay, ON: Trappers Association; 970-995.

Banci, V. 1989. **A fisher management strategy for British Columbia** Wildlife Bulletin No. B-63 Victoria, BC: Ministry of Environment;117 p.

Bull, E. L.; Holthausen, R S.; Bright, L. R. 1992. **Comparison of three techniques to monitor marten**. Wildlife Society Bulletin 20: 406-410.

Chow, L., Wildlife Biologist. National Biological Service, Yosemite Research Center. El Portal, CA [Personal communication]. 1993

Copeland, J. P., Wildlife Biologist. **Department of Fish and Game**. Stanley, ID. [Personal communication]. 1993.

Daffern, T. 1992. **Avalanche safety for skiers and climbers**. Seattle, WA: Cloudcap.

Danielson, W.R.; Fuller, T.K.; DeGraaf, R.M. 1995. **An inexpensive, reliable, and compact camera system for wildlife research**. Unpublished draft supplied by authors.

Forgey, W. W. 1991. **The basic essentials of hypothermia**. Merrillville, IN: ICS Books, Inc.

Forseman, K. R., Professor of Biology. University of Montana. Missoula, MT. [Personal communication]. 1995.

Foresman, K.R.; Pearson, D.E. 1995. **Testing of proposed survey methods for the detection of wolverine, lynx, fisher and American marten in Bitterroot National Foreset**. Final Report. Unpublished manuscript supplied by authors.

Fowler, C., Wildlife Biologist. Tahoe National Forest, Foresthill, CA. [Personal communication]. 1992.

Fowler, C. H.; Golightly, R. T. 1993. **Fisher and marten survey techniques on the Tahoe National Forest.** Final Report. Agreement No. PSW-90-0034CA. Arcata, CA: Humboldt State University Foundation and Forest Service, U.S. Department of Agriculture; 119 p.

Geary, S. M. 1984. **Fur trapping in North America**. Piscataway, NJ: Winchester Press; 154 p.

Gorman, S. 1991. **AMC guide to winter camping: wilderness travel and adventure in the cold-weather months**. Boston, MA: Appalachian Mountain Club Books

Halfpenny, J. C.; Ozanne, R. 1989. **Winter, an ecological handbook**. Boulder, CO: Johnson Publishing Co.

Hash, H. S. 1987. **Wolverine**. In: Novak, M.; Baker, J. A.; Obbard, M. E.; Malloch, B., eds. Wild furbearer management and conservation in North America. North Bay, ON; Ontario Trappers Association; 575-585.

Hatler, D. F. 1989. **A wolverine management strategy for British Columbia**. Wildlife Bulletin No. B-60. Victoria, BC: Ministry of Environment; 135 p.

Holden, T., Wildlife Biologist, Malheur National Forest. Prairie City, OR. [Personal communication]. 1994.

Hornocker, M. G.; Hash, H. S. 1981. **Ecology of the wolverine in northwestern Montana**. Canadian Journal of Zoology 59: 1286-1301.

Jones, L. C.; Raphael, M. G. 1991. **Ecology and management of marten in fragmented habitats of the Pacific Northwest. Progress Report FY91**. Portland, OR: Pacific Northwest Research Station, Forest Service, U.S. Department of Agriculture; 36 p.

Jones, L. L. C.; Raphael, M. G. 1993. **Inexpensive camera systems for detecting martens, fishers, and other animals: guidelines for use and standardization**. Gen. Tech. Rep. PNW-GTR-306. Portland, OR: Pacific Northwest Research Station, Forest Service, U.S. Department of Agriculture. 22 p.

Kucera, T. E.; Barrett, R. H. 1993. **The Trailmaster camera system for detecting wildlife**. Wildlife Society Bulletin 21: 505-508.

Kucera, T. E.; Barrett, R. H. 1995. **Trailmaster camera system: response**. Wildlife Society Bulletin 23: 110-113.

Laurance, W. F.; Grant, J. D. 1994. **Photographic identification of ground-nest predators in Australian tropical rain forests.** Wildlife Research 21: 241-248.

Mace, R. D.; Minta, S. C., Manley, T.; Aune, K. E. 1994. **Estimating grizzly bear population size using camera sightings**. Wildlife Society Bulletin 22: 74-83.

Major, R. E.; Gowing, G. 1994. **An inexpensive photographic technique for identifying nest predators at active nests of birds**. Wildlife Research 21: 657-666.

Martin, S. K. 1994. **Feeding ecology of American martens and fishers**. In: Buskirk, S. W.; Harestad, A. S.; Raphael, M. G.; Powell, R. A., eds. Martens, sables, and fishers: biology and conservation Ithaca, NY: Cornell University Press; 297-315.

Pittaway, R. J. 1978. **Observations on the behavior of the fisher (*Martes pennanti*) in Algonquin Park, Ontario**. Le Naturaliste canadien 105: 487-489.

Pittaway, R. J 1983. **Fisher and red fox interactions over food**. Ontario Field Biologist 37: 88-90.

Pozos, R. S.; Born, D. O. 1982. **Hypothermia: causes, effects, prevention**. Piscataway, NJ: New Century Publishers, Inc.

Raphael, M. G., Barrett, R. 1984. **Diversity and abundances of wildlife in late successional Douglas-fir forests**. In: Proceedings, New Forests for a Changing World, 1983 SAF National Convention, Portland, OR. Washington, DC: Society of American Foresters; 34-42.

Schimelpfenig, T.; Lindsey, L. 1991. **NOLS wilderness first aid**. Lander, WY: National Outdoor Leadership School Publications.

Seglund, A. E.; Golightly, R. T. 1993. **Fisher survey techniques on the Shasta-Trinity National Forest. Progress Report**. Unpublished draft supplied by authors.

Sheneman, J., Medical Doctor, California Department of Health Sciences. Berkeley, CA. [Personal communication]. 1992.

Strickland, M.A.; Douglas, C.W.; Novak, M.; Hunzinger, N.P. 1982. **Marten**. In: Chapman, J.A.; Feldhamer, G.A., eds. Wild mammals of North America: biology, management, and economics. Baltimore, MD: Johns Hopkins University Press; 599–612.

Wahl, F., Wildlife Biologist, Rogue River National Forest. Butte Falls, OR. [Personal communication]. 1995

Weiss, H. 1988. **Secrets of warmth: warmth for comfort or survival**. Brooklyn, NY: Vibe Publications.

Wilkerson, J. A., ed. 1992. **Medicine for mountaineering and other wilderness activities**. 4th ed. Seattle, WA: The Mountaineers.

Wilkerson, J. A., Bangs, C. C.; Hayward, J. S., eds. 1986. **Hypothermia, frostbite, and other cold injuries: prevention, recognition, and prehospital treatment**. Seattle, WA: The Mountaineers.

Wilkinson, E. 1992. **Snow caves for fun and survival**. Boulder, CO: Johnson Publishing Co.

York, E.C.; Fuller, T.K.; Powell, S.M., DeGraaf, R.M. 1995. **A description and comparison of techniques to estimate and index fisher density**. Unpublished draft supplied by authors.

Young, S. P. 1958. **The bobcat of North America**. Washington, DC: Wildlife Management Institute.

Zielinski, W. J.; Truex, R.; Ogan, C.; Busse, K. 1995. **Detection survey for fishers and martens in California 1989-1994: summary and interpretations**. Edmonton, AB: Second International *Martes* Symposium. Unpublished draft supplied by authors.

Appendix A—Data Forms

SURVEY RECORD FORM

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. or m?)

(use another sheet if necessary)

Vegetation type (s) ____

Date installed (or run) _________________ Date terminated ________________

Type of bait or scent ____

Name, address, and phone of investigator _______________________________

____

____

35-mm Camera Results

Date: ____________________ Station ID: ____________________

Comments (condition of site and bait, new batteries and bait, etc.): ____________________

____

____

Settings for TM 1500: Pulses ____________ Camera Delay ____________

TM 500: Pulses ____________ Pt ______ Camera Delay ____________

Date	Event[a]	Frame	Time	Contents
		1		
		2		
		3		
		4		
		5		
		6		
		7		
		8		
		9		
		10		
		11		
		12		
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		31		
		32		
		33		
		34		
		35		
		36		
		37		

Left on Frame # __________ and Event # ____________ at __________ hours

[a] Only for cameras (e.g. Trailmaster) that store events.

Line-Triggered Camera Results

Observer ______ Weather [a] ______ Date ____________________ Page ___ of ___

Location ____

General Comments ____

Station Number	Camera Number	Exposure Number [b]		Visit Number	Nights since last visit	Animal [c] photo?	Number [d] of test shots	Outcome [e]	Comments
		arriving	leaving						

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

[b] Note the exposure number (on camera back) when arriving AND when leaving the station.

[c] Indicate, Y or N, whether a photogragh was taken since the last visit.

[d] Indicate the number of test shots taken during the visit.

[e] If no new exposure, enter a dash. If a photograph has been taken enter either the four-letter species code (eg. MAAM, for marten; NOSB, no subject; UNKN, unknown; or NULL, improper exposure) after the film has been processed.

SPECIES DETECTION FORM

Please complete each field after a survey has detected either lynx, wolverine, fisher, or marten, and send a copy to your state's Natural Heritage Division (addresses in Chapter 1) and other appropriate entities. The meaning of each code is explained on the following page. It is important to coordinate with the State Wildlife Agency/Natural Heritage Program within your State to assure uniform codes are used for federal lands, parks, private lands, counties, etc.

1. **SPEC** ______________
2. **DATE** ______________
3. **STATE** ______
4. **CO** ____
5. **LOC** ____
6. **QUAD** ____________________
7. **QUADNO** ________________
8. **OWN** ________

8a. **FOR/PARK** ______________

8b. **DISTRICT** _______________

9. **RNG** __
10. **TWN** __
11. **SEC** ____
12. **QSEC** ____
13. **SIXTHSEC** _______
14. **M** ___
15. **Z** ___
16. **UTM_N** __________________________
17. **UTM_E** _______________________
18. **OBS** ____
19. **SVTP** _
20. **STA_NO** __________
21. **TR_NO** .
22. **ELEV** _
23. **COMMENTS** ____

____

CODES FOR THE SPECIES DETECTION FORM

1. **SPEC** - Species; 1 letter: L = lynx, W = wolverine, F = fisher, M = marten.
2. **DATE** - Date; year, month, day; e.g., Jan. 12, 1994 = 19940112.
3. **STATE** - State; use 2-letter postal abbreviation, e.g., MT, OR.
4. **CO** - County; use 2-letter code, e.g., AP=Alpine, HU=Humboldt
5. **LOC** - Locale; the most specific names possible using names found on USGS maps, e.g., Grizzly Creek. 20 characters.
6. **QUAD** - Name of USGS topographic quad showing survey area; if >1, use additional sheets, e.g., Ship Mountain. 20 characters.
7. **QUADNO** - USGS quad number utilizing latitude and longitude identification system.

*8. **OWN** - Landowner. 4-letter code, e.g., USFS, NPS, BLM, CA, PVT.

8a. **FOR/PARK** - National or State Forest or Park name. 3 characters.

8b. **DISTRICT** - Subdivision of Forest or Park (e.g., Ranger District if "OWN" = USFS. 3 characters.

9. **RNG** - Range. 3-characters.
10. **TWN** - Township. 3-characters.
11. **SEC** - Section. 2-characters.
12. **QSEC** - Quarter section. 2 characters.
13. **SIXTHSEC** - Sixteenth section. 2 characters.
14. **M** - Meridian. 1-character.
15. **Z** - UTM zone. 2-characters.
16. **UTM_N** - UTM-north coordinate; 7-characters.
17. **UTM_E** - UTM-east coordinate; 6-characters.
18. **OBS** - Observer; last name, first name, middle initial of survey crew leader. 20 characters.
19. **SVTP** - Survey type: SNSS = snow-tracking survey (searching); SNSB = snow-tracking survey (at bait); TRPL = track plate; CAMR = camera (35-mm or 110).
20. **STA_NO** - Station number of detection (if camera or track plate). 2 characters.
21. **TR_NO_** - Number of snow transect where detection occurred. 2 characters.
22. **ELEV** - Elevation at detection site. 5 characters.
23. **COMMENTS** - 30 Characters.

* Each state will need to develop 2-3 character codes for specific forests, parks, private landowners and districts therein.

Appendix B—Trailmaster TM1500 commands

1. When first programming the unit, or after changing batteries, when all memory is erased: Press TIME SET then R/O ADV to advance to correct hour. Repeat this command to correct the following: minute, year (tens), year (ones), month, day of month, pulses, and camera delay.

To enable photographs at all times:

- Press and hold TIME SET and press SET UP; **0:1n** should be displayed.
- Press R/O ADV so that the display shows **1:1n.** (In fact, any non-zero digit is fine.)
- Press TIME SET to cycle through the next 7 displays (e.g., **1n:00, 0:1F.** etc.). All these should contain zeros; if they do not, press R/O ADV until they do contain zeros.
- Press TIME SET, and the system will return to Time-Date-Time-Event (T-D-T-E) mode.

2. To read out event data:

- Press R/O ADV once to see date of first event; press it again to see the event number and the time; press it again to see the next event number and the time.

3. To clear event data (note: this does not change pulses or camera delay):

- Press SET UP once or twice so that the display reads **S. uP.**, then press R/O ADV (the display will show **clr**), then press TIME SET. The system shows zero events and automatically goes into event-gathering mode. If you do not want to clear the data when the display reads **clr**, press R/O ADV and it returns to setup mode, or press SET UP and it returns to T-D-T-E mode.

4. To put receiver into Event Gathering Mode:

- With **S. uP** or **clr** displayed, press TIME SET.

Appendix C

A. Fisher; Klamath National Forest, California. Single-sensor camera.

B. Fisher; Six Rivers National Forest, California. Single-sensor camera.

C. Marten; Sierra Nevada, California. Single-sensor camera.

D. Marten; Sierra Nevada, California. Single-sensor camera.

E. Lynx; Montana. Dual-sensor (Manley) camera.

F. Wolverine, Sawtooth National Forest, Idaho. Dual-sensor (Manley) camera.

G. Wolverine, Sawtooth National Forest, Idaho. Dual-sensor (Manley) camera.

H. Marten, Sequoia National Forest, California. Line-trigger camera.

I. Marten; Sequoia National Forest, California. Line-triggered camera (note enclosed track plate box in background).

J. Fisher; Six Rivers National Forest, California. Line-triggered camera.

K. Fisher; Sequoia National Forest, California. Line-triggered camera.

L. Juvenile fisher, Six Rivers National Forest, California. Line-triggered camera.

Track Plates

William J. Zielinski[1]

Introduction

A carbon-sooted aluminum track surface has been used in a variety of ways to detect mammalian carnivores. The method was developed first to monitor rodent abundance (Mayer 1957) and was adapted for use with carnivores by Barrett (1983) to survey for American martens. This application enclosed an aluminum plate in a plywood box ("cubby") that was attached to the side of a tree. Bait was placed near the back of the box. Track impressions were "negatives," in that they were created when an animal's foot removed soot and revealed the underlying plate surface. A record of the track was created by transferring the track image to transparent tape by pressing the tape onto the track and lifting the tape. The method was also adapted for more general use by placing a larger (162.8 × 81.4 × 0.06-cm) unenclosed plate on the ground with bait attached to the center (Barrett 1983, Raphael and Barrett 1984, Raphael 1988). Marten and fisher were detected using this method, but neither wolverine or lynx has been detected at these stations (M. Raphael, pers. comm.).

In 1991 the technique was significantly improved with the addition of a surface capable of collecting a positive track impression (Fowler and Golightly 1991). A slightly tacky, white paper (commercially available Con-Tact[2] paper used to line cabinets and drawers) was placed across the distal end of a rectangular sheet of sooted aluminum. The plate was inserted into a plywood box to protect it from moisture and debris, and the box was scaled to a size that would permit the entrance of marten and fisher (30.0 × 26.7 × 81.3 cm). The soot that adhered to an animal's foot as it entered the box was transferred to the white paper when the animal walked to the rear of the box. The positive track impression, often transferred in great detail, was cut out from the paper and stored in a clear acetate envelope. The clarity of tracks is sufficient to distinguish the previously confusing male marten and female fisher tracks using discriminant function analyses (Zielinski and Truex 1995).

I will describe the use of two types of sooted aluminum plates. The first is the enclosed plate system that records tracks on white paper. This device has been effective at detecting marten and fisher (Fowler and Golightly 1991; Zielinski and others 1995) and was the detection device recommended in the original USDA Forest Service protocol for detecting these two species in Region 5, California (Zielinski 1992). The second device is the larger, unenclosed plate without the track-receptive paper (Barrett 1983, Raphael and Barrett 1984). Despite this shortcoming, this is the only adequately field-tested track-plate method that is capable of detecting all four species, although neither lynx nor wolverine has been detected. However, it is more likely that they would be detected on the uncovered track plate than on a plate in a relatively small box.

A logical combination of the two approaches is to enclose the large plate, partially covered with Con-Tact paper, in a large box. However, boxes larger than that recommended in the Forest Service, Region 5 protocol have not received much testing. Large plywood boxes (35.6 × 38.1 × 78.7 cm) and even larger cardboard boxes (61.0 × 61.0 × 86.4 cm) were used in a modest pilot test in northern Idaho, where all four species were thought to occur, but each box detected only marten (A. Dohmen, pers. comm.). A 40.6 x 30.5 x 81.3-cm version was used in a study of the mammalian

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[2]The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

carnivores associated with the Sacramento River in California (J. Souza, pers. comm.), but none of our four species of interest occurs at that location.

Description of Devices

Track-Plate Box

This device is composed of a carbon-blackened aluminum plate (20 × 76.2 × 0.1 cm) partially covered with white contact paper that is enclosed in a plywood box with the inside dimensions 25.4 × 25.4 × 81.3 cm (*figs. 1, 2*). Bait is placed at the back of the box, beyond the Con-Tact paper. The box described here is designed to be placed on the ground. Somewhat smaller boxes have been attached to the boles of trees (Barrett 1983, Martin 1987), presumably to dissuade visits by non-target species. However, this assumption has not been tested, and because arboreal plates require more time to install and are more expensive than terrestrial boxes, they will not be described in detail here. Those interested in attaching boxes to trees should consult the references cited above.

The aluminum plate should be about 1 mm thick (0.063 gauge). Thicker material has no advantage and is heavier. Aluminum can usually be acquired as flat stock from a

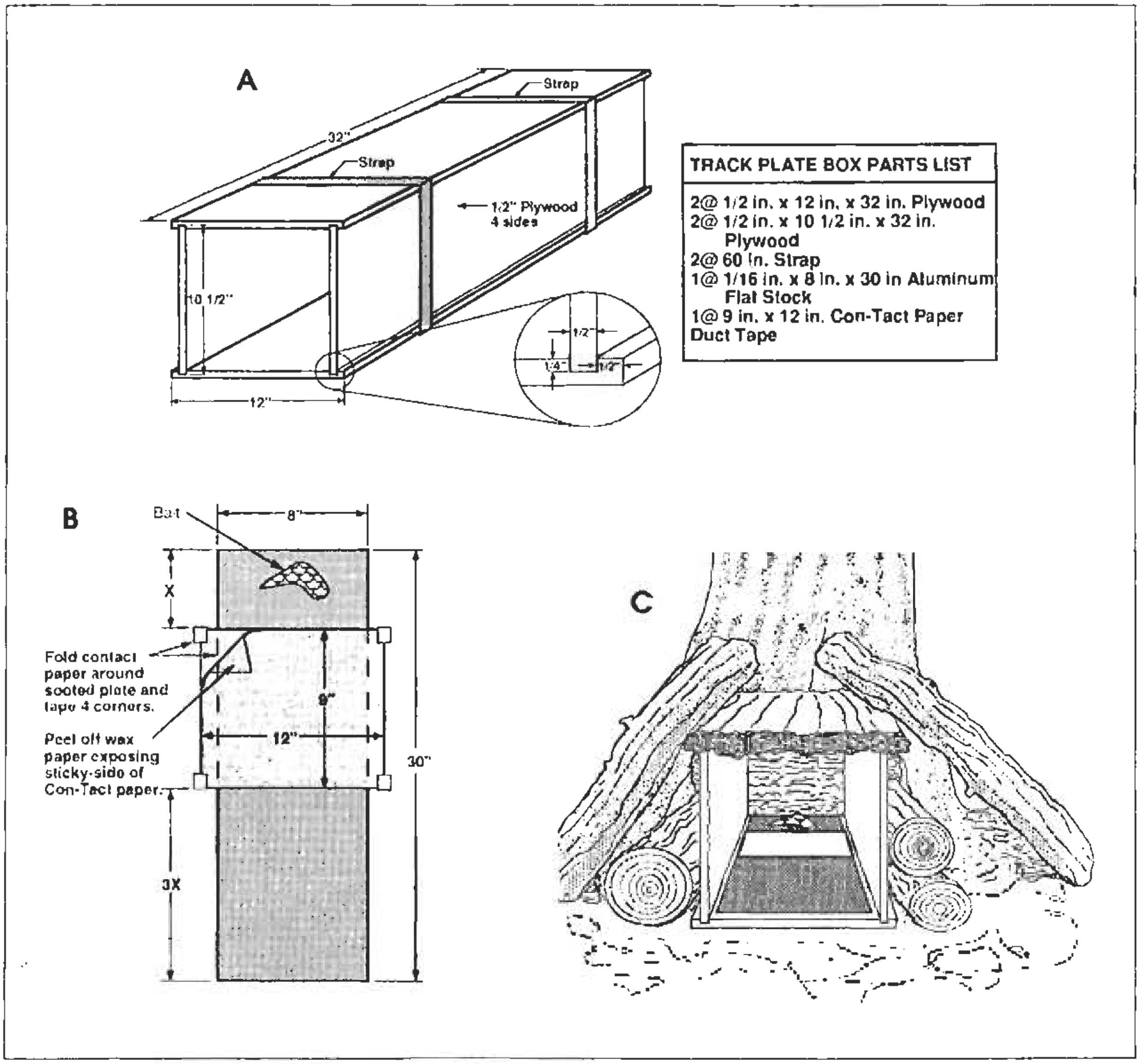


Figure 1—Schematic drawings of a track-plate box station and its components: A) wooden, plywood track box, B) sooted aluminum plate with Con-Tact paper, C) established station in field. (Based on original figure in Fowler and Golightly 1993).

sheet metal shop, but some biologists have received donated aluminum from newspaper publishers (e.g., J. Souza, pers. comm.). The preferred method for applying soot is with acetylene gas from a welding torch. Carbon production is maximized by covering the oxygen intake on the nozzle with duct tape. Alternatively, the soot can be applied from a burning kerosene-dipped wand. Suspend the plates horizontally above the ground between sawhorses (or some similar support), and soot them from below as the soot rises. Soot the plates outdoors in a well-ventilated area. A water source should be available at all times to prevent spread of fire. A half-mask respirator and safety glasses are recommended to minimize inhalation of the soot (see Safety Concerns). If the respirator is not available, wear a dust mask to block large particulates. Soot should cover the plate evenly and lightly; do not oversoot, as excessive soot may produce a poor quality track on the paper. The area of the plate that will be covered with the paper need not be sooted. When learning the process, test that the soot is sufficient by transferring some from the plate to a piece of Con-Tact paper with your finger.

Carpenter's chalk, dissolved and applied in isopropyl alcohol, has also been used as a tracking medium (G. Fellers, pers. comm.; Orloff and others 1993). In the best circumstances, under completely dry conditions, the results can approach the quality of those from a carbon-sooted plate (Orloff and others 1993; W. Zielinski, pers. observ.). However, track quality can be quite poor under even moderately damp conditions, so the use of chalk is not recommended to detect the forest carnivores considered here.

After the plate is sooted, wrap a 31- × 23-cm piece of Con-Tact paper, with sticky side up and backing intact, around the plate, and tape it to the back of the plate using pieces of duct tape. Align the paper so it is slightly rear of the center of the plate but with about 9 cm of exposed plate beyond it where the bait is placed (*fig. 1B*). To save time, prepare the pieces of Con-Tact paper and duct tape in advance. Keep the protective backing on the paper until the plate is placed in the field for use, and then peel it off.

The box is constructed of four pieces of 1/2-inch, medium-grade plywood (*fig. 1A*). The back of the box is open to facilitate construction and transportation and to minimize cost. The top and bottom pieces should have two, approximately $^{1}/_{2}$-inch grooves running the length of their inside surfaces into which the two side pieces can be slid or gently hammered. Use no hardware to assemble the box. Rope, strips of tire tubes (often

Figure 2—Track-plate box station in the field. Note how the back of the box is against the base of a tree and how the box is covered with debris to stabilize and camouflage it.

available at no cost from local tire dealers), or plastic banding (applied with a commercial banding tool) can be used to hold the sides together. Cotton clothesline works well and biodegrades if left in the field. Heavy woody debris, placed over the box in the field, will strengthen it further.

A lighter-weight alternative for protecting the track plate uses thin plastic sheets (L. Chow, pers. comm.). The plastic is bent into a half cylinder and the edges are placed inside a raised lip on each of the outer edges of a galvanized steel base (28.0 × 76.0 × 0.1 cm with a 1.0-cm raised lip along the sides) and are kept in place by a combination of the force acting to straighten the plastic and liberal use of duct tape (*figs. 3, 4*). Alternatively, holes can be drilled through the raised lip of the steel base and through the plastic at corresponding locations so that sheet-metal screws can be used to secure the canopy (Foresman and Pearson 1995). Although one large piece of plastic is sufficient, two smaller pieces (each 40.5 × 70.5 × 0.2-cm) can fit in a backpack more easily. At the station location, each piece is bent, positioned in the base, and then taped

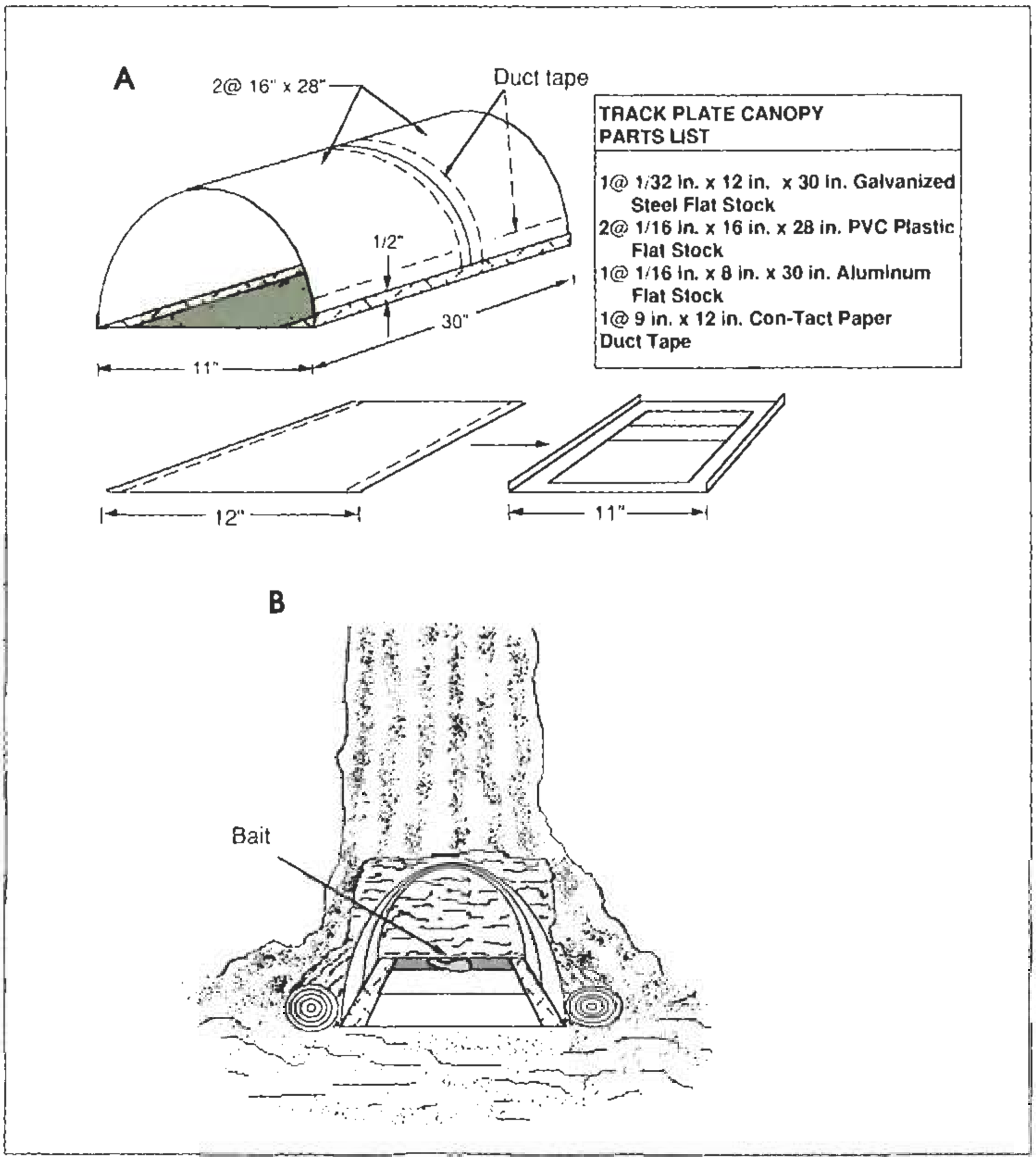


Figure 3—Schematic drawing of a plastic canopy-covered track plate and its components: A) dimensions and construction of the unit, B) established station in the field.

together where they overlap. The sooted aluminum plate with Con-Tact paper is placed on the galvanized base. Track-plate stations with this type of protection have successfully detected marten and fisher. The materials for this design weigh somewhat less than the plywood box, but the structure is much less sturdy. The roof is very flexible and cannot support woody debris that might be used to strengthen and camouflage it. The entire enclosure appears to move more readily when an animal enters it than does the plywood box. In addition, the plate may be less protected from moisture than when the absorbent plywood box is used.

There are several means by which the sooted plates can be transported in the field. For storage in a vehicle, a travel case should be constructed that can accommodate field-ready track plates (sooted, with Con-Tact paper and backing attached) (*fig. 5*). This can

Figure 4—Plastic canopy-covered track plate in the field. Note how the back is against the base of a tree and how the unit is stabilized with bark and logs.

Figure 5—Example of track-plate carrying case designed to be transported in a vehicle.

be a sturdy wood or plastic box with parallel grooves cut on the inside surface of two sides into which the plates can slide. Grooves separated by at least 1/2 inch will keep plates apart during travel, and a box lid will prevent dust from settling on the plates. To protect individual plates from being marred while you walk from the vehicle to the station location, cover the sooted plate(s) with an unsooted one and bind them together tightly with duct tape or welding clips. Alternatively, holes can be drilled in diagonal corners of each plate; a bolt and wing-nut can secure a number of plates firmly together. Nothing need be placed between the plates, provided each Con-Tact paper has its protective cover in place and plates are stacked front to back. This procedure is particularly useful when multiple plates must be back-packed into a roadless area.

Unenclosed Track Plate

This device is an uncovered, carbon-blackened aluminum plate made of the same material described above and sooted in the same fashion. The plate is actually composed of two plates (40.0 × 80.0 × 0.1 cm each), placed side-by-side, to create an 80.0 × 80.0 cm surface (*figs. 6, 7*). Because this method does not involve the use of a white track-receptive surface, it is important that the soot be applied lightly enough so that the feet of visiting animals remove it all and expose the underlying plate. Bait is placed in the center of the two plates.

To prevent the sooted surfaces from rubbing together, carry the plates in wooden boxes bolted to pack boards. Flat, army surplus pack boards made of particle board are the best. The lightest boxes are made of 0.25-inch plywood on the front, back, and the bottom; sides and hinged top are made of 0.5-inch plywood. One box, 41.5 cm long and 135 cm deep, will hold six sets of plates. Cut six slots, 5 mm wide and 5 mm deep, spaced about 12 mm apart, into the interior surfaces of the box. Fit the sheets into the slots back to back. A larger and sturdier box of the same general design that can be carried in a vehicle will be helpful in transporting many plates at once.

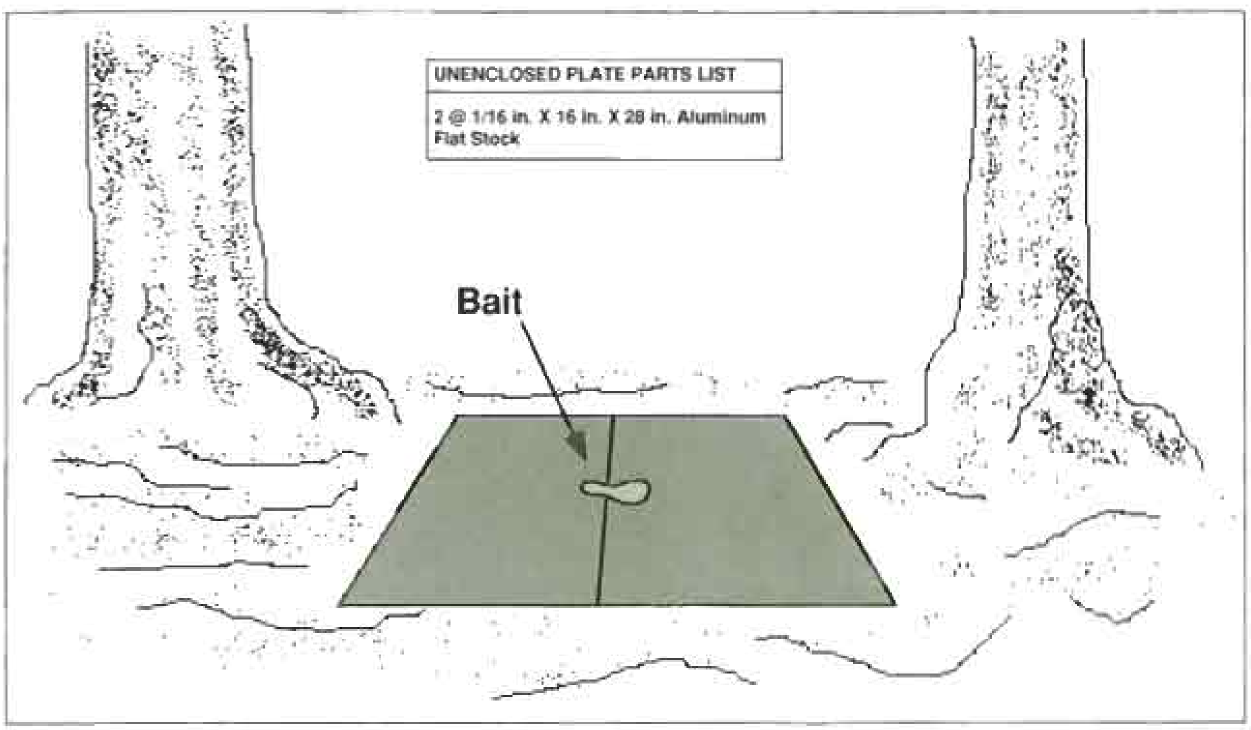


Figure 6—Schematic drawing of an unenclosed track plate and its components.

Baits and Lures

Recommendation: Chicken is the recommended bait. Also use a commercial lure and a visual attractant (e.g. hanging bird wing, large feather, or piece of aluminum foil).

In tests with captive fishers, chicken and tuna were equally attractive, but in the field, chicken elicited significantly more detections of a variety of carnivores, including martens (Fowler and Golightly 1993). Chicken is used exclusively for bait in the original USDA Forest Service, Region 5 protocol (Zielinski 1992) because it is readily available, relatively inexpensive, of a convenient size for use in the boxes, and poses no greater risk of microbial disease than other meats if hands are washed after use (see Safety Concerns). However, other baits have successfully attracted fisher (e.g., fresh fish, deer carrion) and marten (e.g., fresh fish, deer, beef bones, jam). Laymon and others (1993) found that jam did not increase visits to detection stations, and Jones and Raphael (1991) suggested that martens prefer chicken bait without the addition of jam. There is no consensus as to the relative effectiveness of different bait combinations. The unenclosed plates have typically been used with a perforated can of tuna cat food in the center and the excess juices distributed on surrounding vegetation. However, alternative baits were not tested. In the box or canopy-enclosed plate, place the bait behind the paper; with the unenclosed plate, place bait at the union of the two plates (*figs. 1, 3, 6*).

Commercially available trapper lures such as skunk scent may be useful attractants, and we recommend that they be used in addition to chicken bait. Sources for these lures include M & M Fur Company, P.O. Box 15, Bridgewater, SD, 57319-0015, (605-729-2535), and Minnesota Trapline Products, 6699 156th Ave. NW, Pennock, MN 56279, (612-599-4176). Fish emulsion, sold as fertilizer in garden-supply stores, can also be an effective lure, especially when mixed with vegetable oil to retard evaporation.

Visual attractants (e.g., suspended bird wings, aluminum pie tins) are frequently used by commercial trappers, but their effectiveness at increasing detections has received only one modest test, in which they did not increase detections of "carnivores" (a group of species that included marten but excluded lynx, wolverines, and fishers; Laymon and others 1993). This is insufficient evidence to discourage their use, especially in light of their reputed value by trappers (Young 1958, Geary 1984, R. Aiton, pers. comm.). Whenever possible, use a visual attractant, and use it consistently. Suspend either a dried wing, feather, or aluminum foil about 2 m above the ground within 5 m of the station.

Figure 7—Unenclosed large, sooted track plate in field, with perforated tuna can as bait.

Survey Seasons

Recommendation: Conduct two surveys per year per sample unit, one in spring and one in fall. However, do not conduct the second survey if the target species is detected during the first.

Because both the enclosed and unenclosed plates are placed on the ground where they could quickly be covered with snow, and because of the increased costs of operation, avoid conducting surveys during winter. However, because the target species may be more easily detected during the winter when food may be less available, conduct surveys as soon after snowmelt in the spring and (if necessary) as late as possible in the fall.

Survey Duration

Recommendation: Stations should be set for a minimum of 12 nights and checked every other day for a total of at least six visits (excluding setup). Discontinue the survey when the target species is detected even if this occurs before 12 nights have elapsed. If the target species is not detected during the first 12-day session, run a second session at the same station locations during the alternate season (either spring or fall) for a minimum of 12 days.

Because the objective of the survey is to determine whether a sample unit is occupied, effort need not be expended beyond the detection of the target species. However, the minimum effort without detection is set at 12 nights in response to a number of sources of information on the "latency to first detection" for marten and fishers. In reviewing the results of 207 track-plate and line-trigger camera surveys, Zielinski and others (1995) found that the mean (SD) latency to first detection for surveys that had from 6 to 12 stations (n = 50) was 4.2 (2.4) and 3.7 (2.6) days for fisher and marten, respectively. This estimate is biased downward, however, because it included only those surveys that detected a target species before the surveys were concluded. Raphael and Barrett (1984) recommended that 8 days were sufficient to achieve high detection probabilities when measuring mammalian carnivore diversity at a site. Jones and Raphael (1991), however, discovered that 60 percent (3 of 5) of first detections during marten surveys in Washington occurred after day 8 but before day 11. They concluded that surveys should run more than 11 days. Foresman and Pearson (1995) detected marten after a mean of 3.3 days and 2.3 days at enclosed and open plates, respectively; fishers were detected after a mean of 5.3 days at enclosed track plates. Fowler and Golightly (1993) suggest a 22-day survey duration, but this is with the goal of increasing the number of detections to the point where a statistical decline in detections will be discernible at a subsequent sample. Because the objective of detection surveys is to detect presence only, and because the statistical merit of using number of detections as an index has not been adequately addressed, the 22-day survey duration is probably excessive.

Because lynx and wolverine have not yet been detected on track plates, there are no data on which to base recommendations on survey duration. Until data are collected to suggest otherwise, the 12-day duration, twice per year if necessary, is considered sufficient effort.

Preparations for the Field

Defining the Survey Area

Recommendation: Conduct surveys in 4-mi^2 sample units, as described in Chapter 2, "Definition and Distribution of Sample Units."

The survey approach will be different depending on whether the survey is a "Regional Survey" or a "Project Survey" (see Chapter 2). In each case, however, we recommend the use of separate 4-mi^2 sample units as the basis of the survey. Conduct surveys on as many sample units concurrently as time, personnel and funds permit. If it is a Regional Survey, choose one of the scheduling options suggested in Chapter 2; if it is a Project Survey, focus your attention first on the sample units within the project area.

Station Number and Distribution

Recommendation: Use a minimum of six track-plate stations in each sample unit. Distribute them as a grid, with 0.5-mile intervals, in the area of the sample unit with the most appropriate habitat or where unconfirmed sightings have occurred (see Chapter 2, *fig. 2*).

Detection success increases with an increase in number of stations in the survey (Zielinski and others 1995). Although the data are too few to determine the point of diminishing returns on station number, it seems reasonable to have stations that collectively sample at least 0.5 mi^2 (12.5 percent) of the unit, especially if they are placed in the most appropriate habitat. Six stations provide at least this much coverage if one assumes that a target individual will be detected if it travels within the rectangle created by joining the perimeter stations. Additional stations will provide a greater assurance of detecting occupants, but more than 12 stations (covering 1.5 mi^2, 37.5 percent of the area) would probably be excessive.

If habitat is homogeneous throughout the 4-mi^2 sample unit and there are no previous sightings, center the grid in the middle of the sample unit. If roads are available, the shape of the grid can be adjusted to accommodate road access, but maintain the recommended inter-station distances. If the sample unit is roadless, the track-plate materials will need to be backpacked into the survey area.

Before conducting on-site reconnaissance, study aerial photographs and topographic maps of the sample unit(s) to be surveyed. Station locations should be assigned on maps or photos before conducting any field work.

In the Field

Station Location

First conduct reconnaissance to verify the existence and location of roads and trails that will be used to access the stations. Locate each station at least 50 m perpendicular to the road; placement of stations closer to roads may reduce their attractiveness to target species and increase visibility to people. When possible, mark the station locations with flagging and metal tape or rebar, and identify them using Global Positioning Satellite (GPS) technology. These locations may need to be revisited during a second survey. In roadless areas, record the compass bearings, elevation (using an altimeter), and distances between landmarks used for orientation so others can find the stations with ease.

Station Setup

Set out all the detection stations you plan to check during the survey before baiting them. Because the original location and establishment of the stations will require more time than checking them, it is best to bait them after all have been established. For reference, if there are six stations per sample unit, an experienced 2-person crew can set up about 18 track-plate stations per day; 24 if there are 12 stations per sample unit. Additional time is required for roadless sample units. No more stations should be established than can be checked every other day by available personnel. However, because stations are checked once every 2 days, only half the stations need to be checked on any one day. If this is difficult, then additional crews should be hired, or the number of sample units surveyed during that particular period should be reduced (see Chapter 2 for recommendations on how to survey multiple sample units).

Track-Plate Box

Assemble the box, and place it on level ground so it will not move when entered. Place the baited end of the box against the base of a tree, rock, or log to discourage entry from the rear (*figs. 1C, 2*). Cover the box with heavy debris (e.g., limbs, bark) to secure it in place and to hide it from passers-by. Remove the protective cover from the Con-Tact paper, and insert the sooted plate in the box. Mark a flag near the box with the station number. Place the bait on the plate behind the Con-Tact paper, using kitchen tongs to minimize contact with meat. Wash hands thoroughly after handling chicken, or wear gloves to prevent contact.

Unenclosed Track Plate

At each station, clear and level an area of about one square meter. A small, folding shovel is a useful digging tool. Place the sooted plates side-by-side onto the cleared spot in a manner that will provide a stable surface for animals to step on. Attach the bait with wire to the center of the sheets. At a conspicuous location, attach the following laminated message to a tree:

> This is part of an important wildlife study being conducted by ______________________. Please do not touch. The sooted aluminum plate will record the tracks of animals. It will not harm or entrap them. If you have any questions, please contact ______________________________.
>
> Thank you.

Checking the Stations

Recommendation: Check the stations every 2 days, including weekends, for a minimum of six checks (12 days). Replace the plates as necessary, either when the soot becomes ineffective (test with finger) or when the tracks of non-target species occupy more than 20 percent of the plate. Rebait at every visit (at least six times), and remove old bait from the station area. Apply lure at least twice during the survey period.

The day a station is baited is Day 0, and the subsequent visits should occur on Days 2, 4, 6, 8, 10, and 12. If there are too many sample units for all stations to be checked on one day, then half of the stations should be run on alternate days. If using the alternate day method, the minimum survey period will be 13 rather than 12 days. If rain or snow renders the stations ineffective (especially common for the unenclosed plates), add additional days to the survey period to compensate for the days during which visits could not be detected.

Survey crews should be familiar with the tracks of potential target species. The track guide of Taylor and Raphael (1988) describes the tracks of species that commonly occur on track plates in the Pacific Northwest, but their key is only for tracks directly on the aluminum plate. Examples of marten and fisher tracks on Con-Tact paper are provided in *appendix A*. Although the tracks of male marten and female fisher can overlap in size (Taylor and Raphael 1988), they can be easily distinguished by using the discriminant function developed by Zielinski and Truex (1995) (*appendix B*). Unfortunately, the tracks of wolverine and lynx on plates or paper have not been described. It is extremely helpful to build a library of life-sized examples of tracks of the common carnivores in the area. These can be used to identify most species quickly.

As the stations are checked, complete the Track Plate Results form (*appendix C*). Make an entry on this form every time a station is checked, regardless of the results. If tracks of the target species are on the paper, cover it with one of the original protective sheets, and return the plate to the field station. Record the station number and date on the paper and the plate as they are removed from the box (a fingernail can etch these numbers in untracked soot on the plate). Remove the paper from the plate, and cut away the untracked portion of the paper. Record the date, sample unit number, and station number on the paper, and place it in a clear 8 1/2- by 11-inch document protector with perforations for a 3-ring binder. To collect and preserve tracks from the sooted portion of plates, place a wide strip of clear tape over each print. Press the tape on the print with a burnishing tool (the tip of a capped pen will usually do). Carefully peel away the tape, and transfer it onto a sheet of heavy white paper. Practice this procedure on tracks of non-target species before lifting those of potential target species.

Data Management

We recommend three forms for data: Survey Record, Track-Plate Results, and Species Detection form (*appendix C* and in the pocket inside the back cover). We strongly recommend using indelible ink and photocopies of the data sheets (especially the Track-Plate Results form) made on waterproof paper. All forms should be stored in a 3-ring binder as a permanent record of the survey.

Survey Record Form

The Survey Record form contains information on the survey location and its configuration. It is important to identify the legal description *and* the Universal Transverse Mercator (UTM) coordinates at each unit. Collectively, these forms become a record of all the surveys conducted in the administrative area, regardless of their outcome.

Track-Plate Results Form

Use one copy of the Track-Plate Results form for each day in the field. Record information from each track plate station, whether there were tracks on the plate or not. Note the station number, the visit number (1-6), the nights since last visit (should usually be two), whether there were tracks of target species and which ones, the identity of tracks of other species of interest, and general comments. Remember that Visit 1 occurs after the second night the station has been set up; the set-up visit can be referred to as Visit 0. If you are uncertain about the identity of tracks, use track reference materials (especially Taylor and Raphael, 1988), the examples provided in *appendix A*, and the discriminant function in *appendix B* to assist in the identification, *and* ask a biologist who is experienced with tracks to confirm your identification. Tracks from Con-Tact paper can be easily photocopied and sent by FAX to qualified biologists. Make certain to record the season, date, a code for weather since the last visit, and the location of the survey on each copy of the data form. Completed forms and survey maps should be archived at the local administrative office (e.g., Forest Service Ranger District), and a duplicate set should be filed at a second location of your choice.

Species Detection Form

When a survey is successful at detecting lynx, wolverine, fisher, or marten, complete the Species Detection form, submit one copy to the state Natural Heritage office, and archive a copy at the administrative office of the agency that manages the land where the survey was conducted. Most Natural Heritage databases record only positive results from detection surveys. Complete one form for each species detected. This standardized form characterizes successful surveys for marten, fisher, lynx, and wolverine and is used for all methods (camera, track plate, snow track).

Safety Concerns

Sooting the Plates

The use of acetylene to soot plates can expose the operator to carbon monoxide and acetone. Soot the plates outdoors where there is adequate ventilation and where the risk of fire is low. A "Half-Mask Respirator" with organic vapor filter and goggles is recommended. At a minimum, a dust mask should be worn to exclude large particulates. Always receive training in the use of the welding equipment (tank and torch) from an experienced technician. A "Job Hazard Analysis" for sooting plates is available upon request from Bill Zielinski (Redwood Sciences Laboratory, USDA Forest Service, 1700 Bayview Dr., Arcata, CA 95521).

Handling Bait

Uncooked chicken and many other meat baits are a potential source of *Salmonella* bacteria. Contact with both fresh and old bait should be minimized. Chicken pieces should either be individually wrapped in sandwich bags and frozen until the day they are used or be handled using kitchen tongs. Carry soap and water or disposable wipes so that you can wash your hands thoroughly before meals. Careful attention to cleanliness will make the risk of contamination from chicken negligible (Dr. J. Sheneman, pers. comm.). The risk of poisoning the target species with rotting meat baits is also negligible, as most target species regularly consume carrion.

Comparison of Track-Plate Methods

The methods recommended here have not been compared in the same study. However, it is generally agreed that the enclosed-plate method is superior to the open plate because it is protected from moisture and debris, the white surface collects positive track impressions with fine detail, and the track can be easily collected and stored with minimum loss of information. Furthermore, the unenclosed plates require larger and more unwieldy aluminum plates than the enclosed box because an animal is not directed over the plate from a single direction. However, in a recent study where plastic-canopy enclosed plates were alternated with unenclosed plates the latter received first detections by marten earlier than the former (Foresman and Pearson 1995). These authors suggest that some animals man be more reluctant to enter an enclosed area than to walk across an open plate. This conclusion is premature, however, until the unenclosed plate is compared with the *wooden box*-enclosed plate, which is sturdier and can be reinforced with logs and sticks in the field more easily than the plastic canopy version (K. Schmidt, pers. comm.).

Wolverine and lynx will probably step on the unenclosed plate more readily than the plate enclosed in the relatively small box described here. Thus, unenclosed plates should be used when sooted track plates are the chosen device for the detection of wolverine or lynx. Continued experimentation with the use of large (greater than 30.0 × 26.7 × 81.3 cm) boxes is encouraged for the detection of these species. When either wolverine or lynx are the target species, stations with plates enclosed in large boxes should be interspersed with unenclosed-plate stations, or both types of stations should be placed at the same location. This is the only way we will discover whether the larger target species will be successfully detected on box-enclosed plates. A potential advantage of the plastic canopy design is that the enclosure size could be increased to accommodate lynx and wolverine without the additional weight that would be incurred by enlarging the plywood box.

Costs

Assumptions:

- Five adjoining sample units, 4 mi^2 each, are surveyed simultaneously for a total survey area of 20 mi^2.
- There are six stations per sample unit (a total of 30 stations).
- All sample units have adequate road access.
- No target species are detected during the survey and therefore a second survey period is necessary. Because a survey is terminated when the target species is (are) detected, costs can be significantly less if the target species is detected early in the first survey period.
- The work is conducted by a crew of two federal employees paid about $75.00/person/day. No contractors are used.
- Costs for some elements of labor will be less for the unenclosed than for the enclosed plate, but these costs are trivial compared to the balance of the costs so they have not been listed separately.

Season 1

1. Labor		
Planning	2 person days (pd) 2 × $75/pd =	$150
Training	2 pd × $75 =	150
Materials acquisition and construction	5 stations/day 6 pd × $75 =	450
Establish stations	10 stations/pd 3 pds × $75 =	225
Station visits (crew members split station checking duties)	6 at 2-day frequency 6 × 30 =180 visits 20 stations/pd = 9 pds (including ≥ 1 Sunday @ time + 1/2) (8 × $75) +(1 × 112) =	712
Station removal, plate cleaning, data analysis	4 pds × $75 =	300
Total Labor		*$1,987*
2. Vehicles and Gas		700
3. Materials		
Track plate stations	$15/station × 30	450
Extra plates	15 @ $2.50 ea. =	37
Acetylene, bait, and miscellaneous supplies		350
Total Materials		$837
Total, Season 1		*$3,524*

Season 2 (if necessary)

1. Labor		
Plan, survey, establish, visit, and remove stations		1,387
2. Vehicles and Gas		700
3. Materials		
Track-plates	replace 15 percent of first season's stations; 5 stations × 15 =	75
Acetylene, bait and miscellaneous supplies		250
Total, Season 2		*$2,412*
Grand Total (Two seasons, if both are necessary)		**$5,936**

Equipment

Orientation

- ☐ Maps/aerial photos
- ☐ GPS equipment (if available)
- ☐ Indelible marker
- ☐ Flagging tape
- ☐ Compass
- ☐ Altimeter
- ☐ Metal stakes or tape
- ☐ Backpack

Track-Plate

- ☐ Aluminum plates
- ☐ Con-Tact paper (white)
- ☐ Plate-carrying case(s)
- ☐ Flashers
- ☐ Transparent tape (wide)
- ☐ Sandwich bag
- ☐ Surgical gloves/kitchen tongs
- ☐ Acetylene and torch
- ☐ Plywood box
- ☐ Bait (chicken)
- ☐ Data forms
- ☐ Track ID references
- ☐ Disposable wipes
- ☐ Duct tape
- ☐ Rope, tubing or banding material
- ☐ Commercial lure
- ☐ Document protectors
- ☐ Rags and steel wool to clean plates

General

- ☐ Tool or tackle box
- ☐ Scissors
- ☐ Hatchet or hammer
- ☐ Pliers
- ☐ Small, folding shovel
- ☐ Plastic garbage bags

References

Aiton, R., Trapper, Simpson Timber Co., Arcata, CA. [Personal communication]. 1994.

Barrett, R. H. 1983. **Smoked aluminum track plots for determining furbearer distribution and relative abundance.** California Department of Fish and Game 69: 188-190.

Chow, L., Wildlife Biologist, National Biological Service, Yosemite National Park, El Portal, CA. [Personal communication]. 1994.

Dohmen, A., Wildlife Biologist, Panhandle National Forest, Sand Point, ID. [Personal communication]. 1994.

Fellers, G., Research Wildlife Biologist, National Biological Service, Point Reyes, CA. [Personal communication]. 1994.

Foresman, K.R.; Pearson, D.E. 1995. **Testing of proposed survey methods for the detection of wolverine, lynx, fisher and American marten in Bitterroot National Forest.** Final Report. Unpublished manuscript supplied by authors.

Fowler, C. H.; Golightly, R. T. 1991. **Marten and fisher survey techniques**. Progress Report. Arcata, CA: Redwood Sciences Laboratory, Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 65 p.

Fowler, C. H.; Golightly, R. T. 1993. **Fisher and marten survey techniques on the Tahoe National Forest** Final Report. Unpublished draft supplied by authors.

Geary, S. M. 1984. **Fur trapping in North America.** Piscataway, NJ: Winchester Press; 154 p.

Jones, L. C.; Raphael, M. G. 1991. **Ecology and management of marten in fragmented habitats of the Pacific Northwest.** Progress Report FY91. Olympia, OR: Pacific Northwest Research Station, Forest Service, U.S. Department of Agriculture; 36 p.

Laymon, S. A.; Holterman, M. D.; Barrett, R. H. 1993. **Distribution of marten, fisher, wolverine, and Sierra Nevada red fox in portions of the Sierra National Forest** Final report of cooperative agreement Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 42 p.

Martin, S. 1987. **The ecology of the pine marten (*Martes americana*) at Sageben Creek, California** Berkeley, CA: University of California; 223 p. Unpublished dissertation.

Mayer, M. V. 1957. **A method for determining the activity of burrowing mammals.** Journal of Mammalogy 38: 531.

Orloff, S. G.; Flannery, A. W.; Belt, K. C. 1993. **Identification of San Joaquin kit fox (*Vulpes macrotis mutica*) tracks on aluminum tracking plates.** California Department of Fish and Game 79(2): 45-53.

Raphael, M. G. 1988. **Long-term trends in abundance of amphibians, reptiles, and mammals in Douglas-fir forests of northwestern California**. In: Szaro, R. C., Severson, K. E.; Patton, D., tech. coords. Management of amphibians, reptiles and small mammals in North America. Gen. Tech. Rep. RM-166. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 23-31.

Raphael, M. G., Research Wildlife Biologist, Pacific Northwest Research Station, USDA Forest Service, Olympia, WA. [Personal communication]. 1994.

Raphael, M. G.; Barrett, R. 1984. **Diversity and abundances of wildlife in late successional Douglas-fir forests**. In: Proceedings, new forests for a changing world, 1983 SAF National Convention, Portland, OR. Washington, DC: Society of American Foresters; 34-42

Schmidt, K., Wildlife Biologist, USDA Forest Service, Six Rivers National Forest, Eureka, CA [Personal communication]. 1994.

Sheneman, J., Medical Doctor, California Department of Health, Berkeley, CA. [Personal communication]. 1994.

Souza, J., Graduate Student, Department of Biology, Chico State University, Chico, CA. [Personal communication]. 1994.

Taylor, C. A.; Raphael, M. G. 1988. **Identification of mammal tracks from sooted track stations in the Pacific Northwest**. California Department of Fish and Game 74: 4-15.

Young, S.P. 1958. **The bobcat of North America**. Washington, DC: Wildlife Management Institute.

Zielinski, W. J. 1992. **A survey protocol to monitor forest carnivores in proposed management activity areas**. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 18 p.

Zielinski, W. J., Truex, R. 1995. **Distinguishing tracks of closely-related species: marten and fisher**. Journal of Wildlife Management 59: 571-579

Zielinski, W. J.; Truex, R.; Ogan, C.; Busse, K. 1995. **Detection survey for fishers and martens in California 1989-1994: summary and interpretations**. Unpublished draft supplied by authors.

Appendix A—Examples of fisher and marten tracks from Con-Tact paper

Fisher Tracks. All are *Martes pennanti pacifica* except G, which is from *M. p. pennanti*.

A. Sequoia National Forest, California (Adult female, left foot).
B. Sequoia National Forest, California (Adult female, right foot).
C. Mountain Home State Forest, California (Adult male, right foot).
D. Sequoia National Forest, California (Adult female, right foot).
E. Six Rivers National Forest, California (Adult female, right foot).
F. Six Rivers National Forest, California (Adult female, right foot).
G. Captive individual; Massachusetts origin (Adult male, right foot).
H. Shasta-Trinity National Forest, California (Adult female, right foot).

Marten Tracks. All are *Martes americana sierrae* except those of Yukon origin which are *M. a. actuosa*.

A. Lassen National Forest, California (Juvenile male, left foot).
B. Captive individual; Yukon origin (Adult female, right foot).
C. Mountain Home State Forest, California (Sex unknown, left foot).
D. Mountain Home State Forest, California (Sex unknown, left foot).
E. Sequoia National Forest, California (Sex unknown, right foot).
F. Captive individual; Yukon origin (Adult male, right foot).
G. Captive individual; Yukon origin (Adult female, left foot).
H. Captive individual; Yukon origin (Adult female, left foot).
I. Captive individual; Yukon origin (Adult female, right foot).
J. Captive individual; Yukon origin (Adult female, left foot).
K. Sequoia National Forest, California (Sex unknown, left foot).

Fisher Tracks. All are *Martes pennanti pacifica* except G, which is *M. p. pennanti.*

A. Sequoia National Forest, California (Adult female, left foot).

B. Sequoia National Forest, California (Adult female, right foot).

C. Mountain Home State Forest, California (Adult male, right foot).

D. Sequoia National Forest, California (Adult female, right foot).

E. Six Rivers National Forest, California (Adult female, right foot).

F. Six Rivers National Forest, California (Adult female, right foot).

G. Captive individual; Massachusetts origin (Adult male, right foot).

H. Shasta-Trinity National Forest, California (Adult female right foot).

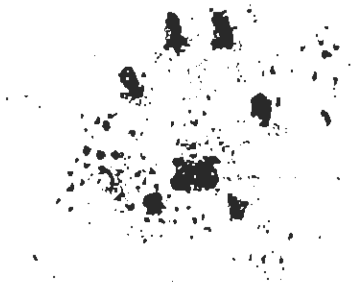
Marten Tracks. All are *Martes americana sierrae* except those of Yukon origin which are *M. a. actuosa*.

A. Lassen National Forest, - California (Juvenile male, left foot).

B. Captive individual; Yukon origin (Adult female, right foot).

C. Mountain Home State Forest, California (Sex unknown, left foot).

D. Mountain Home State Forest, California (Sex unknown, left foot).



E. Sequoia National Forest, California (Sex unknown, right foot).

F. Captive individual; Yukon origin (Adult male, right foot).

G. Captive individual; Yukon origin (Adult female, left foot).

H. Captive individual; Yukon origin (Adult female, left foot).

I. Captive individual; Yukon origin (Adult female, right foot).

J. Captive individual; Yukon origin (Adult female, left foot).

K. Sequoia National Forest, California (Sex unknown, left foot).

Appendix B—Discriminant function to distinguish marten and fisher tracks

Adapted from "Zielinski, W. J. and R. L. Truex (1995). Distinguishing tracks of marten and fisher at track-plate stations. J. Wildl. Manage." The complete manuscript is available by contacting the authors (Redwood Sciences Laboratory, USDA Forest Service, 1700 Bayview Dr., Arcata, CA 95521; 707-822-3691).

Several problems arise in attempting to distinguish marten and fisher tracks. First, there are no widely accepted qualitative means of distinguishing the tracks. Some biologists have suggested that the shape and connectedness of palm pad segments, hairiness of the track, and absence of particular toe pad impressions may differ between species, but exceptions are not uncommon (Zielinski, pers. observ.). Second, there is overlap in quantitative traits (length and width) of adult animals, much of which is likely attributable to overlap between male marten and female fisher (Taylor and Raphael 1988) due to intraspecific sexual size dimorphism.

A discriminant function was developed using tracks collected from wild and captive individuals of two subspecies of marten (*M. americana sierrae* and *M. a. actuosa*) and two of fisher (*M. pennanti pacifica* and *M. p. pennanti*). The method assumes the track was made by an adult marten or fisher.

Distinguishing Right from Left Feet and Pad Definitions

Before toe and interdigital pads are identified, it is necessary to determine whether the track was made by the right or left foot. This can be assessed by using four rules, presented in order of reliability. First, the medial-most digit (the "thumb"; 1 in *fig. 1*) is generally smaller and posterior to the remaining toe pads and is often even with the largest interdigital pad. Second, a small metacarpal pad (I1) is posterior and lateral to the "thumb," quite close to the main interdigital pads (I2, I3, and I4). The "thumb" (1) and the metacarpal pad (I1) are on the medial side of the track. Thus, if they are on the left side of the track, the track is from a right foot. When both pads are lacking, the location of a heel pad (H), present on forefoot only, is used to determine left or right foot. This pad is posterior to the interdigital pad and is angled such that its anterior margin is directed toward the lateral (outside) portion of the track. If none of the above indicate left or right foot, the relative location of the outermost toe pad (5 in *fig. 1*) and the pad lateral to the "thumb" (2) was assessed. In general, pad 5 is smaller than pad 2, and its anterior margin is posterior to that of pad 2. Once left or right foot is established, identify toe pads as 1, 2, 3, 4, and 5 (medial to lateral), and divide the interdigital pad into three primary pads, I2, I3, and I4 (medial to lateral), and a metacarpal pad, I1. The heel pad, if present, is identified as H (*fig. 1*). These basic track features and foot criteria should be applicable to other mustelids as well.

Reference Point (Origin) Formation

After identifying the pads, create a single reference point that becomes the origin of a Cartesian grid superimposed on the track. The origin is formed by following several simple steps. First, two lines are drawn, one connecting the medial margins of 2 and I3 and one connecting the lateral margins of 5 and I3. Bisecting this angle creates the ordinate. A line drawn perpendicular to the ordinate at the anterior margin of I3 creates the abscissa (*fig. 1*). This coordinate system serves to maintain precision in Cartesian measurements while providing a reference point from which numerous measurements can be derived. Because some measurements based on a Cartesian coordinate system were different for right and left feet, variables collected along the X axis should be standardized to the right-foot condition by recording their absolute value. Measure variables to the nearest 0.01 mm, using digital calipers if possible.

Classification Guidelines

We recommend a three-variable function involving the width of the center palm pad (I3), the length of center palm pad (I3), and the length of lateral palm pad (I4) (*fig. 1*). Use the following classification protocol for unknown tracks suspected to be either marten or fisher collected from contact paper and measured as described above:

If (4.595*width I3) + (3.146*length I3) + (0.906*length I4) - 80.285 > 0, classify the track as fisher; if < 0, classify the track as marten.

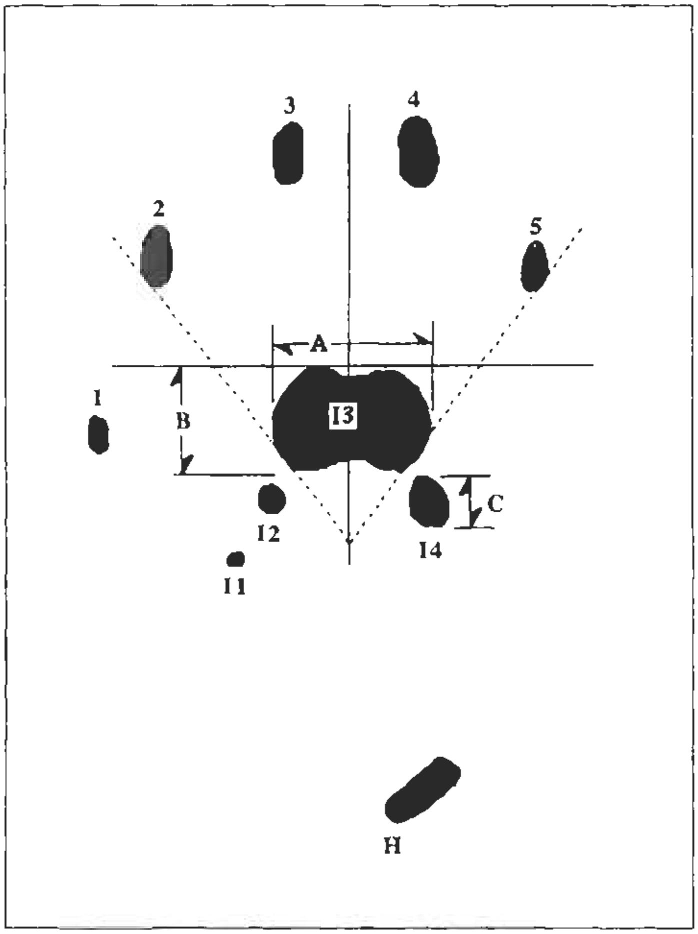


Figure 1—Schematic diagram of right marten or fisher forefoot track collected from sooted track impressions on white Con-Tact paper. Toe pads are identified with numbers (*1–5*) while interdigital pads and the heel pad are represented with letters (*I1–I4, H*). The ordinate of the Cartesian grid is formed by bisecting the angle of intersection created by lines joining the medial margins of *2* and *I3* and the lateral margins of *5* and *I3*. A is the width of *I3*, *B* is the length of *I3*, and *C* is the length of *I4*.

Appendix C—Data forms

SURVEY RECORD FORM

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. or m?)

(use another sheet if necessary)

Vegetation type (s) ________________________

Date installed (or run) ____________ Date terminated ____________

Type of bait or scent ________________________

Name, address, and phone of investigator __________________

____

____

Track Plate Results

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 (eg. MAAM, for marten) until identity is confirmed.

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

SPECIES DETECTION FORM

Please complete each field after a survey has detected either lynx, wolverine, fisher, or marten, and send a copy to your state's Natural Heritage Division (addresses in Chapter 1) and other appropriate entities. The meaning of each code is explained on the following page. It is important to coordinate with the State Wildlife Agency/Natural Heritage Program within your State to assure uniform codes are used for federal lands, parks, private lands, counties, etc.

1. **SPEC** ______________
2. **DATE** ______________
3. **STATE** ______
4. **CO** _____
5. **LOC** ____
6. **QUAD** ___________________
7. **QUADNO** ________________
8. **OWN** ________
8a. **FOR/PARK** _______________
8b. **DISTRICT** ________________
9. **RNG** __
10. **TWN** __
11. **SEC** ____
12. **QSEC** ____
13. **SIXTHSEC** _______
14. **M** ____
15. **Z** ____
16. **UTM_N** __________________________
17. **UTM_E** _______________________
18. **OBS** ____
19. **SVTP** __
20. **STA_NO** _________
21. **TR_NO**
22. **ELEV** _
23. **COMMENTS** ____

____

CODES FOR THE SPECIES DETECTION FORM

1. **SPEC** - Species; 1 letter: L = lynx, W = wolverine, F = fisher, M = marten.
2. **DATE** - Date; year, month, day; e.g., Jan. 12, 1994 = 19940112.
3. **STATE** - State; use 2-letter postal abbreviation, e.g., MT, OR.
4. **CO** - County; use 2-letter code, e.g., AP=Alpine, HU=Humboldt
5. **LOC** - Locale; the most specific names possible using names found on USGS maps, e.g., Grizzly Creek. 20 characters.
6. **QUAD** - Name of USGS topographic quad showing survey area; if >1, use additional sheets, e.g., Ship Mountain. 20 characters.
7. **QUADNO** - USGS quad number utilizing latitude and longitude identification system.

*8. **OWN** - Landowner. 4-letter code, e.g., USFS, NPS, BLM, CA, PVT.

8a. **FOR/PARK** - National or State Forest or Park name. 3 characters.

8b. **DISTRICT** - Subdivision of Forest or Park (e.g., Ranger District if "OWN" = USFS. 3 characters.

9. **RNG** - Range. 3-characters.
10. **TWN** - Township. 3-characters.
11. **SEC** - Section. 2-characters.
12. **QSEC** - Quarter section. 2 characters.
13. **SIXTHSEC** - Sixteenth section. 2 characters.
14. **M** - Meridian. 1-character.
15. **Z** - UTM zone. 2-characters.
16. **UTM_N** - UTM-north coordinate; 7-characters.
17. **UTM_E** - UTM-east coordinate; 6-characters.
18. **OBS** - Observer; last name, first name, middle initial of survey crew leader. 20 characters.
19. **SVTP** - Survey type: SNSS = snow-tracking survey (searching); SNSB = snow-tracking survey (at bait); TRPL = track plate; CAMR = camera (35-mm or 110).
20. **STA_NO** - Station number of detection (if camera or track plate). 2 characters.
21. **TR_NO_** - Number of snow transect where detection occurred. 2 characters.
22. **ELEV** - Elevation at detection site. 5 characters.
23. **COMMENTS** - 30 Characters.

* Each state will need to develop 2-3 character codes for specific forests, parks, private landowners and districts therein.

Snow Tracking

James C. Halfpenny,[1] Richard W. Thompson,[2] Susan C. Morse,[3] Tim Holden,[4] and Paul Rezendes[5]

Introduction

Snow tracking is used to conduct reliable field surveys to detect American marten, fisher, lynx, and wolverine (MFLW). Because detection is the goal, such surveys do not require the statistical considerations of those designed to monitor changes in population size (see Chapter 2) or to determine habitat preference. Because efforts to determine the presence of rare species often are linked to activities such as proposed timber harvests or recreational or residential developments, the field biologist must be able to provide records that will withstand the scrutiny of the professional community. Results of surveys may be challenged, even in court, so methods must be rigorous and data should be collected in a standardized fashion.

Tracking has advanced considerably since the days of Ernest Thompson Seton and Olaus Murie. It is not possible simply to read their books and be a tracker. This manual will provide the necessary background for tracking, but it cannot substitute for training and practice. After studying the material in this chapter, the tracker should be familiar with the fundamentals of designing a snow-tracking survey and identifying and documenting the footprints and trails of MFLW. However, becoming a good tracker takes time. Spend that time by gaining experience in the field and by learning from others. Where MFLW are legally harvested, seek the advice of local trappers. Special seminars and workshops on tracking are also available. Attend these, and compare notes with other trackers.

Two methods for detecting the presence of the target species are discussed: "Searching for Tracks" and "Tracking at Bait Stations." The former, and historically more common, method involves traversing trails and roads in search for tracks. The latter method, suggested by recent observations by Copeland and Harris (1994), involves the detection of tracks in the snow at bait stations. This chapter does not cover snow tracking from the air. Snow tracking from airplanes is used in Alaska and Canada not only to detect individuals, but also to inventory and monitor populations in relatively open habitats, (e.g., Golden 1987, 1988, 1993; Golden and others 1992; Stephenson 1986). However, if the target species prefers closed habitats or is of low density, it is possible to miss the tracks from the air. The probability of missing tracks must be weighed against the advantage of covering large numbers of miles per day from the air.

Although airplanes and helicopters have seldom been used for the detection of rare species in the contiguous United States, this technique should be considered, especially if large areas with good surface visibility are to be surveyed. When possible, use flight time to supplement ground time. Aerial trackers require special training to search clearings and edges, spot tracks within the forest, and identify tracks seen from the air. Special features, such as wolverine dens, are more visible from the air (Magoun in Golden 1993) but require training to recognize. Additional references on the use of aerial snow tracking are provided in the section on Inventory and Monitoring, below.

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Survey Season and Snow Conditions

Snow-tracking surveys depend on conditions that may vary across regions and over time, and in some areas snow tracking may seldom be possible. The minimum requirement is snow deep and soft euough for identifiable footprints to register. If possible, wait until the second morning after a snowfall to allow tracks to accumulate. This allows the animals time to lay down trails, but is not so long that tracks of other animals make it difficult to find those of the target species. On some days it is not possible to track. For example, tracking during snowfall or during strong winds is not advised because tracks are quickly obscured.

In early spring, the sun melts snow on south-facing slopes, and this can rapidly destroy tracks each morning. Although a wet afternoon snow makes excellent tracks, the target species tend not to travel then. Later, when the snow freezes, animals may move on top of it without leaving detectable tracks. During periods of melting and freezing, tracking must be done early in the morning. When recurring melting and freezing prevent tracking on south-facing slopes, good tracking may be possible on the north-facing slopes.

Defining the Survey Area

Recommendation: Conduct surveys in 4-mi^2 sample units (see Chapter 2, "Definition and Distribution of Sample Units").

The approach may differ depending on whether the survey is a "Regional Survey" or a "Project Survey" (see Chapter 2). In each case, however, we recommend that 4-mi^2 sample units be the basis of the survey. For regional-distribution surveys, choose one of the scheduling options suggested in Chapter 2. In project-level surveys, focus first on the sample units within the project area. Conduct surveys on as many sample units each winter as time, personnel, and funds will permit, and survey as many sample units in a day as possible.

Searching for Tracks

Route Selection, Mode of Travel, and Duration

Recommendation: Drive by truck or snowmobile to the area(s) of the sample unit with the most likely habitat for the target species (or the area where unconfirmed sightings have been reported), and start your search there. Conduct the search on foot, using either skis or snowshoes. Conclude the search after either a minimum of 10 km have been traversed or the target species is (are) detected.

Routes should be chosen to favor preferred habitats, and to use foot travel. Use motorized vehicles for speedy transport between habitats not preferred by MFLW. The most thorough job of tracking is done on foot, either on skis or snowshoes. The best approach is to use skis or snowshoes to travel routes in preferred habitats and a snowmobile or other vehicle to reduce travel time between focal areas.

If snowmobiles must be used, avoid routes used by other snowmobiles, and travel between 5 and 15 mph. Two snowmobiles or two observers per snowmobile will decrease the likelihood that tracks are missed. When the track of a potential target species is sighted, stop the snowmobile and examine the trail on foot. Fatigue while driving a snowmobile contributes to poor performance, so be certain that, as the day wears on, all potential tracks and trails are checked carefully. The tracks of target species traveling on packed trails made by ungulates or snowshoe hares can easily be missed!

Topographic Considerations

Topographic features may provide important travel routes for target species. Within appropriate habitat, select survey routes on ridges, saddles, and valley bottoms or drainages. Avoid locations with avalanche potential, including avalanche chutes and steep, open slopes (see Safety Concerns, below).

Survey Frequency

Recommendations: *Wolverine, Fisher, and Marten*: Survey each 4-mi^2 sample unit (see Chapter 2) at least three times during one winter *or* until the target species is (are) detected. Distribute survey outings throughout the snow season.

Lynx: Survey each sample unit three times per winter and for three consecutive winters (or at least three out of five winters) *or* until lynx are verified on the sample unit.

As snow conditions permit, traverse the survey routes in a sample unit at least three times during the winter. If suitable snow is available for only a short time, sample all the routes in a sample unit at least twice; one survey per winter is inadequate. Lynx populations exhibit cycles in abundance, especially in northern latitudes. Although the magnitude of these cycles is unknown in the southern part of their range, we recommend that surveys acknowledge the possibility of extremely variable population sizes. Where lynx are of interest, each sample unit should be surveyed three times per winter for at least 3 years, consecutively if possible. This will minimize the probability that sampling will occur during the low point in the lynx population cycle and misrepresent the status of lynx in the area.

Tracking at Bait Stations

Baits and Lures

Recommendations: Use road-killed deer, fish, or a combination of the two. Use as large an amount as possible, up to a whole deer carcass, but at least 5 kg. A commercial lure such as skunk scent may help attract mustelids. For lynx, a freely hanging bird feather or wing, or piece of aluminum foil and a commercial lynx lure and catnip should be used in addition to the bait. (See Chapter 3, "Photographic Bait Stations" for additional information on baits and lures.)

Station Number and Distribution

Recommendations: Establish a minimum of two bait stations in each sample unit, no closer than 1 mile apart, at the sites of the most appropriate habitat or where unconfirmed sightings have occurred.

Attach the bait to a tree or stump with wire or heavy rope so that it cannot be dragged away. Fish and smaller meat baits may need to be enclosed in wire mesh (welded wire or chicken wire) and nailed to the trunk of a tree. Be prepared to move the bait up the trunk as snow accumulates during the winter. Seek a location that lacks complete canopy closure so that snow can fall directly on the ground in the vicinity of the bait. However, avoid open, south-facing slopes where the sun may quickly ruin the tracking surface.

Survey Duration and Check Frequency

Recommendations: Check each station for tracks every few days if possible, especially after new snow, for a minimum of 30 days or until the target species is detected.

Because the objective of the survey is to determine whether a sample unit is occupied, effort need not be expended beyond the detection of the target species. The minimum duration is set primarily on the basis of data for wolverine provided by J. Copeland (pers. comm.) who found that wolverine tracks in snow were first detected at bait stations after a mean of 26.7 days. Five of six first detections occurred within the first 31 days. Because the densities of fishers, martens, and possibly lynx are probably higher than that of wolverines and because fishers and martens are detected at track-plate stations considerably sooner than 30 days (see Chapter 4 "Track Plates"), we assume that 30 days are sufficient to establish presence within the sample unit.

Preparations for the Field

Data collected must be compatible with those of other trackers. Preparation for the field should include an understanding of tracking terminology and methods, as well as the ecology of MFLW. Here we provide a background on tracking techniques, including the interpretation of the effects of changing snow conditions on tracks.

Background

Modern tracking goes beyond sketching a track and recording a few measurements. Today's biologist must know how to measure prints, identify gait patterns, recognize pattern changes with speed, interpret behavior, and document field evidence. Decisions about the presence of rare species will often rest solely on track evidence. Tracking books such as those by Forrest (1988), Halfpenny (1987), Murie (1954), and Rezendes (1992) have good overviews of the target species. Here we focus specifically on the tracks of MFLW and summarize available information on characteristics useful for identification. We start with an overview of the basics of tracking.

Footprints form the basis for mammal identification from tracks. However, it is often not possible, especially in snow, to find a clear print. When identifiable prints are not available, an understanding of the trail left by an animal, its preference for habitats, and its behaviors provide valuable clues and may sometimes be used to identify the species. Always examine the entire scene, following suspect trails forward and backward as far as time will allow. During the trailing procedure, study the gait patterns and look for clear prints in sheltered areas. The strongest evidence from snow tracking comes from footprints cast in plaster or photographed. However, because obtaining clear footprints in snow may be difficult, trail patterns and gaits provide supporting evidence. Be careful of identifications made only from patterns and measurements of trails. The combination of footprint and trail information is best, but one may be lacking, so the tracker must be familiar with both.

Morphology of Carnivore Feet and Tracks

The feet of carnivores can have either four or five digits (*fig. 1*), but often only four toes register in a track. Toes are numbered from medial to lateral (*fig. 2*). In some species toe 1 is reduced to a "dew claw" high on the medial side of the foot, or is absent. Each foot has an interdigital pad, also called a plantar pad, which, if clear in the front print, may diagnose family. In species where all five toes of the front foot contact the ground, a metacarpal pad is present and may register (e.g., wolverines). In species where the fifth toe of the hind foot touches the ground, the metatarsal pads join the interdigital pad to form the heel (e.g., bears *Ursus* sp.). In some mustelid species the heel is naked (e.g., striped skunk *Mephitis mephitis*), and in others it is haired (e.g., marten) and thus more difficult to see in a print. The complete heel is visible in most bear tracks.

Important characteristics distinguish the tracks of the Canidae, Felidae, Procyonidae, Mustelidae, and Ursidae (*table 1*). We include procyonids and ursids because of possible confusion with tracks of MFLW. The track formula indicates whether front or hind prints are larger, how many toes show in a print, and the presence of claws. For example, the formula for the bear family, f5(4) H5(4) co, indicates that the hind print is larger (capital H), and in a clear print all five toes will show with claws often (co) showing. In a poor quality print, only four toes may show in either the front or hind print.

The larger prints are from the front feet of canids and felids and the hind feet of ursids; in mustelids it varies by species. Canids and felids show four toe prints. In the mustelids and ursids, toe 1 does not always show, which causes the appearance of a four-toed animal. The front tracks of cats tend to be wide or round, and the hind tracks are more rectangular. Canid toes are nearly symmetrical in size and position on the foot; those of the other families show more asymmetry in size and position. Sizes of individual toes of felids, mustelids, and ursids vary from large to small, with the largest toe most lateral in mustelids and ursids. The long axes of the toes of canids are nearly parallel, a pattern rarely seen in felids and mustelids. Felid toes form a shallow, asymmetric arc; a paired or stepped pattern is found in canids. The toes of mustelids tend to be grouped in a 1-3-1 spacing; when the small, medial toe does not show, a 1-3 pattern is typical.

Features of the interdigital pad can be extremely helpful in identifying a track to family. A bilobate anterior edge on the interdigital pad positively identifies a print as that of a cat. Poor prints or prints from heavy cats may show a blunt anterior edge, but this still will usually differ from the more pointed single lobe in the Canidae. An asymmetric, chevron-shaped interdigital pad is characteristic of the Mustelidae; red fox also have a chevron, but it is symmetrical. Metatarsal pads may be visible in prints of mustelids and ursids. The feet of all carnivores become hairier during the cold season, which obscures detail left in tracks. Lynx feet remain relatively hairy in the summer.

Footprints in Snow

Tracking in snow presents two types of interpretive problems: tracks often lack definitive shapes because of the fragile nature of the snowpack, and snow metamorphism may alter tracks. Understanding how tracks change in the snow is critical to proper identification.

Table 1—*Comparative characteristics of tracks of carnivore families*

	Family				
Characteristic	Canidae	Felidae	Procyonidae	Mustelidae	Ursidae
Track formula[1]	F4 h4 C	F4 h4	f5 H5 co	f5(4) h5(4)co	f5(4) H5(4)co
Foot shape[2]	Rectangular	Round, wide, Rectangular	Small rectangular Large rectangular	Wide	Wide, long
Larger feet	Front	Front	Hind	Varies	Hind
Toe-position asymmetry[3]	Little	Some	Some	Significant	Significant
Toe shape	Rounded	Teardrop	Finger-like, bulbous tips	Rounded	Rounded
Toe arc[4]	Stepped	Flat	Rounded	Rounded	Flat to rounded
Relative toe sizes	Nearly equal	Graduated	Graduated	Graduated	Graduated
Position of largest toe[5]	Medial	Medial	Medial	Lateral	Lateral
Toe splaying[6]	Common	Uncommon	Common	Uncommon 1-3-1	Rare
Claw presence	Usually	Seldom	Variable	Variable	Variable
Interdigital pad	1 lobe, or pointed anterior edge	2 lobes, or flat anterior edge	Chevron, full Heel	Asymmetric Chevron	Wedge Full heel
Interdigital pad relative size	Small	Large	Large	Narrow, large	Large
Metatarsal pad	No	No	Yes	Yes	Yes

[1] In track formula, F = front track, H = hind track, the capital letter F or H indicates which foot is bigger, numbers indicate how many toes usually show in a clear print, and numbers in parenthesis indicate the number of toes that often show in indistinct prints. C = claws almost always show, co = claws often show.

[2] Outline of the footprint including all pads.

[3] Position of the toes relative to an anterior-posterior center line

[4] A line drawn around the anterior edge of the toe pads. In felids, toe 3 (toe 1 is absent), and in mustelids, toe 4 may appear slightly anterior to the line.

[5] Relative location of the big toe.

[6] Separation between toes, often a function of substrate and speed.

Failure to interpret metamorphic processes may result in incorrect print and gait measurements. For example, the metamorphosed tracks of a bobcat or coyote can easily be misidentified as those of a lynx by the inexperienced or unprepared tracker.

Melting and evaporation, sublimation, erosion, and settling of the snowpack can alter tracks to varying degrees. One process may predominate, almost to the exclusion of the others. Warm temperatures will cause melting, but melting also may occur because of solar radiation when the ambient temperature is below freezing. Snow loss from sublimation can be dramatic, especially where chinook winds blow from high mountains. Both melting and sublimation can occur at night or on a cloudy day. To the trained eye, sublimated snow appears different than melted snow. Sublimated snow contains small crystals, whereas non-sublimated snow is characterized by crystals melted and frozen together. In sublimated snow, track edges appear well rounded but dry.

Tracks undergoing metamorphism may enlarge and be distorted in one dimension or both. Enlargement can be dramatic, with prints increasing up to four times in area. Because the variables that cause melting (solar radiation and temperature) and sublimation (wind, relative humidity, and temperature) can differ, the amount and type of directional distortion differ. During melting, maximum distortion occurs in portions of the track opposite the sun, usually the northeast part of the track. Distortion from sublimation occurs mostly on the downwind edge of the track, with the amount of distortion proportional to the wind speed. Wind-deposited snow on the lee side of the track combined with snow loss on the windward side can cause the track indentation to move downwind. Sublimation may increase track size without directional distortion. However, sublimation without directional distortion causes all pad impressions to enlarge to the same extent. Therefore, toe imprints will join and eventually merge with the interdigital and heel pads. If the track is distorted, the print size is altered and accurate measurements of trails may be possible only using center measurements (see Understanding Gaits).

Settling occurs within the snowpack because of gravity. Because snow sticks to vegetation, inverted cones around tree trunks indicate settling. The effect of settling is to shrink, and, in extreme cases, to destroy a track, often in a matter of hours.

Identify directional distortion by studying the track shape. Be suspicious of tracks that lack symmetry. Fortunately, most melt-enlarged and settled prints are apparent with careful examination. Therefore, when following a trail, avoid the temptation to make judgments based on only a few prints. Follow trails of interest in both directions as far as time and effort will allow. If inverted cones around tree trunks are visible, suspect reduced track sizes, and seek sheltered places, such as under the canopy of trees or shrubs, to measure prints.

Understanding Gaits

It is necessary to identify track patterns left by different gaits and to understand how the patterns change with speed; otherwise, measurements taken from track patterns may result in erroneous identification. For example, gait measurements are used to distinguish among bobcat, lynx, and mountain lion; mistaking a gallop for a walk could result in misclassifying a lynx as a mountain lion.

Four mutually exclusive gaits can be identified in carnivore trails: walks, trots, gallops, and bounds (synonymous with hops or jumps) (Halfpenny 1986, 1987). Gaits are defined by mechanical differences in modes of locomotion, not by differences in speed (Bullock 1971; Hildebrand 1959, 1965; Muybridge 1899). Below is an overview of gait track patterns and a brief discussion of some of the pitfalls in their interpretation.

Four terms are necessary to understanding gait patterns: stride, straddle, group, and intergroup. A *stride* is one cycle of locomotion and is measured as the distance from where a point on a foot touches the surface to the next spot where the same point on the same foot touches the surface (*figs. 3, 17*). The stride of a walking animal approximates the distance from the hip to the shoulder and provides an estimate of the length of the animal. *Straddle* is the distance from the left edge of the left footprint to the right edge of the right footprint of the same pair (front or hind). A *group* includes all footprints within one stride, i.e., a right front, a left front, a right hind, and a left hind, and is measured from the posterior edge of the posterior-most pad to the anterior edge of the anterior-most pad. *Intergroup* is the distance between two groups. It is measured from the anterior edge of the anterior-most pad of a group to the posterior edge of the posterior-most pad of the next group. No footprints occur within the intergroup space. A stride is composed of a group plus intergroup. Stride, group, and intergroup are measured parallel to the line of travel, and straddle is measured perpendicular to the line of travel.

Gait Patterns

Walking is the most common gait of many mammals (*fig. 3*). Tracks generally appear in a line, and hind prints tend to register directly on top of front prints. The more the animal relies on stealth, the more often the prints register with the hind print directly on top of the front print (compare *figs. 3A* and *3C*). Lynx, for example, usually show direct registry. At slow speeds, the hind print registers behind the front print; as speed increases, the hind print registers more anteriorly relative to the front print (*fig. 3B*).

Trotting is characterized by paired movements of diagonal limbs. For example, the right front foot moves at the same time as the left hind foot. The trail pattern appears the same as that of the walk, but the stride is longer and the straddle tends to be narrower in the trot (*fig. 4A*). Again, the placement of the hind feet varies with speed, and the hind print registers more anteriorly relative to the front print as speed increases (*fig. 4B*). A common variant occurs when an animal turns its body slightly sideways to the direction of travel. All front prints register on one side of the line of travel, and all hind prints register on the opposite side (*fig. 4C*). This side trot is commonly shown by canids; you have probably observed a dog trotting at an angle to its direction of travel.

Galloping is characterized by two periods during each stride when the animal has all feet off the ground. This produces the group and intergroup portions of each complete stride pattern (*fig. 5A*). The gallop creates variable track patterns because of changes in the lead foot (either front or hind) and changes in speed. The C-shaped pattern in *fig. 5A* is produced by a common canid gallop. The effect of a hind-foot lead-change results in the difference between the pattern in *fig. 5A* (a rotatory gallop) and *fig. 5B* (a transverse gallop). The rotatory gallop pattern resembles the letter "C" or its mirror image, whereas the transverse pattern resembles the letter "Z" or its mirror image. *Figures 5B, 5C*, and *5D* illustrate the effect of decreased speed on the relative positions of the hind and front prints. As speed decreases, the hind prints register farther back in reference to front prints. The gait pattern produced when the hind print registers at or posterior to the anterior edge of the front prints (the "lope line") is referred to as a lope. The lope, which is a slow gallop, is commonly used by mustelids (*figs. 5C, 5D*).

Bounding, like galloping, includes two periods during each stride when the animal has all feet off the ground (*fig. 6*). However, the bound differs from the gallop in that during the bound, the hind feet are placed side by side and not in front of each other. As bounding speed decreases, the hind print registers more posteriorly relative to the front print (*fig. 6B*).

Gaits are often described by their pattern on the ground, and their names are derived from repeated track sequences. Similar patterns can result from different gaits. The right-left, direct registry patterns created by walking or trotting are called alternating or simply right-left patterns (*figs. 3A, 4A, 7, 8*). When patterns of two prints repeat, they are called "2×" (pronounced "two-by") (*figs. 5D, 9*). Patterns designated 2× can be created by trots or gallops and would be called 2× trot, 2× lope, or 2× gallop. Gallops may also show 1× 2× 1 (*fig. 5C*), 3× (*figs. 10, 11*) or 4× (*figs. 5A, 5B, 12, 13*) patterns. A 3× bound or jump is illustrated by the last sequence at the top of *figure 7*.

Errors in Identifying Gait Patterns

Three types of error can occur when identifying trail patterns in the field: (1) mistaking a walk for a trot, (2) mistaking a slow gallop for a walk, and (3) confusing a side trot, lope, and gallop. The first is the hardest to detect. Compare *figures 3A* and *3B* with *4A* and *4B*. The track patterns are the same, differing only by the greater stride in trot patterns. Misreading a trot for a walk results in overestimating the size of an animal; a bobcat trail becomes that of a lynx, or a coyote becomes a wolf. To avoid this mistake, follow the trail and look for an area where the animal does not appear to be hurrying. Find a place where the animal is maneuvering around closely spaced objects and has slowed to a walk. Measure the gait pattern where the stride is shortest and the trail relatively straight. The measurement should be done on level ground where the pattern is a consistent, alternating right-left set of imprints. Take your time trying to find a walk, because *walking patterns are critical to identification when footprints are not clear.*

The other types of error usually happen in soft or metamorphosed snow where identifying front and hind prints is difficult. An alternating right-left pattern may appear to result from walking or trotting (*fig. 14A*). However, the pattern can also result from a slow transverse gallop (*fig. 14B*). While the pattern may appear similar if front and hind feet are not identified, the error in measuring stride is substantial (compare *figs. 14B* and *14C*). The error is compounded because a typical slow transverse gallop will have spacings between track imprints that are longer than would be found on a walk. Lynx often use a transverse gallop for a short distance. Because measurements taken from walking patterns are necessary for field identification of lynx, mistaking a gallop for a walk could result in the misidentification of a lynx track as that of a mountain lion.

To avoid misidentifying gaits, follow the trail. Because carnivores seldom gallop long distances with consistent track spacing, the gallop pattern will usually show spacing variation within a few strides. The intergroup distance will increase and provide the distinct group and intergroup patterns shown in *figure 4B*. In contrast, a walk or trot will continue with the same, even track spacing for long distances.

The third type of error results from confusing a side trot, a lope, and a fast gallop. All three gaits can leave a similar 2× pattern depending on speed (*fig. 15*). Because the three patterns cannot be mistaken for a walk, this mistake occurs when characterizing the behavior of the study animal. Red fox (*Vulpes vulpes*) often use the 2× side trot (*fig. 15B*) and leave prints that are about the same size as marten tracks. Mustelids commonly use the lope and gallop. When a mustelid is moving slowly, the hind feet register on top of the front feet (*fig. 15C*). However, when the mustelid is loping fast, the hind feet overstep the front feet and may register well anterior to the front feet (*fig. 15D*). Problems occur when trying to distinguish similar-sized mustelids, for example, martens and fishers. A marten using a fast gallop (*fig. 15D*) might be mistaken for a fisher using a lope (*fig. 15C*).

To avoid confusion, study prints carefully to identify front and hind prints. If the tracks are not clear, other characteristics may help identify the pattern correctly. Often mustelids drag their front feet in the fast gallop, leaving a "dumbbell-shaped" track pattern. If the dumbbell pattern is not evident, look for alternating short and long spaces between track impressions (*fig. 15D*). The short-long pattern indicates a fast gallop. Another way to separate the lope from the fast gallop is to follow the trail for a distance to see if it changes into a short-long pattern.

All three errors can be avoided by taking the time to account for all feet in each group pattern: two fronts, two hinds, two rights, two lefts. To identify walking and trotting patterns, care must be taken to verify direct registry of hind over front prints. When print detail is lacking, follow the trail until you spot a change in gait. Walking and trotting gaits continue with the alternating, right-left-right, placement of prints, whereas gallops of any type will soon tend to deviate from this pattern.

Measuring Tracks and Trails

Footprints

Track size is influenced by the depth that the foot sinks into the surface; feet leave larger footprints in soft substrates than in hard ones. Measurements of tracks from the same animal in different substrates may be considerably different. A cross section of a footprint shows the effect of sinking into the substrate (*fig. 16*). A track that sinks into the surface may be several millimeters bigger than one on a hard surface. Because area increases with the square of the linear measurement, the track appears to increase dramatically in size when it is only slightly longer and wider. Therefore, visual impressions of track size can be misleading, especially to the untrained observer.

Two methods have been used to account for depth-induced variation. The Interagency Grizzly Bear Team records the depth that the footprint sinks into the ground (R. Knight, pers. comm.). This provides an indication of how much a track may enlarge in a soft surface, but the increase in size resulting from sinking into the substrate is not measured. Fjelline and Mansfield (1989) controlled for depth-induced variation by measuring just the portion of the foot that would touch a hard surface, measured from the break of the track on one side to the break on the other side (*fig. 16*). The sides are not included in the measurement. This is the Minimum Outline (MO). The measurement that includes the sides is referred to as the Variable Outline (VO) because the same foot may yield different track sizes. MO measurements are more consistent across all surfaces, and their use reduces variation when measuring multiple tracks of one animal and when different observers measure the same track. For example, when one person measured five prints from one wolf, the coefficient of variation was 7 percent. Three different measurers, trained to use the MO method, had a coefficient of variation less than 1 percent for the same footprint (J. Halfpenny).[6] Tracks of few species have been measured using MO methods. Data contained in the current literature were not developed using this method and therefore are not directly comparable. Whenever possible, data should be collected and archived using both MO and VO measurements. Although measurements are often difficult to obtain in the field, they should be the standard for measurements from track impressions that are brought into the laboratory (see Track Preservation). However, when working with photographs or data from others not using the MO methods, you must usually use VO methods.

[6]Unpublished data on file at A Naturalists' World, P.O. Box 989, Gardiner, MT 59030

Prints may be measured at two levels: simple and complete. *Simple* measurements include width, length, and claw, metacarpal, and total lengths (*fig. 2*). Measure lengths parallel to the long axis of the foot; measure widths perpendicular to the long axis. Length includes toe and interdigital pads but excludes the metacarpal pad on front feet. Metacarpal length includes toe, interdigital, and metacarpal pads. Total length is from the anterior tip of the claws to the posterior edge of the metacarpal pad. Width is measured as the widest part of the track. Note whether the widest part of the track occurs at the interdigital pad or the toe pads. *Complete* measurements include the length and width of all pads. Collect complete measurements whenever time permits in the field or from photographs or casts in the laboratory. For rare species, it is desirable to make complete measurements in the field if casts or photographs are not taken.

Trails

Trail measurements add to our ability to discriminate among species when individual print measurements are difficult to obtain, and are essential when using discriminant analysis to distinguish the tracks of felids (see below). Four measurements should be made of the walking trail: stride, straddle, center straddle, and trough (*fig. 17*).

Trail measurements are made parallel or perpendicular to the line of travel. Data should be collected using the following three reference locations: (1) the center of prints, (2) the outer margin of prints, and (3) the trough created by foot drag (*fig. 17*). Straddle measurements are affected by curves in the trail and should be recorded only where the trail is straight. Center measurements are important because they are easily recorded and change little with metamorphosed snow. To obtain center measurements, mark the center of each footprint with a small dot; a pencil may be pressed into the surface. Lay a ruler between print centers on one side of the trail to measure the stride. Center stride is the same as the regular stride. Center straddle is the distance perpendicular from the center stride line to the center of the footprint on the other side and is always smaller than the regular (outer margin) straddle. The trough is a common feature of lynx trails where the hair on the feet drags along the snow surface. The trough is measured from the left-most outside drag mark to the right-most outside drag mark. It differs from the straddle measurement, which spans only the edges of the foot pad. If no hair drag is discernible, the straddle and the trough are the same.

Lynx, Wolverines, Fishers, and Martens: Tracks and Trails

The following guide to the tracks and trails of rare carnivores assumes that the reader knows the techniques described above. If not, previous sections should be reviewed. The purpose of this section is to provide a concise guide to the identification of tracks and trails. We emphasize field identification, but provide detailed measurements to aid in the examination of photographs and casts in the laboratory. We provide VO measurements for initial species identification in the field. MO measurements are provided for detailed analysis in the laboratory, but we encourage trackers to collect and use MO measurements in the field. Print measurements are listed as length followed by width (L × W). Where necessary, we lumped 2× , 3× , and 4× gait measurements because authors have not always clearly distinguished among them. See Rezendes (1992) for additional photographs and Forrest (1988) for drawings of tracks in snow. In addition to information about tracks and trails, we provide for each species some common signs and behaviors that can assist in identification of the tracks.

The data were collected primarily in the Rocky Mountains and Alaska; some lynx and fisher data were collected in Michigan, Massachusetts, and Maine. The data were either collected by one of the authors or gleaned from original literature that was supported by photographs, casts, or field notes. An effort was made to eliminate "guesstimates" or values from earlier authors. Murie's (1954) data are particularly valuable because all drawings come from plaster casts that are preserved at the Murie Museum, Teton Science School, Grand Teton National Park, Wyoming. Original data are also found in Brunner (1909), Forrest (1988), Haglund (1966), Mason (1943), Murie (1951-52, 1954), Nelson (1918a, 1918b), Rezendes (1992), Seton (1937, 1958), and Sorensen and others (1984). Carefully collected measurements of tracks and trails known to be from lynx, wolverines, fishers, and martens are uncommon, which makes such data extremely important. This information should be submitted to tracking authorities so that it can be incorporated into track databases that will refine future work.

Trackers need to develop an intuitive feel for the size of tracks and gait patterns of MFLW. It simply is not possible to measure every set of carnivore tracks, so those outside the possible range of sizes must be passed over quickly to maximize search efforts. The size of front prints of adult MFLW ranges from about 5 × 4 cm (marten) to 16 × 11 cm (wolverine) (*fig. 18*). Life-size schematic drawings of typical prints for each species are shown in *figs. 19, 20, 21, 22.*

Lynx

The tracks of members of the cat family share certain characteristics (*table 1*). Front feet are larger than hind feet and tend to be round, or wider than long. Four toes usually show, and claws usually do not. The teardrop-shaped toes register in an asymmetrical position and are graduated in size; the largest toe is medial, the smallest lateral, and the leading toe is number 3. The anterior edge of the toes forms a shallow arc. The interdigital pad is large, and no metatarsal pad is present. The most diagnostic feature of felid tracks, when visible, is the presence of two lobes on the anterior edge of the interdigital pad.

The feet of the lynx are densely covered with hair (*fig. 23*), and even in summer very little of their toe pads shows in tracks (Rezendes 1992). Few measurements of lynx tracks exist in the literature. Although little attention has been paid to measuring lynx tracks, much has been learned by following their trails (Brand and others 1976, Butts 1992a, Halfpenny and Thompson 1991, Nellis and Keith 1968, Nellis and others 1972, Parker 1981, Saunders 1963). Reviews by Koehler and Aubry (1994), Koehler and Brittell (1990), McCord and Cardoza (1982), Quinn and Parker (1987), and Tumlison (1987) describe lynx ecology, including information obtained by snow tracking.

Prints: Lynx have large feet for their size, an adaptation for support on snow. Although lynx weigh about 10 kg, and mountain lions up to 75 kg, their prints are about the same size. Lynx prints are usually poorly defined because of the densely haired foot. Typical variable and minimum outline measurements are presented in *table 2*. The length of the front print is generally less than or equal to the width; the length of the hind print generally exceeds the width. On hard snow after freezing and melting in the spring, toes may appear more distinct even though pads do not register (*figs. 24, 25*). The amount of variation by sex and age in track measurements is unknown.

Lynx tracks typically show a relatively large interdigital pad, the impression possibly resulting because the pad covered by hair creates a relatively large visual impression. Sometimes a naked interdigital pad may be observed (*fig. 26*). In some tracks, the naked pad leaves a relatively small imprint, and the posterior edge of the print appears concave because the lateral lobes extend considerably posterior to the medial lobe (*fig. 27*)

Table 2—***Variable Outline (VO) and Minimum Outline (MO) measurements for the length and width and the interdigital pad length and width of lynx front and hind prints (cm).[1,2]***

Print	Length Mean (SD)	n	Width Mean (SD)	n	Interdigital length Mean (SD)	n	Interdigital width Mean (SD)	n
Front VO	8.7 (1.4)	5	9.0 (0.8)	4	--		–	
Front MO	8.5 (0.2)	2	8.8 (0.8)	2	4.5 (0.3)	2	5.3 (0.3)	2
Hind VO	7.7 (0.1)	2	9.4 (0.2)	7	—		–	
Hind MO	6.7 (0.7)	2	7.2 (0.4)	2	3.6 (0.4)	2	4.2 (0.5)	2

[1]Data from Brunner (1909), Forrest (1988), Halfpenny (1987), Halfpenny and Thompson (1991), Jaeger (1948), Mason (1943), Murie (1951-52), Rezendes (1992), and Seton (1937, 1958).

[2]Track specimens are from Alaska, Colorado, and Massachusetts. When a lynx track impression reveals a naked interdigital pad, the values may be smaller than presented here. n = the number of different individuals whose tracks were measured.

(S. Morse, pers. observ.). The relative amount of posterior extension of lateral lobes has also been suggested as a means to separate dogs from lions, but is highly variable (Smallwood and Fitzhugh 1989). Tracks with a clearly defined interdigital pad that is relatively small and concave in shape may be from lynx. However, because the application of this clue to lynx track identification is relatively new, more information is needed to assess its importance.

Gaits: Lynx trails are characterized by conspicuous troughs even in soft snow (*figs. 7, 28*). They typically use two gaits, the walk and the bound, although the walk is by far the more common. When lynx are in open areas, they will frequently stretch the walk into a trot. The bound is used to quickly close the distance to the prey during a chase. Often only three footprints show because one hind print typically lands on a front print. The walking stride averages 71.9 cm (SD = 8.9, n = 11), and the group averages 49.2 cm (SD = 0.2, n = 4). Straddle averages 21.2 cm (SD = 3.6, n = 11), with center straddle averaging 8.9 cm (SD = 1.7, n = 8). The trough averages 26.9 cm (SD = 1.4, n = 3). The stride of a captive 2.5-year-old female lynx ranged from 75 to 90 cm for a walk, 107 to 120 cm for a trot, and 140 cm for a lope, with a group length of 80 cm (J. Weaver, pers. comm.).

Trail Characteristics and Signs: Lynx tend to be solitary, crepuscular animals. Trails of more than one lynx usually reflect female with young (Parker 1981), but cooperative hunting has been observed (McCord and Cardoza 1982, Quinn and Parker 1987). Trails through open, mature forest are typically straight, suggesting that these habitats may be used for travel. Trails through earlier-successional habitat typically meander, possibly indicating searching for prey (Parker 1981). Infrequently used forest roads and trails are commonly traveled by lynx during winter. Trails of walking lynx often show bounding gaits for several meters (Parker 1981), possibly indicating attempts to take avian prey (Nellis and Keith 1968).

Scent marking includes frequent urination on stumps and bushes (Saunders 1963). Scats are seldom buried by adults and are often found in the center of trails and at trail intersections (Berrie 1973). Lynx cache remains of kills, which typically appear as mounds of snow or debris such as pine needles and grass (Berrie 1973, Nellis and Keith 1968, Parker 1981). Lynx typically rest in open, sunny sites in either long- or short-duration beds (Parker 1981). Long beds, also called resting beds, were clearly defined, spherical, ice-encrusted depressions that had been used for several hours for resting. Short beds, also called hunting beds, are poorly-defined depressions without icy crusts, because of their short period of use.

Lynx can be curious about human activities. Tracks have been observed at garbage dumps at ski areas and construction camps, and trackers have reported lynx tracks on top of their own (Berrie 1973). Lynx are capable swimmers, and trails may lead into water.

Similar species:

Canids and Mustelids: Lynx tracks are similar in size to those of wolverines, mountain lions, wolves, and large dogs (*fig. 18*). They differ from those of wolverines in having only four toes and in lacking clearly defined toe pads, claws, a chevron-shaped interdigital pad, a metatarsal pad, and 1-3 toe spacing typical of mustelids (*table 1*). Lynx tracks may be distinguished from wolf (*fig. 29*) and dog tracks by their more round shape, their lack of definition because of their densely-haired foot, the usually large hairy interdigital pad, asymmetrically placed and sized toe pads, lack of claws, and the bi-lobed anterior edge of the interdigital pad. Lynx seldom lope or gallop as wolves do.

Other felids: Lynx tracks are distinguished from those of bobcat (*figs. 30, 31, 32*) by their larger size, hairy foot, wide trough, wider straddle, and longer walking stride. Toe pads in bobcat tracks are clear, while those in lynx prints are often indistinct. Separating lynx tracks from mountain lion tracks (*figs. 33, 34, 35*) may be difficult. In general, lynx tracks are less distinct because of the hair on the feet, the walking stride is shorter, and although their tracks are about the same size, lynx tend not to sink into the snow as far as mountain lions. Clear prints of lynx may show a relatively small interdigital pad with concave posterior lobes (S. Morse, pers. observ.). When following a trail, try to judge whether the depth of the track is that of a 10-kg or 50-kg animal. The densely hairy foot of the lynx produces a trough of hair drag marks outside the load-bearing surface of the foot, a characteristic lacking in mountain lion trails.

To aid in the identification of felid tracks we have developed several discriminant functions to distinguish lynx tracks from those of bobcat and mountain lions. These discriminant techniques were derived from a relatively small sample (n = 3, 6, 7 bobcat, mountain lion, and lynx prints, respectively) collected from animals in Colorado, and thus the results should be interpreted with caution. We encourage those with additional data from these species to submit it to the senior author to be included in future revisions of the discriminant test.

The first step is to exclude bobcat. If possible, collect measurements of at least three stride and print widths, and insert the mean values into the following equation:

$$\text{Species Score} = -5.842 - 0.075(\text{stride}) + 1.471(\text{print width}).$$

If the score is less than -0.5, the track is most likely from a bobcat; if the score is 0 ± 0.5, the result is ambiguous and further tests should be conducted for verification. If the score is > 0.5, the track is too large to be that of a bobcat and is probably that of lynx or mountain lion.

The next step is to distinguish lynx and mountain lion tracks. If possible, collect at least three measurements of stride, straddle, and track print width from the unknown track, and insert the means into the following equation:

$$\text{Species Score} = -5.01 + 0.103(\text{stride}) + 0.225(\text{straddle}) - 0.947(\text{print width}).$$

If the score is less than -1.0, the track was probably made by a lynx. If the score is greater than 1.0, the track was probably made by a mountain lion. If the score is 0 ± 1.0, further tests should be conducted for verification. Additional insight can be gained by comparing track measurements to the complete data set used to develop these functions in *appendix A*. If additional testing is needed, send measurements (and casts and photographs if available) to the senior author or another qualified biologist.

Mustelids

The mustelids share many track characteristics. Wolverine, fisher, and marten tracks appear relatively large because of the presence of five toes. The 2× lope or gallop gait is very common. Toes typically show a 1-3-1 grouping (*fig. 1*). When only four toes show, the 1-3 grouping is diagnostic. The position of toes is asymmetric to the center line of the foot. Toe shape is rounded, and the toes vary in size from the small medial to the large lateral toe. The medial toe is the most posterior on the print and often does not register. Claws may or may not be present in the track. The interdigital pad is an asymmetric, narrow chevron (upside-down "V") that is relatively large (*fig. 1*). The front print may show a metacarpal pad. The metatarsal pad of the hind foot is densely haired and does not show as clearly in wolverine, fisher, or marten prints as it does in some other mustelids (e.g., skunks). The metatarsal and metacarpal pads show only when the animal is moving at a slow speed or going downhill.

There are few published measurements of tracks and gait patterns for mustelids. Measurements given here summarize those in the literature and those of the authors. It is often difficult to determine whether measurements in the literature include claws and metacarpal pads; those given here do not. It is important that new information on mustelid tracks be collected, especially from animals of known age, sex, and weight. With the acquisition of additional measurements, guidelines suggested here may change.

Wolverines

Wolverines are the largest terrestrial mustelid and their prints can be confused only with those of the largest carnivores: mountain lions, lynx, wolves, domestic dogs, and bears (*fig. 18*). Snow tracking has revealed more about their natural history than about that of any of the other species covered in this manual (J. Copeland, pers. comm., Haglund 1966, Murie 1951-52, 1954, Sorenson and others 1984). Reviews of the habitats used by wolverines are included in Hornocker and Hash (1981) and Banci (1987, 1994).

Prints: Large prints that often show hair drag marks characterize wolverine prints (*figs. 20, 36*). Good prints show all five toes, although poorer prints may show only four toes (*fig. 37*) with a 1-3 spacing. The front foot often shows a distinct metacarpal pad (*figs. 1, 38, 39*). Typical wolverine track measurements are presented in *table 3*. Considerable size variation occurs in the field, especially when it is not possible to distinguish the claws, toes, and other pads of the front foot (*fig. 18*).

The only data addressing differences by age and sex of tracks are from Sweden (Haglund 1966) where the hind prints of adult wolverines are usually greater than 13 × 10 cm VO. Hind prints greater than 14.5 × 11 cm are probably from males. Wolverines have nearly adult-sized feet by three months of age.

Gaits: Wolverines typically use two types of gait: the 2× patterns and the 3× lopes. The 3× lope is the most common, and it is used for covering long distances (*figs. 10, 40, 41*). It is a bouncing gait in which all four feet may be off the ground at once. Observers have described it as "humping along." It is often done at an angle to the direction of travel, and angled lines of large prints, even when observed at great distances, suggest wolverines. When the snow is soft and deep, wolverines tend to use 2× gaits. On harder snow, 3× lopes are more common. In very soft, deep snow, the group of prints falls into a single hole, and a series of relatively closely spaced holes (45-115 cm) results (see Murie 1951-52, 1954 for illustrations). In deep snow the wolverine may create a trough as it plows along, and hair drag-marks on each print are also evident. A wide straddle (20 to 40 cm), produced by the tendency to use sideways 3×-lopes, strongly suggests wolverine.

Trail Characteristics and Signs: Wolverine trails typically cross large openings and are often found above treeline. They may intersperse long-distance travel (50 km or more) with several days of more localized activity (J. Copeland pers. comm., Krott 1959). Wolverines will use the same paths repeatedly, creating packed "wolverine trails" (Haglund 1966), especially in the vicinity of food. Although wolverines seldom cross highways (J. Copeland pers. comm.), they will travel on snow-covered roads and snowmobile trails (H. Hash, pers. comm.).

Many kinds of sign have been reported on wolverine trails including scent marks, rubs, bites, caches, digs, dens, and scat. Scent marking is done with only a few drops of urine, or by rubbing an object with the body. Wolverines walk over small saplings, bending them over as they mark with their belly. To find rubs, look closely for sites where these rubs knock snow or bark from shrubs and trees. Wolverines often roll in the snow and may depress an area up to 4 m across.

When food is plentiful, wolverines cache remnants of carcasses (Haglund 1966, Krott 1959). They may drag food long distances to cache sites, their tracks showing beside deep drag marks. When mounds of snow, dirt, or brush are encountered along a trail, check the interior for food caches. Food is also cached in crevices and rockpiles. Caches are often marked with urine or feces, but wolverines often bury the feces.

Similar Species: Wolverine tracks can be separated from those of wolves (*fig. 29*), mountain lions (*figs. 33, 34*), and lynx (*figs. 25, 26*) by the presence of a fifth toe. Bear tracks also have five toes (*fig. 42*); however, wolverine prints show 1-3-1 grouping of toes and chevron-shaped interdigital pad. The 3x side lope with a large straddle can distinguish a wolverine trail from that of dogs, wolves, mountain lions, and lynx. Wolverine tracks are larger than river otter (*Lutra canadensis*) tracks (*fig. 43*) and lack webbing between the toes. River otter tracks are most frequent in riparian habitats, although river otter may travel considerable distances overland, especially during the winter. River otter trails in the snow will often show slide marks of 1 to 5 m in length. A summary of track data for wolverine and similar species is provided in *appendix A*.

There is some overlap between gaits of wolverine and fisher (*fig. 44, table 4*). It appears that only the stride length at a full gallop may distinguish them. The average

Table 3—*Variable Outline (VO) and Minimum Outline (MO) measurements for the length and width and the interdigital pad length and width of wolverine front and hind prints (cm)*[1,2]

Print	Length Mean (SD)	n	Width Mean (SD)	n	Interdigital length Mean (SD)	n	Interdigital width Mean (SD)	n
Front VO	9.1 (1)	5	9.4 (0.9)	4	4.2 (0.4)	5	6.4 (0.7)	5
Front MO	8.3 (0.4)	3	8.3 (0.2)	2	3.6 (0.6)	3	5.6 (0.5)	3
Hind VO	8.8 (0.6)	2	9.9 (1.5)	2	4.1 (0.4)	2	7.3 (2.6)	2
Hind MO	7.0	1	–		2.5	1	–	

[1]J. Halfpenny, unpublished data on file at A Naturalist's World, Gardiner, MT; Murie (1951-52), Murie Museum; Nelson (1918a, b); and Seton (1958).

[2]Track specimens are from Alaska, Montana, and Wyoming. n = the number of different individuals whose tracks were measured. Refer to figure 2 for definitions of pad components

Table 4—*Comparative measurements of mustelid gaits (cm)*

Species	Gait	Typical stride	Stride (range)	Straddle (range)	Group (range)	Intergroup (range)
Marten[1]	Walk	29	28–40	7–11	–	20–60
Marten	2x gait	55	20–120	7–11	14–24	25-35
Marten	3x lope	–	55–75	5–8	30–40	25-30
Marten	4x gallop	83	50–155	6–8	20–45	–
Fisher[2]	Walk	51	30–65	7–14	-	-
Fisher	2x gait	72	40–145	9–14	10–55	35–65
Fisher	3x lope	–	45–140	7–17	–	
Fisher	4x gallop	87	50–180	–	31–64	15–76
Wolverine[3]	Walk	65	65	18–20	23-46	8–30
Wolverine	2x gait	–	25–115	–	43–94	13–89
Wolverine	3x lope	–	75–170	20–38	74–119	18–48
Wolverine	4x gallop	–	160–260	20–38	–	> 89

[1]Sources include Forrest (1988); Gordon pers. comm., J. Halfpenny unpublished data on file at A Naturalist's World, Gardiner, MT; Jaeger (1948); Murie Museum; Murie (1954); Raine (1983); and Seton (1958). Geographic locations include Colorado, Idaho, Montana, Minnesota, Wyoming, Massachusetts, and Manitoba.

[2]Sources include Forrest (1988); J. Halfpenny unpublished data on file at A Naturalist's World, Gardiner, MT; Murie Museum; Murie (1954); Raine (1983); and Rezendes (1992). Geographic locations include Alaska, Massachusetts, Minnesota, Michigan and Manitoba.

[3]Sources include N. Bishop pers. comm., 1994; J. Copeland pers. comm., 1994; Forrest (1988); Halfpenny unpublished data on file at A Naturalist's World, Gardiner, MT; Lederer pers. comm., 1994; Murie Museum; Murie (1951-52, 1954); Raine (1983); Rezendes (1992); and Seton (1928 in Nelson 1918a,b). Geographic locations include Alaska, Idaho, Massachusetts, Montana, Wyoming, British Columbia, and Manitoba.

stride for walks and 3× lopes appears to be larger for wolverines than fishers. Wolverine prints are distinguished from those of marten and fisher by their larger size (*fig. 18*).

Fishers

Of the three mustelid species covered here, the least is known about fisher tracks and trails. Fishers occur primarily in late-successional forests with dense canopy closure, often in association with riparian areas. Reviews of the habitats used by fishers are included in Banci (1989), Heinemeyer and Jones (1994), Powell (1993), and Powell and Zielinski (1994). A snow-tracking database needs to be developed for fishers, especially for western subspecies, similar in quality to that of the wolverine. When tracking fishers, keep good notes; much of the information may be new.

Prints: Fisher tracks are medium in size, have sparse hair, and the pads show well in a clear print (*figs. 21, 45, 46*). Footprints vary considerably in size, probably because of sexual dimorphism. Typical variable and minimum outline measurements are presented in *table 5*. Rezendes (1992), working in the northeastern United States, has suggested that tracks less than 6.5 cm wide (VO) are probably those from females and that those wider than 7 cm are likely males. However, these values should be interpreted with caution by biologists in the western United States.

Gaits: Fishers typically walk or use 2× gaits and 3× lopes (*fig. 8*). Gait patterns are influenced by snow hardness, which is indicated by the depth an animal sinks. For example, in Manitoba, when the mean depth of fisher tracks decreased to 5 cm, they changed gait from a bound to a lope (Raine 1983). On soft snow, fishers walk and use 2× gaits; on harder surfaces fishers gallop. On snowshoe hare trails, strides of 2× gaits are longer than those made off trails. When they sink into snow more than a few inches, fishers tend to walk and their body often produces a trough up to 25 cm wide and 10 cm deep depending on snow depth (Raine 1983).

Trail Characteristics and Signs: Although fishers are often described as arboreal, snow tracking demonstrates that they may cover considerable distances on the ground, seldom going to trees (Powell 1980). Snow conditions may restrict travel by fishers, especially during mid-winter when snow is deep and soft. When the snow is crusted, fishers used habitat in proportion to its availability (southeast Manitoba, Raine 1983). Fisher trails seldom venture far into openings. Routes tend to be along drainage bottoms rather than sides of valleys (Jones 1991). Fishers often travel the same routes repeatedly and will use the packed trails produced by snowshoe hares. Trails made while hunting for snowshoe hare wander with frequent changes of direction (Powell 1978). Tracks of fishers traveling together have been reported, both before and during the spring mating

Table 5—***Variable Outline (VO) and Minimum Outline (MO) measurements for the length and width and the interdigital pad length and width of fisher front and hind prints (cm)***[1,2]

Print	Length Mean (SD)	n	Width Mean (SD)	n	Interdigital length Mean (SD)	n	Interdigital width Mean (SD)	n
Front VO	6.2 (1.0)	5	6.9 (1.1)	6	3.0 (0.3)	5	4.4 (0.5)	6
Front MO	6.2 (0.8)	2	6.6 (0.7)	2	2.7 (0.2)	2	3.6 (0.5)	2
Hind VO	6.4 (0.4)	4	5.9 (0.3)	3	3.2 (0.6)	4	3.8 (0.2)	4
Hind MO			–		–		–	

[1] J. Halfpenny, unpublished data on file at A Naturalist's World, Gardiner, MT; Murie Museum; Rezendes (1992); and W. Zielinski, unpublished data on file at Redwood Sciences Laboratory, Arcata, CA.

[2] Tracks specimens were collected in California, Michigan, Massachusetts, and Wisconsin. n = the number of different individuals whose tracks were measured. Refer to figure 2 for definitions of pad components.

season (de Vos 1951). Raine (1983) reported drag marks left by the tail. Scats composed entirely of porcupine quills suggest that the trail was produced by a fisher.

Similar species: Fishers are between wolverines and martens in size. While their prints are closer in size to those of the marten, their gaits show considerable overlap with both species (*fig. 44, table 4*). The size of fisher tracks also overlaps with that of other carnivores such as coyotes. The tracks and gaits of fishers can be separated from those of wolverines and river otters by their smaller size (*fig. 44*); webbed-foot impressions also distinguish river otter tracks (*fig. 43*). Separating fisher tracks and trails from those of marten is difficult because overlap in size exists between the tracks and gaits of these sexually dimorphic mustelids (*fig. 44*) (de Vos 1951, Murie 1954, Raine 1983, Taylor and Raphael 1988). Compared to martens, fishers tend to walk more, use the top of logs more, leave straighter trails, create troughs when walking in soft snow, drag their feet, and leave tail drag-marks in the snow (de Vos 1951, Murie 1951-52, Raine 1983). Fisher footprints tend to show clearer pad prints, having less hair than marten (Rezendes 1992). Fishers seldom tunnel under the snow (for an exception, see Murie 1954); martens often dig subnivean tunnels and dens. Marten and fisher tracks from sooted track plates can be discriminated (Zielinski and Truex 1995, Chapter 4), but additional work is needed before tracks in the snow can be distinguished with confidence.

Fisher tracks lack the long claw impressions that distinguish badger tracks (*fig. 47*). Badger prints, especially front ones, are distinctly "pigeon-toed." Badgers have a very wide straddle and tend to use a walking gait more than other mustelids. Fisher tracks are distinguished from those of canids and felids by the presence of five toes. Fishers are plantigrade but lack the naked heel characteristic of bears and raccoons (*Procyon lotor*) (*figs. 42, 48*). Fishers commonly show a 2× lope pattern; only the side trot of canids may be confused with the 2× pattern. A summary of data for fisher and similar species is provided in *appendix A*.

Martens

Marten feet (*fig. 49*) are intermediate in size between fishers and the smaller weasels and mink (*Mustela* sp.). Marten trails are probably found more consistently in mature coniferous forests, and less in openings, than the other three species considered in this manual. Reviews of the habitat ecology of American marten are included in Buskirk and Powell (1994) and Buskirk and Ruggiero (1994). Readers interested in learning more about tracking martens should review the detailed snow-tracking studies of the European pine marten (*Martes martes*) by Pulliainen (1981a, b, c).

Prints: Perhaps it is because they are the most common of the four species considered here that few marten tracks and trails have been measured (*table 6*). Marten feet and tracks are medium in size (*figs. 22, 49*) and may show a metacarpal pad (*fig. 50*). On

Table 6—***Variable Outline (VO) and Minimum Outline (MO) measurements for the length and width and the interdigital pad length and width of male marten front and hind prints (cm)***[1,2]

Print	Length			Width			Interdigital length			Interdigital width		
	Mean	(SD)	n	Mean	(SD)	n	Mean	(SD)	n	Mean	(SD)	n
Front VO	5.3	–	1	4.9	–	1	3.3	–	1	3.8	–	1
Front MO	5.1	–	1	4.6	–	1	3.1	–	1	3.7	–	1
Hind VO	5.8	0.2	2	5.2	2.5	3	3.1	–	1	3.9	–	1
Hind MO	5.4	–	1	4.9	-	1	3.0	–	1	3.8		1

[1]J. Halfpenny (unpublished data from A Naturalist's World, Gardiner, MT). Variable Outline measurements from two animals, apparently females from California and Wyoming, respectively, are length (4.4, 3.2), width (3.6, 3.2), interdigital length (Calif. 2.3), and interdigital width (Calif. 2.5).

[2]Tracks specimens were collected in Colorado and Wyoming. n = the number of different individuals whose tracks were measured. Refer to figure 2 for definitions of pad components.

hard surfaces only four toes may show, and the heel of the hind foot is usually absent (*figs. 51, 52*). However, in a good print five toes and the heel will usually be evident (*fig. 53*). During the winter the pads tend to be covered with hair. We strongly encourage biologists to collect standard measurements on marten tracks to improve our poor database on this species.

Gaits: Martens typically use 2× gaits (*fig. 9*). Their gaits are influenced little by snow hardness, and they rarely produce body-drag troughs. Typical measurements of marten strides are presented in *fig. 44*.

Trail characteristics and signs: Martens, like fishers, are often described as arboreal, but snow tracking reveals that they can cover considerable distances on the ground, seldom going to trees (Soutiere 1979, Zielinski 1981). They frequently burrow beneath the snow; their tunnels are near tree stumps and fallen logs. Snow conditions seldom restrict travel. Marten trails are erratic and frequently cross themselves as the animal investigates cavities in the snow and emergent trees or rocks. Martens will nse packed trails, especially those produced by snowshoe hares. During the course of their travels, martens scent mark by dragging their abdominal gland over objects that protrude above the snow surface.

Similar species: Distinguishing marten tracks and trails from those of fishers has proven difficult (*fig. 44, table 4*); see the description for fishers, above. Marten tracks can be separated from those of badger because martens lack long digging claws (*fig. 47*) and have a much narrower straddle. Mink tracks (*fig. 54*) tend to be smaller than marten tracks, though the difference can be slight, and mink tend to be restricted to streamcourses. A summary of print data for marten and similar species is provided in *appendix A*.

In the Field

Analyzing Tracks and Trails

The worst problem in interpreting tracks can be the careless actions of the tracker and helpers. When a set of tracks is spotted, STOP and THINK! Keep other personnel at a distance. Take the time to do a mental exercise we call "Big Picture - Little Picture." Step back and look at the whole scene. Where does the trail originate and lead to? Where can you walk without destroying clues? Once you get your nose down to a track, it is easy to forget the big picture of what is happening.

Big Picture

During the "Big Picture" exercise, set the stage for field analysis. The leading letters STS serve as a reminder of questions to ask yourself.

S = Setting: geography and habitat?
T = Time: year and day?
S = Surface?

The setting is critical to initial identification of tracks. Medium-sized mustelid tracks in central New Mexico are probably weasel, not marten, and the same tracks along a stream may be mink. Second, knowing the time when tracks were made provides important information for track interpretation. Cat tracks made during the night are more likely to be bobcat, while those made during the day may be domestic cat. The last S stands for the surface. Has it changed since the tracks were made? Understanding how it has changed, and over what time period, provides information on track metamorphism.

Approach the tracks carefully, and avoid stepping on any clues. Because a slip in the snow on a hill can destroy tracks, it is best to approach from the downhill side.

Ideally, select a level piece of ground or a section of trail where the animal is contouring the slope so that movement up- or downhill will not interfere with your interpretation. Take pictures of the trail as you approach and before your foot prints interfere with the trail pattern.

Establish the animals' line of travel or line of direction to help with later analysis. This may be done by laying a string or long ruler through the center of the trail. You may also do this mentally by just imagining where the center of the trail runs. However, a real marker will help visualize right and left footprints and interpret gait patterns.

Little Picture

Light

Natural lighting should be used to the best advantage. Two factors control lighting: sun position and shade. At any point the track may be in direct sunlight or in shade. It often helps to cast a shadow over a sunlit track that is difficult to see. During the day, changes in angle and aspect of the sun can change visibility dramatically. Experiment over the course of a day, if possible, by viewing tracks from different directions and angles above the ground. Tracks that are not visible on the way out in the morning may be prominent when you return in the afternoon. When possible, track by going out and back on the same route.

Polarized sunglasses may greatly improve the ability to see tracks. Lift them off your nose to view the surface without the polarized effect, and compare visibility. Winter light is often "flat," that is, with little three-dimensional definition. Yellow glasses or goggles may help, as may light from a flashlight directed at a low angle across the tracks. Lightly spraying individual prints with Snow Print Wax (see section on Casting, below) may make them more visible.

Touch

While vision is the primary sense used to track, the sense of touch may reveal things that cannot be seen. This is particularly true when new snow covers tracks. The original force of the step creates relatively hard footprints in compacted snow. Subsequent falling or drifting snow creates a depression with little track definition. The depression may be larger or smaller than the original track, depending on the type of snow and amount of metamorphism. The depression must be checked by feeling with bare fingers, using the "pedestal test" to reveal the true size of tracks (*fig. 55*). To form the pedestal, excavate snow from a circle around the track. Blow loose snow off the pedestal. Then, with your bare fingers, carefully excavate the remaining snow to reveal the original footprint. The compacted footprint on the pedestal will be the best possible rendition of the original track. It may not provide conclusive identification to species, but can provide important size information.

Measuring Tracks and Trails in the Field

Select the best footprints available along a trail, and mark them with a nearby scratch in the snow. Locate both front and hind prints, if possible. Try to locate at least three front and three hind prints so measurements may be averaged. Take some photographs before disturbing tracks, and then take additional photographs with a scale (see below). Make a drawing on the back of the Track Observation form (*appendix B* and in pocket inside back cover) to supplement measurements. If a measurement, e.g., toe length, cannot be made because of track quality, indicate in field notes.

Carry two rulers to facilitate measuring. Rulers marked in both English and metric units are best; measure in metric whenever possible. A folding ruler provides a rigid straight line for marking between two tracks to measure the straddle. The folding ruler may also be used along a trail to provide continuous perspective in spite of parallax problems. A plumber's rule is best because it is made out of fiberglass and will not warp when it gets wet. Rigid Plumbing manufactures such a ruler.[7] A retractable, power return ruler (e.g. Stanley Powerlock 33-328) can be used to complete measurements. The 3m / 10 ft combination is light for travel, but rigid enough to span tracks in the snow without collapsing and destroying the track. Calipers or drafting dividers improve the ability to measure prints in the snow.

[7] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

Minimum Outline (MO) measurements are most important. Measure MO on a footprint or cast by estimating where the edge of the foot would start to turn away from a hard surface (*fig. 16*). If time remains, then take Variable Outline (VO) measurements. Measure length parallel to the long axis of the track (*fig. 2*) and widths perpendicular to this axis. Prints may be measured at two levels of resolution: simple and complete (see Measuring Tracks and Trails, above). If casts or photographs are taken, or if time is short, simple measurements in the field are satisfactory. If tracks are from a rare species, always take some measurements before attempting to make casts.

The best measurements of gait patterns are made on level ground where the animal is moving in a relatively straight path. Select the most uniform section of strides to provide the position of gait measurements. Avoid sections where gaits change. The walking gait is the most important for identification. Avoid sections where the animal is trotting. To do this you will need to know the approximate length of a walking stride for the target species (see individual species accounts above). Follow the trail in both directions to find the walking gait with the smallest strides. The section of trail with direct registry, neither understep or overstep, will represent the true walking gait of the animal.

To obtain center measurements from the trail of a walking animal, mark the center of each footprint with a small dot; a pencil may be pressed into the surface (*fig. 17*). Lay a ruler between print centers on one side of the trail to measure the stride. To obtain center straddle, draw a line along your ruler, and measure perpendicularly from the line to the center of the footprint on the other side. Take the trough measurement from the left-most outside drag mark to the right-most outside drag mark.

Straddle and trough vary with curves in the trail; try to measure straight sections of trail. Three to five sets of measurements should be taken and later averaged. The more measurements the better, within time and safety limitations.

Track Preservation

When track identification is critical to a search, preserve a record for later analysis. Three methods of preservation are commonly used: drawing, casting, and photographing.

Drawing

Although you may not be an artist, any sort of drawing will aid in the subsequent identification of an unknown print. Drawings often include details that the tracker may not realize are important at the time. Make drawings on a one-to-one scale using a form or graph paper if possible, or draw on the back of the Track Observation Form (*appendix B* and pocket inside back cover). If you hold your notebook near the print, the picture may be drawn to size without transferring measurements to the paper. Alternatively, hold a clear sheet of thick acetate over the print and trace the VO using a permanent marker (Smallwood and Fitzhugh 1993). If the print is too big for your paper or acetate, draw at a 2:1 scale (2 inches on the ground equals 1 inch on the paper). Measure the track, divide by 2, and then mark key points on your paper. Mark length and width of the footprint, toes, and metacarpal pads. Draw a simple outline of all pads. Add details with shading and make notes as to the meaning of the details.

When drawing gaits, find a section of trail that is consistent for at least three strides, neither turning nor changing stride length. If possible, locate the gait on level ground. First identify and record the type of gait, then draw a line of travel (direction). Draw to scale, but use ratios of 10:1 or 20:1 to facilitate transfer of measurement to the drawing. Mark key points on your drawing (e.g., stride, group, and straddle), and indicate foot positions with letters (F = front, H = hind, D = direct registry of hind on front print). It is not necessary to sketch each footprint. Draw or indicate all clues: drag marks, hair and tail drags, scat, etc.

Should you find yourself in the field without drawing equipment or measuring devices, you can still record size data. Take a string, pack cord, or even shoe lace. Tie knots in the cord to represent different measurements, that is length, width, pad length, pad width, etc. If you have no cord, break sticks to the representative length, or notch your skis with a knife. If feasible, find a way to protect the track from disturbance or melting, mark your exact location, and plan to return with the equipment for appropriate documentation. If the tracks may be important, take the time to figure out a way to measure them!

Casting

Materials.—The most common material used for casting is plaster; the most readily available is plaster of Paris. Avoid any plaster that is labeled patching compound or indicates that it is to be used on wallboard. Wallboard plaster tends not to harden well, and poorly hardened plaster casts can shatter. Plaster is available at hardware and building supply stores. Sometimes it can be obtained from drug stores, but quantities are usually small and expensive.

Dental stone, which is dried and sieved more than regular plaster, records detail better but it is more expensive. Passing plaster through a flour sieve will make it finer. Dental silicon does not work well in cold temperatures, is expensive, and may shrink if not kept moist. Law-enforcement agencies have replaced silicon compounds with Mikrosil (Kinderprint Co., Inc., P.O. Box 16, Martinez, CA 94553, 800-227-6020), but it is expensive and comes only in small quantities. Mikrosil provides excellent detail, but we have not tested it under cold field conditions. While sulfur casting has been used in the past, it is not recommended for snow casting.

As plaster of Paris sets, it gives off heat that melts the snow. This dilutes the plaster, causing a rough surface on the cast that makes it useless for identification. Snow Print Wax (Kinderprint Co., see above) is used to seal the snow before the plaster is poured into the track. Although the heat will still melt the snow, water cannot reach the plaster to dilute it. One can of wax will do at least four lynx-sized tracks. Snow Print Wax also works well in mud and even dry soil, where it stabilizes the track and shields the plaster from the substrate, enhancing details in the final cast. We have tested other compounds to seal the snow, including spray rubber insulation for electrical tools, spray paint, Krylon clear plastic spray, and hairspray, but all produced unacceptable track enlargement.

Method.—Making plaster casts is relatively easy, but should be practiced before attempting to cast important tracks. Assemble all materials and have them ready next to the track. In addition to the items already mentioned, you will need two large (2 × 2-ft) plastic sacks, a mixing cup (32-oz. plastic cup), a mixing stick (1-inch wide rubber spatula works well), and insulation in the form of your hat, coat, mittens, etc.

If it is sunny, shade the track by working on the south side so that your shadow falls on the track. Pick or blow out any debris from the print. Build a wall about 1 inch high around the track with sticks, long-flat snowballs, or plastic from a milk container.

Spray the red-colored Snow Print Wax on the track from each of three directions, 120 degrees apart. Follow directions on the can. Allow the wax to harden at least one minute between sprayings. This is a good time to take photographs because the wax will accentuate details of the track. After the third spraying, examine the wax surface for complete coverage and spray more wax where the snow is visible. When snow is wet, first spray propane from a hand-held cartridge onto the track. The expanding propane cools rapidly and freezes the water. Then apply Snow Print Wax.

Mix approximately two parts of plaster to one part water by volume. Fill the cup less than half full with water; any more will cause the final volume to exceed the container size. While stirring firmly, add plaster rapidly because you will have only about 2 minutes to work. Scrape plaster from the sides of the container, and make sure all lumps are broken and mixed. As the mixture starts to thicken, add additional plaster slowly and carefully. The final mixture should be about the consistency of a thin milkshake, but not runny. Work quickly; the chemical reaction will start the plaster hardening, and the correct amount of plaster must be in the mixture before pouring. Without the correct amount of plaster, the mixture will harden but later break.

Hold the mixing stick so the tip is a half inch above the fragile, detailed parts of the track. Pour plaster on the stick about 3 inches up, and let it run down the stick. Because the first plaster out of the container will be the thinnest, it should be poured into the small detail of the print. Once fragile parts are covered, quickly pour in the rest of the plaster. The plaster should be about 1/4 inch above the level of the snow for a lynx-size print. For a larger print, or two prints together, the plaster should be 1/2 inch above the level of the snow. The proper thickness above the snow is necessary to prevent breakage. Insert the mixing stick about 1/16 inch into the plaster. Move the stick rapidly back and forth to vibrate the plaster. This motion causes the plaster to liquefy and flow to a smooth, level surface.

Cover the plaster with a plastic garbage bag, and place insulation on top. Be sure the weight of the insulation does not crush the plaster and destroy the track. Clean the plaster container with water. After 40 minutes, carefully pick up the cast by digging below it. Insert your fingers underneath and lift it straight up; if you try to pick the cast up by the edge, it may break. Scratch the date, time, and location into the back of the cast. The plaster has completed its initial setting but will continue to cure for at least 24 hours. Wrap the cast in a brown paper sack or cloth to carry it out of the field. Never wrap casts in plastic bags because the water lost during curing can cause the plaster to crumble. Place the cast in a warm dry place. The Snow Print Wax should be washed off with hot water, but avoid washing it down the sink. Do not worry about getting the plaster spotless; a bit of remaining wax provides contrast and better viewing of the cast.

Photography

Photographs provide records of prints and the trail for little time and effort compared to casts. However, field work often dictates that photographs be taken under poor lighting conditions. Making casts *and* taking photographs ensure a good record of the tracks of rare carnivores.

The equipment needed includes a good 35-mm camera, zoom-macro lens (F-stops less than 2.0 are ideal), flashlight, medium-fast color film (ASA 100 or 200), and a ruler. Although snow is highly reflective and may be very bright, photographs often must be taken at twilight or in dark forests, necessitating a fast film and lens. Prints offer an advantage in that they can be marked upon for measuring and analysis, and print films may be developed at most 1-hour services for quick results. However, color xerox prints may be made from slides at many copy centers. Slides can then be used to illustrate presentations, and prints can be archived for documentation.

To make a photographic record of the print, place a ruler next to it, but do not cover important features such as claws or hair drag-marks. Get as close to the print as possible, and photograph from directly above the track. Any deviation from vertical will cause distortion due to parallax and reduce the discriminating power of the photograph. If the lighting is bad, shine a flashlight from a low angle at the side to increase definition. A flash may also provide definition, but practice this technique before using it in the field. Carry a sheet of aluminum foil to reflect light onto the print if necessary. Try to fill the frame of the camera completely with the print and the ruler. Take several shots of each track, bracketing the exposures to account for the possibility that the light meter in automatic cameras will misinterpret light from snow, producing a dark image. Some photographs should include the track and the partially-completed Track Observation form (*appendix B* and in pocket inside back cover). Complete the upper portion of the form using a broad-tipped black pen, and place it next to the track. These photographs will help cross-reference tracks and the data collected from them.

To make a photographic record of a trail, use a carpenter's or plumber's ruler, which consists of 6-inch segments that fold out to 6 feet. Fold the ruler so that one segment at each end is bent 90 , with both bent segments on the same side (*fig. 29*). Lay the ruler along the trail with the bent segments crossing it. The ruler will help compensate for parallax during analysis. If only a straight ruler is available, lay other hard objects across the trail for scale. It is best to photograph the ruler from a position perpendicular to it at its center. Make sure that the photograph includes more than one complete stride, that is, at least five footprints. Some photographs should also be taken to include two or more complete strides.

Take many photographs. Film is cheap evidence once rare tracks are found. A good procedure is to photograph a stride series (five prints) along a ruler. Then, before moving the ruler, move closer and photograph each print in position, making certain that the ruler is in view. As you move down the trail, take photographs so they overlap with previous fields to provide a continuous record. If good prints are far apart, it may not be possible to show overlap in the photographs. Take good notes of the position of photographs that do not overlap. If a ruler is not available, put some recognizable hard object (e.g., knife) into the picture. Soft objects, such as a stocking cap or mitten, can vary in shape and size and make poor scales.

Video cameras work in much less light than film cameras, but often the images lack three-dimensional perspective and clarity. Thus, if video is used, it is best to take pictures with a 35-mm camera also. When video taping, shoot minute-long sequences to allow sufficient time in the laboratory to analyze the tape. Use a tripod if possible. Carry extra batteries and keep them warm inside your coat; cold greatly reduces the operating time of video batteries. Hi8 and super VHS-C videos take better pictures than regular VHS, 8 mm, or regular VHS-C, and they are smaller. Information on interpreting track data from photographs is provided in *appendix C*.

Scat and Hair

Identification of scat and hair is not within the scope of this manual. Bile acids have been used to distinguish carnivore scat (e.g., Quinn and Jackman 1994), and new molecular genetics techniques permit the identification of species from DNA in hair, scat, and small fragments of tissue (e.g. Hoss and others 1992, Woodruff 1993). Currently, genetic analysis is costly, and there are few laboratories conducting the work. However, as technology improves and price decreases, molecular techniques may be more common. Therefore, all hair and scat suspected to be from a rare species should be collected. Try to learn of individuals, laboratories, or universities in your region that specialize in these techniques and can help with identification. The USDI Fish and Wildlife Service Forensics Laboratory (1490 E. Main, Ashland, OR 97520) may be of assistance.

Identification of scats in the field can reduce the amount brought home. Halfpenny (1987) and Rezendes (1992) provide color photographs and simple scat keys. Collect scat in a plastic bag. Invert the bag over your hand, pick up the scat, re-invert the sack and seal. Write on the sack with a permanent ink marker, or on a 3×5-inch card, and insert the card in the sack. Immediately upon returning from the field, freeze or dry the scat. The simplest technique is to place the scat in the center of a newspaper and fold the paper in half. Fold a 1-inch wide strip over twice, on each edge, and staple it shut. Write identification information on the paper with a wide-tip permanent ink marker, and place it in a safe spot to dry.

It takes a keen eye to find samples of hair. When following a trail, look for hair on the underside of branches the animal has walked under, on tree bark where it has rubbed or climbed, and in beds. Refreezing snow may also trap hairs. If snow is lacking in a bed site, look closely among the vegetation debris, using a flashlight if available. Collect as many hairs as possible, and place them in a small plastic bag. Hair identification is best done in the laboratory by someone with considerable experience. The best guides to identifying hair by morphology are by Adorjan and Kolensosky (1980), Brown (1942), Mayer (1952), Moore, and others (1974), and Stains (1958).

Data Management

Four forms are recommended for data: Snow Tracking, Track Observation, Survey Record, and Species Detection forms (*appendix B* and in pocket inside back cover). Complete the Snow Tracking and Survey Record forms for each sample unit. The Snow Tracking form contains information on travel, sign detected, habitat, and snow tracking quality. We have modified the tracking quality classes of Van Dyke and others (1986) and created the Snow Tracking Quality (STQ) index. Copy guidelines for STQ ratings on the back of the Snow Tracking form so the information is available in the field. On long routes, it is possible that data recording will require more than one sheet per route. Indicate additional sheets by filling out the "Sheet 1 of 3" designation with the same date. Use a Track Observation form each time sign from a potential target species is discovered. This Track Observation form contains information on track location, measurements for identification, and an account of photographs taken. It is important to record as much information as possible, and it is helpful to draw tracks on the back of this sheet, so copy the form on only one side of the page. If questions remain about a track identification, contact experienced biologists for help. Copies of report forms, photographs, and even casts may be sent to the senior author for help with identification.

Collectively, these forms become a record of all the surveys conducted in the administrative area, regardless of their outcome. Completed forms and survey maps should be archived at a local administrative office (e.g., Forest Service Ranger District), and a duplicate set should be filed at a second location of your choice.

When a survey is successful at detecting MFLW, complete the Species Detection form and submit to the state's Natural Heritage program office (addresses in *appendix A* of Chapter 1). Most Natural Heritage databases do not record the effort to detect rare species if the exercise is unsuccessful. Archive a copy at the administrative office of the agency that manages the land where the survey was conducted. Complete one Species Detection form for each species detected. This standardized form characterizes surveys for MFLW and is used for all methods (camera, track-plate, snow-tracking).

Inventory and Monitoring

Growing concern over rare species and their management emphasizes the importance of developing methods to monitor changes in abundance over time (Weaver 1993), yet developing monitoring programs requires considerable statistical and logistic planning

(Chapter 2). Snow tracking, more than the other detection methods, has been used to attempt to inventory *and* monitor changes in populations of MFLW. Anderson and others (1979), Davis and Winstead (1980), Fitzhugh and Gorenzel (1985), Hatler (1988, 1991), Kutilek and others (1983), Miller (1984), Smallwood and Fitzhugh (1995), and Van Dyke and others (1986) have discussed various aspects of using line transects to survey mammal species. Becker (1991), Bull and others (1992), Copeland (1993), Formozov (1967), Golden and others (1992), Halfpenny (1992), Paragi (1992), Priklonski (1970), Pulliainen (1981 a, b, c), and Thompson and others (1981) discuss the use of winter tracking to index population abundance. Recent research has centered on the statistical power of line transects to detect differences in population index values (e.g., Kendall and others 1992, Taylor and Gerrodette 1993, Verner and Kie 1988).

A review of more than 40 published and unpublished papers that deal with inventory and monitoring methods (noted with an asterisk in the References section) revealed a lack of consistency in snow tracking techniques. Most snow tracking methods have never been tested for their power to detect differences in densities, habitat use, or changes in abundance over time. The most comprehensive methods include those of Becker and Gardner (1992), Golden (1987, 1988), Golden and others (1992, 1993), Paragi (1992), Stephenson (1986), and Thompson and others (1981). It is not our objective to address inventory and monitoring considerations. However, in *table 7* we have drawn from the literature some key considerations for designing snow surveys for this purpose.

Monitoring techniques should provide early detection of significant population changes or differences in habitat use so that management actions can forestall extirpation or extinction. Verner and Kie (1988) recommend that biologists be able to detect these changes at "5 percent significance levels and statistical power of at least 80 percent."

Table 7—***Considerations for designing snow surveys to monitor MFLW populations.***

Parameter	Recommendation
Transect	More transects of shorter length
Snow depth	Requires at least 2 to 5 cm of snow depending on surface below snow
Mode of travel	Skis or snow shoes are best
Frequency	One per month to include seasonal changes
Snowfall	Record time since last snowfall
Track age	Estimate time since track was made in 24-hour increments
Presence	Presence/absence of sign per short trail segments favored over number of tracks
Tracks/distance	Record number of tracks encountered per unit of linear distance
Intersections	Record only tracks that intersect the trail
Multiple tracks	If observer can tell that an animal has crossed the trail more than once, record only one trail
Habitat	Record linear distance of each habitat traversed
Effort	For habitat surveys try to allocate distance traveled evenly among habitats

Using these values, a pre-survey model can be developed to determine the sample size (number of trails and their length) needed. Once a statistically appropriate sample size has been estimated, costs for the survey should be calculated. For low-density species, costs of monitoring may be higher than can be afforded. Indeed, it may not be possible to monitor rare species for change over time using survey methods. The only financially feasible and practical solution may be to detect presence, and then protect the species from harvest while maintaining habitat and prey.

Please be certain to review the cautions in Chapter 2 before attempting to monitor change in population size. If you attempt to monitor, strive for consistency over space and time. No standards presently exist, and yon must exercise caution before embarking on a monitoring program.

Safety Concerns

Winter Hazards

Techniques described in this manual will be used during winter when potentially hazardous conditions exist. Obtain training about winter hazards and camping. Carry adequate equipment to spend the night comfortably in case of an emergency. Avoid working alone in the field during winter. It is the responsibility of the supervisor to evaluate potential hazards in the survey area and to obtain proper training for all personnel before they go to the field. Being a field biologist does not necessarily mean that one is competent to conduct winter work.

Job descriptions for field technicians should stress winter field skills including skiing, snowshoeing, snowmobiling, snow camping, and avalanche training. Employees can be trained using in-house experts, or by any of the schools and individuals that provide training seminars (a number are listed below). References on avalanche awareness include Armstrong and Williams (1986), Daffern (1992), and Perla and Martinelli (1978). Selected references on winter competence include Forgey (1991), Gorman (1991), Halfpenny and Ozanne (1989), Pozos and Born (1982), Schimelpfenig and Lindsey (1991), Weiss (1988), Wilkerson and others (1986), Wilkerson (1992), and Wilkinson (1992).

Training for Avalanche Awareness and Rescue

American Avalanche Institute
Box 308
Wilson, WY 83014
307 733-3315

Kim Fadiman
P.O. Box 2603
Jackson, WY 83001
307 733-6842

National Avalanche School
U.S. Forest Service
Doug Abromeit
801 943-1798

Avalanche Education Directory
Box 176
Garderville, NV 89410
702 782-3047

Training for Winter Camping

Colorado Outward Bound School
945 Pennsylvania
Denver, CO 80203
303 837-0880

National Outdoor Leadership School (NOLS)
288 Main Street
Lander, WY 82520-0579
307 332-6973

Local and State Mountaineering or Hiking Clubs
National Ski Patrol
Local Ski Patrols

Scat Collection Hazards

It is possible to pick up some diseases from scats. Therefore, do not smell scats too closely. Use latex gloves or an inverted plastic sack for handling. Wash your hands after handling scats, even with snow.

Costs

Assumptions:

- Five adjoining units, each 4 mi^2, are surveyed simultaneously for a total survey of 20 mi^2.
- Each sample unit is surveyed three times during one winter. Effort to survey each sample unit is limited to one day per survey.
- All access is relatively simple, but survey routes are covered on skis.
- No target species are detected during the survey. Because surveys in a sample unit are terminated when the target species is (are) detected, costs could be significantly less if the target species is detected early in the session.
- The work is conducted by a crew of federal employees at FY 1994 rates. No contractors are used.
- The minimum crew size is two persons traveling together, each carrying a personal radio. While crew members may be separated over short distance (within earshot), two crew members should work together in all dangerous situations including snowmobiling and traveling on backcountry routes, especially if avalanche danger exists.
- Costs of winter training are not included.
- Extra costs may be incurred for snowmobile use and safety equipment. Please see the safety section for approximate cost estimates.

I. Labor	pd = person day	
Day-planning	2 pd @ $75/pd	$150
Training	4 pd @ $75/pd	300
Track suveys (3 surveys/winter)	2 people @ 5 field days	
	10 pd @ $75 = $750	
	3 surveys @ $750	2250
Lost field days due to bad tracking conditions	2 people @ 2d/survey	
	2 pd @ $75	450
Data analysis	2 pd @ $75	150
Subtotal, Labor		*$3300*

2. Vehicles and Gas $700

3. Materials-miscellaneous supplies $250

Total $4250

Safety and Winter Travel Costs:
The cost of safety training and winter equipment should be considered as well. These are itemized separately below.

Assumptions:

- Existing equipment, such as trucks or snowmobiles, will be used when available.
- Costs for training can be as high as several hundred dollars per employee. Hiring instructors to provide customized seminars may run several hundred dollars per day, but by conducting joint training seminars the costs can be shared by several administrative districts or even forests.

Cost approximations for items that must be rented or purchased:

Snowmobile rental . . . . $100 to $150 /person/day

Snowmobile purchase $5000

Snowshoes . . . . $100 to $150 / person

Skis, boots, poles . . . . $150 to $300 / person

Avalanche rescue beacons . . . . $100 to $150 / person

Avalanche probes . . . . $100 / person

Avalanche shovels . . . . $50 / person

Equipment and Training

Tracking Equipment

Maps and aerial photos
Field notebook
Data forms (copy on to waterproof paper)
Pencils
Pens
Permanent felt marking pen
Watch
Plumber's or carpenter's rule (metric and English scales)
Retractable tape ruler (metric and English scales)
Camera (with combination macro and wide-angle lens)
Flashlight (Buck Light is a strong and lightweight recommendation)
Film (ASA 100 or 200 ASA); 25 ASA for bright days

Casting materials
Propane torch
(warm weather only)
Plaster
Snow print wax
Mixing cups
Plaster garbage bags
Paper sacks or newspaper

Emergency and Winter Equipment
Skiing and/or snowshoeing supplies
Bivouac and camping equipment
Avalanche beacons
Avalanche probes
Avalanche shovels

Training in Tracking

You can enhance the probability of success of a survey by receiving training from a biologist experienced in tracking lynx, wolverines, fishers, and martens. Try to identify local expertise, such as trappers, to train field personnel before the survey starts. General tracking seminars are taught through the Glacier, Grand Teton, Rocky Mountain, Yellowstone, and Yosemite National Park Associations, and by private individuals around the United States. Professional seminars titled "Field Verification of Rare Species" and a training slide show for tracking (Halfpenny 1986) are available from Dr. James C. Halfpenny, A Naturalist's World, P.O. Box 989, Gardiner, MT 59030, (406) 848-9458.

For additional reading on tracking see Forrest (1988), Halfpenny (1987), Murie (1954), and Rezendes (1992). The Murie Museum at Teton Science School (307-733-4765), Grand Teton National Park, Wyoming, maintains the scientific track and scat collection developed by the Muries.

References

*Papers and reports that deal specifically with inventory and monitoring are indicated by an asterisk.

Adorjan, A. S.; Kolensosky, G. B. 1980. **A manual for the identification of hairs of selected Ontario mammals.** Ottawa, ON: Ontario Ministry of Natural Resources. Research Report (Wildlife) No. 90.

*Anderson, C. [n.d.] **Lynx capture and marking study in the Vail area**. Phase 1 - Progress Report. Ft Collins, CO: Colorado Division of Wildlife. Unpublished draft supplied by author.

Anderson, D. R.; Lake, J. F.; Crain, B. R.; Burnham, K. P. 1979. **Guidelines for line transect sampling of biological populations**. Journal of Wildlife Management 43(1): 70-78.

*Andrews, T. 1991. **A survey of Rocky Mountain National Park and surrounding areas of Arapaho and Roosevelt National Forests for wolverine and lynx, Winter 1990-1991.** Unpublished draft supplied by author.

Armstrong, B.; Williams, K. 1986. **The avalanche book**. Golden, CO: Fulcrum, Inc.; 231 p.

*Arnett, E. [n.d.] **Methods of monitoring pine marten and other small mammals (snow tracking surveys)**. Chemult, OR: Winema National Forest.

Banci, V. 1987. **Ecology and behavior of wolverine in Yukon**. Vancouver: University of British Columbia; 178 p. Thesis.

Banci, V. 1989. **A fisher management strategy**. Wildlife Bulletin No. B-63, Victoria, BC: Ministry of Environment.

*Banci, V., Research Wildlife Biologist, B. C. Ministry of Environment, Wildlife Branch, Victoria, BC. [Personal communication]. 1992.

Banci, V. 1994. **Wolverine**. In: Ruggiero, L. F.; Aubry, K. B.; Buskirk, S. W.; Lyon, L. J.; Zielinski, W. J.; tech. eds. The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the western United States. Gen. Tech. Rep. RM-254. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 74-98.

*Becker, E. F. 1991. **A terrestrial furbearer estimator based on probability sampling**. Journal of Wildlife Management 55(4): 730-737.

*Becker, E. F.; Gardner, C. 1992. **Wolf and wolverine density estimation techniques**. Federal aid in wildlife restoration, Research Progress Report. 1 July 1991 - 30 June 1992, Project W-23-5, Study 7.15. Juneau, AK: Alaska Department of Fish and Game; 31 p.

Berrie, P. M. 1973. **Ecology and status of the lynx in interior Alaska**. In: Elton, R. L., ed. The world cats. Vol. 1. Proceedings of the International Symposium of the World's Cats; March 1971. Winston, OR: World Wildlife Safaris; 4-41.

Bishop, N., Resource Interpreter, Yellowstone National Park. WY. [Personal communication]. 1993.

Brand, C. J.; Keith, L. B.; Fisher, C. A. 1976. **Lynx responses to changing snowshoe hare densities in central Alberta.** Journal of Wildlife Management 40: 416-428.

Brown, F.,M. 1942. **The microscopy of mammalian hair for anthropologists.** Proceedings of the American Philosophical Society 85(3): 250-274.

Brunner, J. 1909. **Tracks and tracking**. New York: Outing Publishing Co.; 219 p.

*Bull, E. L.; Holthausen, R. S.; Bright, L. R. 1992. **Comparison of three techniques to monitor marten.** Wildlife Society Bulletin 20: 406-410.

Bullock, R. E. 1971. **Functional analysis of locomotion in pronghorn antelope.** In: Geist, V.; Walther, F., eds. Symposium on the behavior of ungulates and its relation to management. International Union Conservation Natural Resource, New Ser., 24, Calgary, AB; 274-305.

Buskirk, S. W.; Powell, R. A. 1994. **Habitat ecology of fishers and American martens.** In: Buskirk, S. W.; Harestand, A.; Raphael, M., comps., eds. Biology and conservation of martens, sables and fishers. Ithaca, NY: Cornell University Press; 283-296.

Buskirk, S. W.; Ruggiero, L. F. 1994. **American marten.** In: Ruggiero, L. F.; Aubry, K. B.; Buskirk, S. W.; Lyon, L. J.; Zielinski, W. J., tech. eds. The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the western United States. Gen. Tech. Rep. RM-254. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 7-37.

Butts, T. W. 1992a. **Lynx (Felis lynx) biology and management: a literature review and annotated bibliography.** Report. Threatened, Endangered and Sensitive Program. Missoula, MT: Northern Region, Forest Service, U.S. Department of Agriculture.

*Copeland, J. 1993. **Assessment of snow-tracking and remote camera systems to document presence of wolverines at carrion bait stations.** Progress Report. Boise, ID: Nongame and Endangered Wildlife Program, Bureau of Wildlife, Idaho Department of Fish and Game. Unpublished draft supplied by author.

Copeland, J., Wildlife Biologist, Department of Fish and Game, Stanley, ID. [Personal communication]. 1994.

Copeland, J. P.; Harris, C. E. 1994. **Wolverine ecology and habitat use in central Idaho.** Progress Report. Boise, ID: Idaho Department of Fish and Game; 29 p. Unpublished draft supplied by authors.

Daffern, T. 1992. **Avalanche safety for skiers and climbers.** Seattle, WA: Cloudcap; 172 p.

Davis, D. E.; Winstead, R. L. 1980. **Estimating the numbers of wildlife populations.** In: Giles, R.H., ed. Wildlife management techniques manual. Washington, DC: The Wildlife Society; 221-246.

*de Vos, A. 1951. **Tracking of fisher and marten.** Sylva 7: 14-18.

*Dewey, S. [Letter to J. Halfpenny] **Winter track survey.** Ashley National Forest. Flaming Gorge and Vernal Ranger Districts. 1992.

Fitzhugh, E. L.; Gorenzel, W. P. 1985. **Design and analysis of mountain lion track surveys.** In: Bleich, V. C., ed. Cal-Neva Wildlife Transactions, Western Section, The Wildlife Society; 78-87.

Fjelline, D. P.; Mansfield, T. M. 1989. **Method to standardize the procedure for measuring mountain lion tracks.** In: Smith, R.H., ed. Proceedings of the third mountain lion workshop; 1988, Dec. 6-8, Prescott, AZ. Flagstaff, AZ: Arizona Game and Fish Department; 49-51.

Forgey, W. W. 1991. **The basic essentials of hypothermia.** Merrillville, IN: ICS Books, Inc; 68 p.

*Formozov, A. N. 1967. **Methods of censusing sable populations.** Bureau of Technical Information of the Main Administration for Hunting and Reserves of the Council of M0287 Ministers of the RSFSR. Moskava, 1965. Jerusalem: Israel Program for Scientific Translations.

Forrest, L. R. 1988. **Field guide to tracking animals in snow.** Harrisburg, PA: Stackpole Books; 194 p.

*Fowler, C. H.; Golightly, R. T. 1993. **Fisher and marten survey techniques on the Tahoe National Forest.** Final Report. Unpublished draft supplied by authors.

*Ghormley, R. W. [Letter to J. Halfpenny] Monitoring techniques for wolverine in the Blue Mountains of Oregon and Washington. Gardiner, MT: A Naturalist's World. 1992.

*Giddings, B. 1993. **Region I furbearer / lynx-hare winter track survey summary.** Missoula, MT: Montana Department of Fish, Wildlife, and Parks. Unpublished draft supplied by author.

*Golden, H. N. 1987. **Survey of furbearer populations on the Yukon Flats National Wildlife Refuge.** Cooperative Agreement Proj. No. 14-16-007-84-7416. Fairbanks, AK: Alaska Dept. of Fish and Game and U.S. Fish and Wildlife Service. Unpublished draft supplied by author.

*Golden, H. N. 1988. **Distribution and relative abundance, population characteristics, and harvest of furbearers in gates of the Arctic National Park and Preserve.** Final Report NRFR AR-8088. Anchorage, AK: National Park Service. Unpublished draft supplied by author.

Golden, H. N. 1993. **Furbearer track count index testing and development. Federal aid on wildlife restoration.** Research progress report. 1 July 1992 - 30 June 1993, Project W-24-1, Study 7.17. Anchorage, AK: Alaska Department of Fish and Game; 48 p. Unpublished draft supplied by author.

*Golden, H. N.; Route, W. T.; Becker, E. F. 1993. **Wolverine demography and ecology in southcentral Alaska.** Project Outline and Phase I Progress Report. Alaska Department of Fish and Game, Division of Wildlife. Conservation and National Park Service. Wrangell-St. Elias National Park and Preserve. Unpublished draft supplied by authors.

*Golden, H. N.; Route, W.; Jenkins, K.; Johnson, W. N.; Paragi, T., Doyle, T.; Shults, B.; Adams, L. 1992. **Furbearer track count index testing and development.** Wildlife Research Study Plan. Anchorage, AK: Alaska Dept. of Fish and Game, National Park Service, U.S. Fish and Wildlife Service, Unpublished draft supplied by author.

Gordon, G., Student. Teton Science School. Kelly, WY. [Personal communication]. 1985.

Gorman, S. 1991. **AMC guide to winter camping: wilderness travel and adventure in the cold-weather months.** Boston, MA: Appalachian Mountain Club Books; 206 p.

Haglund, B. 1966. **De stora rovdjurens vintervanor.** Viltrevy Swedish Wildlife 4:(3): 1-297.

Halfpenny, J. C. 1986. **Tracks and tracking: a "how to" guide**. A 35-mm slide educational program. Gardiner, MT: A Naturalist's World; 120 images. 15 p.

Halfpenny, J. C. 1987. **A field guide to mammal tracking in North America**. Boulder, CO: Johnson Books; 176 p.

*Halfpenny, J. C. 1992. **Wildlife field techniques workbook.** Logan, UT: Bio/West, Inc.

Halfpenny, J. C.; Ozanne, R. 1989. **Winter, an ecological handbook.** Boulder, CO: Johnson Publishing Co.; 273 p.

*Halfpenny, J. C.; Thompson, R. W. 1991. **Field survey techniques for lynx and wolverine.** seminar workbook. Gardiner, MT: A Naturalist's World.

Hash, H. S., Wildlife Biologist, Stevensville, MT. [Personal communication]. 1980.

*Hatler, D. F. 1988. **A lynx management strategy for British Columbia**. Wildlife Working Report No. WR-34. Victoria, BC: Ministry of Environment, Wildlife Branch.

Hatler, D. F. 1991. **A method for monitoring wildlife in managed forests. A field manual**. Forest Resource Development Agreement Report 172. Victoria, BC: Forestry Canada.

Heinemeyer, K.; Jones, J. L. 1994. **Fisher biology and management in the western United States. A literature review and adaptive management strategy.** Missoula, MT: Northern Region and Interagency Forest Carnivore Working Group, Forest Service, U.S. Department of Agriculture.

Hildebrand, M. 1959. **Motions of the running cheetah and horse**. Journal of Mammalogy 40: 481-495.

Hildebrand, M. 1965. **Symmetrical gaits of horses**. Science 150: 701-708.

Hornocker, M. G.; Hash, H. S. 1981. **Ecology of the wolverine in northwestern Montana**. Canadian Journal of Zoology 59: 1286-1301.

Hoss, M.; Kohn, M.; Paabo, S.; Knauer, F. 1992. **Excrement analysis by PCR**. Nature 354: 199.

*Hugie, R. D.; Gantz, G. 1990. **Supplement to: the Lake Catamount Ski Area project HEP study**. Prepared for the Forest Service, U.S. Department of Agriculture, Routt National Forest. Logan, UT: BIO/WEST Inc.

Jaeger, E. 1948. **Tracks and trailcraft**. New York: The Macmillan Company; 381 p.

Jones, J. A 1991. **Habitat use of fisher in northcentral Idaho.** Moscow, ID: University Idaho; 147 p. thesis.

Kendall, K. C.; Metzgar, L. E.; Patterson, D. A.; Steele, M. B. 1992. **Power of sign surveys to monitor population trends**. Ecological Applications 2(4): 422-430.

Knight, R. Interagency Grizzly Bear Team, Montana State University, Bozeman, MT. [Personal communication]. 1990.

*Koehler, G. M. 1987. **Proposal to develop habitat management guidelines and to monitor response of lynx to habitat alterations and to develop a method of censusing lynx**. Wildlife Research Institute, Moscow, ID. Unpublished draft supplied by author.

*Koehler, G. M. [Letter to Rocky Beach] Washington Department of Wildlife, Olympia, WA. 1989.

Koehler, G. M.; Aubry, K. B. 1994. **Lynx**. In Ruggiero, L. F.; Aubry, K. B.; Buskirk, S. W.; Lyon, L. J.; Zielinski, W. J., tech. eds. The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the western United States. Gen. Tech. Rep. RM-254. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 74-98.

Koehler, G. M.; Brittell, J. D. 1990. **Managing spruce-fir habitat for lynx and snowshoe hares**. Journal of Forestry 88(10): 10-14.

Krott, P. 1959. **Demon of the north**. New York: Alfred A. Knopf.

Kutilek, M. J.; Hopkins, R. A.; Clinite, W. E.; Smith, T. E. 1983. **Monitoring population trends of large carnivores using track transects**. In: Bell, J. F.; Atterbury, T., eds. Renewable resource inventories for monitoring changes and trends. Corvallis, OR: College of Forestry, Oregon State University; 104-106.

Lederer, N., Consulting Biologist, Boulder, CO. [Personal communication]. 1985.

Mason, G. F. 1943. **Animal tracks**. New York: William Morrow and Company; 95 p.

Mayer, W. V. 1952. **The hair of California mammals with keys to the dorsal guard hairs of California mammals**. American Naturalist 48: 480-512.

McCord, C. M.; Cardoza, J. E. 1982. **Bobcat and lynx (*Felis rufus* and *F. lynx*)**. In: Chapman, J. A.; Feldhamer, G. A., eds. Wild mammals of North America. Baltimore: Johns Hopkins Univ. Press: 728-768.

*McKay, R. 1991a. **Biological assessment and inventory plan for the North American lynx (Lynx canadensis) in the Uinta Mountains**. Ashley National Forest and Utah Natural Heritage Program, Utah Department of Natural Resources, Salt Lake City, UT.

*McKay, R. 1991b. **Biological assessment and inventory plan for the wolverine (*Gulo gulo*) in the Uinta Mountains**. Ashley National Forest and Utah Natural Heritage Program, Utah Department of Natural Resources, Salt Lake City, UT.

Miller, S. T. 1984. **Estimation of animal production numbers for national assessments and appraisals**. Gen. Tech. Rep. RM-105. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 23 p.

Moore, T. D.; Spence, L. E.; Dugnolle, C. E.; Hepworth, W. G., eds. 1974. **Identification of the dorsal guard hairs of some mammals of Wyoming**. Cheyenne, WY: Wyoming Game and Fish Department. 177 p.

Murie, A. 1951-52. **Wolverine trails at Denali** The Living Wilderness 39: 13-20.

Murie, O. 1954. **A field guide to animal tracks**. Peterson Field Guide Series, no. 9. Boston Houghton Mifflin Company

Muybridge, E. 1899. **Animals in motion**. London Chapman and Hall, Ltd. Republished in 1957 by L.S. Brown, ed. New York: Dover Publishing, 173 p.

*Nancy, B 1993. **Lynx survey methodology: snow tracking techniques**. Okanogan, WA: Forest Service, U.S. Department of Agriculture. Unpublished draft supplied by author.

Nellis, C. H.; Keith, L. B. 1968. **Hunting activities and success of lynx in Alberta**. Journal of Wildlife Management 32: 718-722.

Nellis, C. H.; Wetmore, S. P.; Keith, L. B. 1972. **Lynx-prey interactions in central Alberta**. Journal of Wildlife Management 36: 320-329.

Nelson, E. W. 1918a. **The larger North American mammals**. In: Nelson, E. W., ed. Wild animals of North America. Washington, DC: National Geographic Society; 385-472

Nelson, E. W. 1918b. **The smaller North American mammals**. In: Nelson, E. W., ed. Wild animals of North America. Washington, DC: National Geographic Society; 473-612

*Newberry, D 1973. **Pine marten field transect study**. Report to federal aid in wildlife restoration, Project W-54-R, "Special Wildlife Investigations." State of California. Sacramento, CA: The Resource Agency, Department of Fish and Game. Unpublished draft supplied by author.

*Novak, M. 1993. **Furbearer inventory and monitoring proposal: Jackson Ranger District, Bridger/ Teton National Forest, Jackson, WY**. Unpublished draft supplied by author.

*Paragi. T. [Letter to B. Zielinski] **Snowtracking procedures for wildfire-furbearer study, Fish and Wildlife Service**. Koyukuk/Nowitna Refuge Complex. Galena, AK. 1992.

Parker, G. R. 1981. **Winter habitat use and hunting activities of lynx (*Lynx canadensis*) on Cape Breton Island, Nova Scotia**. In: Chapman, J. A.; Pursley, D., eds. World furbearer conference proceedings. Vol. 2; August 3-11, 1980; Frostburg, MD. Falls Church, VA: R. R. Donnelley and Sons, Co.; 221-248.

Perla, R. I.; Martinelli, M. 1978. **Avalanche handbook**. Agriculture Handbook 489. Washington, DC: Forest Service, U.S. Department of Agriculture; 254 p.

Powell, R. A. 1978. **A comparison of fisher and weasel hunting behavior**. Carnivore 1(1): 28-34.

Powell, R. A. 1980. **Fisher (*Martes pennanti*) arboreal activity**. Canadian Field-Naturalist 94: 90-91.

Powell, R. A. 1993. **The fisher: life history, ecology, and behavior**. Minneapolis, MN. University of Minnesota Press; 237 p.

Powell, R. A.; Zielinski, W. J. 1994 **Fisher**. In: Ruggiero, L. F.; Aubry, K. B.; Buskirk, S. W.; Lyon, L. J., Zielinski, W. J., tech. eds. The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the western United States. Gen. Tech. Rep. RM-254. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 38-73.

Pozos, R. S.; Born, D. O. 1982. **Hypothermia: causes, effects, prevention**. Piscataway, NJ: New Century Publishers, Inc.; 173 p.

*Priklonski, S. G. 1970. **Winter transect count of game animals**. Transactions of the International Congress on Game Biology 9: 273-275.

Pulliainen, E. 1981a. **Winter habitat selection, home range, and movements of the pine marten (*Martes martes*) in a Finnish Lapland Forest**. In: Chapman, J. A.; Pursley, D., eds. World furbearer conference proceedings. Vol. 2; August 3-11, 1980; Frostburg, MD. Falls Church, VA: R. R. Donnelley and Sons, Co.; 1068-1087.

Pulliainen, E. 1981b. **Food and feeding habits of the pine marten in Finnish Lapland forest in Winter**. In: Chapman, J. A.; Pursley, D., eds. World furbearer conference proceedings. Vol. 2, August 3-11, 1980; Frostburg, MD. Falls Church, VA: R. R. Donnelley and Sons, Co.; 580-598.

*Pulliainen, E. 1981c. **A transect survey of small land carnivore and red fox populations on a subarctic fell in Finnish Lapland over 13 winters**. Annals Zoologica Fennici 18: 270-278.

Quinn, T.; Jackman, W. R. 1994. **Influence of diet on detection of fecal bile acids by thin-layer chromatography**. Journal of Wildlife Management 58: 295-299.

Quinn, N. W. S.; Parker, G. 1987. **Lynx**. In: Novak, M.; Baker, J. A.; Obbard, M. E.; Malloch, B., eds. Wild furbearer management of conservation in North America. Ontario Ministry of Natural Resources and the Toronto Trappers Association, Canada; 682-695.

Raine, R. M. 1983. **Winter habitat use and responses to snow cover of fisher (*Martes pennanti*) and marten (*Martes americana*) in southern Manitoba**. Canadian Journal of Zoology 61: 25-34

*Raphael, M. G 1994. **Techniques for monitoring populations of fishers and American martens**. In: Buskirk, S. W.; Harestad, A. S.; Raphael, M. G.; Powell, R. A., eds. Martens, sables, and fishers: biology and conservation. Ithaca, NY: Cornell University Press; 224-240.

*Raphael, M. G.; Henry, S. E. 1990. **Preliminary suggestions for monitoring marten in the Rocky Mountain Region**. Unpublished draft supplied by authors. On file at Forest Sciences Laboratory, Pacific Northwest Research Station, Olympia, WA.

Rezendes, P. 1992. **Tracking and the art of seeing: how to read animal tracks and sign**. Charlotte, VT: Camden House Publishing, Inc.; 320 p.

Ruggiero, L. F.; Aubry, K. B.; Buskirk, S. W.; Lyon, L. J.; Zielinski, W. J., tech. eds. 1994. **The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the western United States**. Gen. Tech. Rep. RM-254. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 183 p.

Saunders, J. K., Jr. 1963. **Movements and activities of the lynx in Newfoundland**. Journal of Wildlife Management 27: 390-400.

Schimelpfenig, T.; Lindsey, L. 1991. **NOLS wilderness first aid**. Lander, WY: National Outdoor Leadership School Publications; 337 p.

Seton, E. T. 1937. **Lives of game animals**. New York: The Literary Guild of America. 8 vol.

Seton, E. T. 1958. **Animal tracks and hunter signs**. New York: Doubleday & Company. Also available as the First Laurentian Library edition 1978. Toronto, ON: Macmillan Company of Canada.

Smallwood, K. S.; Fitzhugh, E. L. 1989. **Differentiating mountain lion and dog tracks**. In Smith, R. H., ed. Proceedings of the third mountain lion workshop; Dec. 6-8, 1988; Prescott, AZ. Flagstaff, AZ: Arizona Game and Fish Department; 58-63.

Smallwood, K. S.; Fitzhugh, E. L. 1993. **A rigorous technique for identifying individual mountain lions *Felis concolor* by their tracks**. Biological Conservation 65: 51-59.

Smallwood, K. S.; Fitzhugh, E. L. 1995. **A track count for estimation mountain lion (*Felis concolor californica*) population trend**. Biological Conservation 71: 251-259.

Sorensen, R. O.; Kvam, T. K.; Overskaug, K. 1984. Jerven (*Gulo gulo* L.) I Norge: Utbredelse og bestand 1978-1983. Viltraport 32: 1-76. Trondheim, Norway.

*Soutiere, E. C. 1979. **Effects of timber harvest on marten in Maine**. Journal of Wildlife Management 43(4): 850-860.

Stains, H. J. 1958. **Field key to guard hair of middle western furbearers**. Journal of Wildlife Management 22(1): 95-97.

*Stephenson, R. O. 1986. **Development of lynx population estimation techniques**. Federal Aid in Wildlife Restoration, Research Final Report, Project W-22-2, W-23-3, W-22-4, and W-22-5, Job 7.12R. Alaska Department of Fish and Game.

Taylor, B. L.; Gerrodette, T. 1993. **The uses of statistical power in conservation biology: the Vaquita and Northern Spotted Owl**. Conservation Biology 7(3): 489-500.

Taylor, C. A.; Raphael, M. G. 1988. **Identification of mammal tracks from sooted track stations in the Pacific Northwest**. California Fish and Game 74(1): 4-15.

*Thompson, I. D.; Davidson, I. J.; O'Donnell, S.; Brazeau, F. 1981. **Use of track transects to measure the relative occurrence of some boreal mammals in uncut forest and regeneration stands**. Canadian Journal of Zoology 67: 1816-1823.

*Thompson, R. W.; Halfpenny, J. C. 1987. **Guidelines for the expansion of Vail Ski Area into potential Canada Lynx Habitat**. Report prepared for Vail Associates. Boulder, CO: Western Ecosystems, Inc. Ecological Consultants.

*Thompson, R. W.; Halfpenny, J. C. 1989. **Canada lynx presence on Vail Ski Area and proposed expansion areas**. Report prepared for Vail Associates. Boulder, CO: Western Ecosystems, Inc. Ecological Consultants.

*Thompson, R. W.; Halfpenny, J. C. 1991. **Canada lynx presence on the proposed East Fork Ski Area**. Report prepared for East Fork Joint Venture. Boulder, CO: Western Ecosystems, Inc. Ecological Consultants.

*Thompson, R. W.; Watts, T. J.; Halfpenny, J. C. 1992. **Wolverine survey in the vicinity of the proposed East Fork Ski Area**. Report prepared for East Fork Joint Venture. Boulder, CO: Western Ecosystems, Inc. Ecological Consultants.

Tumlison, R. 1987. ***Felis lynx***. Mammalian Species 269: 1-8.

*U.S. Fish and Wildlife Service. 1993. **The relationship of wildfire to lynx and marten populations and habitat in interior Alaska**. Annual Report, Calendar Year 1992. Koyukuk/Nowitna Refuge Complex. Galena, AK: Fish and Wildlife Service, U.S. Department of Interior.

Van Dyke, F. G.; Brocke, R. H.; Shaw, H. G. 1986. **Use of road track counts as indices of mountain lion presence**. Journal of Wildlife Management 50(1): 102-109.

Verner, J.; Kie, J. G. 1988. **Population monitoring: an essential link between theoretical and applied conservation biology**. 1988 Transactions of the Western Section of the Wildlife Society 24: 18-25.

*Weaver, J. 1993 **Lynx, wolverine, and fisher in the western United States**. Research Assessment and Agenda for the Interagency Lynx-Wolverine-Fisher Working Group. USDA Forest Service Intermountain Research Station Contract No. 43-0353-2-0598. Missoula, MT: Northern Rockies Conservation Cooperative

*Weaver, J., Deputy Grizzly Bear Recovery Coordinator, U.S. Fish and Wildlife Service, Missoula, MT. [Personal communication]. 1994.

Weiss, H. 1988. **Secrets of warmth: warmth for comfort or survival**. Brooklyn, NY: Vibe Publications.

Wilkerson, J. A., ed. 1992. **Medicine for mountaineering and other wilderness activities**. 4th ed. Seattle, WA: The Mountaineers; 416 p.

Wilkerson, J. A., ed.; Bangs, C. C.; Hayward, J. S. 1986. **Hypothermia, frostbite, and other cold injuries: prevention, recognition, and prehospital treatment**. Seattle, WA: The Mountaineers; 105 p.

Wilkinson, E. 1992. **Snow caves for fun and survival**. Boulder, CO: Johnson Publishing Co.; 98 p.

Woodruff, D. S. 1993. **Non-invasive genotyping of primates**. Primates 34: 333-346.

Zielinski, W. J. 1981. **Food habits, activity patterns, and ectoparasites of pine martens (*Martes americana*) at Sagehen Creek, California**. Berkeley, CA: University of California; 121 p. thesis.

Zielinski, W. J.; Truex, R. 1995. **Distinguishing tracks of marten and fisher at track plate stations**. Journal of Wildlife Management 59: 571-579.

Appendix A—Minimum outline databases

Appendix Table 1—*Comparative Minimum Outline measurements (mm) for the tracks of lynx and mountain lion from Colorado and Montana (J. Halfpenny, unpublished data at A Naturalist's World, Gardiner, MT; R. Thompson, unpublished data at Western Ecosystems, Inc., 905 Coach Road, Boulder, CO 80302).*

					---- Interdigital ----		-------- Toe 2 -------		--------- Toe 3 ---------		--------- Toe 4 --------		------ Toe 5 --------	
Species	Foot	Statistics	Length	Width	Length	Width	Length	Width	Length	Width	Length	Width	Length	Width
Lion	Front	Mean	81.6	91.7	35.7	50.0	27.6	17.6	26.7	16.9	27.3	17.4	22.2	15.8
		SD	0.7	0.7	0.8	0.2	1.3	0.8	1.5	1.3	1.0	1.6	0.1	0.6
		n	4	2	4	2	4	4	4	4	4	3	2	2
Lion	Hind	Mean	84.3	91.4	37.4	48.1	28.2	19.8	25.4	17.9	26.1	18.4	25.0	16.1
		SD	3.6	5.3	1.1	2.1	2.6	0.2	1.6	1.4	1.9	0.1	0.8	0.9
		n	2	2	2	2	2	2	2	2	2	2	2	2
Lynx[1]	Front	Mean	85.3	88.4	44.9	52.5	28.5	19.2	30.6	20.9	32.7	19.8	28.1	17.6
		SD	2.1	8.3	2.6	3.0	2.5	3.4	0.8	2.8	0.3	1.8	0.4	0.5
		n	2	2	2	2	2	2	2	2	2	2	2	2
Lynx	Hind	Mean	66.7	71.5	36.2	42.4	25.1	16.7	26.5	17.7	26.3	16.2	24.2	14.9
		SD	7.3	3.7	3.7	5.3	2.2	1.0	2.5	1.9	2.5	0.5	1.1	0.4
		n	2	2	2	2	2	2	2	2	2	2	2	2

[1] A lynx track with naked interdigital pads will be smaller than indicated here.

Appendix Table 2—*Comparative measurements for mustelids (mm).*

Species	Method	Foot	Statistic	Length	Width	--- Interdigital --- Length	Width	---- Toe 1 ---- Length	Width	---- Toe 2 ---- Length	Width	---- Toe 3 ---- Length	Width	---- Toe 4 ---- Length	Width	---- Toe 5 ---- Length	Width
Wolverine	VO	F	Mean	91.0	94.0	42.0	64.0	17.0	12.0	22.0	15.0	23.0	17.0	26.0	18.0	24.0	17.0
Wolverine	VO	F	SD	10.4	8.5	4.1	6.9	4.2	2.9	4.5	2.6	4.9	1.0	4.4	1.8	2.6	3.4
Wolverine	VO	F	n	5	4	5	5	4	4	4	4	5	5	5	5	4	4
Wolverine	VO	H	Mean	88.0	99.0	41.0	73.0	15.0	12.0	26.0	17.0	30.0	19.0	28.0	16.0	24.0	15.0
Wolverine	VO	H	SD	5.8	14.9	4.1	25.8	1.6	1.2	0.6	0.2	1.9	0.8	3.2	2.4	0.6	2.0
Wolverine	VO	H	n	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Wolverine	MO	F	Mean	83.0	83.0	35.0	56.0	13.0	9.0	15.0	10.0	18.0	12.0	20.0	14.0	19.0	16.0
Wolverine	MO	F	SD	4.1	2.4	6.0	4.6	0.2	0.5	0.9	0.8	3.1	0.2	2.1	1.8	3.1	2.0
Wolverine	MO	F	n	3	2	3	3	2	2	2	2	3	3	3	3	2	2
Wolverine	MO	H	n = 1	70.0	–	25.0	46.0	–	–	18.0	16.0	–	–	–	–	–	–
Otter	MO	F	Mean	58.0	71.0	22.0	32.0	12.0		14.0	15.0	13.0	9.0	12.0	9.0	12.0	9.0
Otter	MO	F	SD	2.8	0.9	6.6	0.2	1.3	–	0.6	3.6	3.3	1.9	2.3	1.0	1.7	1.6
Otter	MO	F	n	2	2	2	2	2	1	2	2	2	2	2	2	2	2
Otter	MO	H	n = 1	62.0	87.0	27.0	34.0	15.0	11.0	19.0	12.0	18.0	13.0	17.0	12.0	15.0	11.0
Otter	VO	F	Mean	72.0	69.0	25.0	40.0	17.0	14.0	23.0	15.0	23.0	13.0	20.0	14.0	16.0	11.0
Otter	VO	F	SD	3.5	0.7	0.5	1.6	0.0	0.0	0.0	1.4	1.0	0.2	1.0	0.9	0.9	–
Otter	VO	F	n	2	2	2	2	1	1	1	2	2	2	2	2	2	2
Otter	VO	H	Mean	71.0	81.0	27.0	29.0	–	–	–	13.0	–	12.0	22.0	12.0	15.0	15.0
Otter	VO	H	SD	2.5	0.7	6.5	4.9	–	–	–	2.5	–	1.1	1.2	0.6	1.2	1.0
Otter	VO	H	n	2	2	2	2	–	–	–	2	–	2	2	2	2	2
Fisher	VO	F	Mean	62.0	69.0	30.0	44.0	19.0	15.0	21.0	15.0	22.0	15.0	21.0	16.0	19.0	15.0
Fisher	VO	F	SD	10.0	11.0	3.0	5.0	1.0	2.3	5.5	4.8	4.1	2.0	5.4	5.4	1.6	1.8
Fisher	VO	F	n	5	6	5	6	2	2	2	2	2	2	2	2	2	2
Fisher	VO	H	Mean	64.0	59.0	32.0	38.0	13.0	10.0	14.0	9.0	16.0	9.0	10.0	8.0	12.0	9.0
Fisher	VO	H	SD	4.0	3.0	6.0	2.0	–	–	4.0	1.0	2.0	0.9	0.3	-	–	–
Fisher	VO	H	n	4	3	4	4	1	1	2	2	2	2	2	1	1	1
Fisher	MO	F	Mean	62.0	66.0	27.0	36.0	13.0	11.0	16.0	12.0	17.0	11.0	13.0	12.0	12.0	10.0
Fisher	MO	F	SD	7.5	6.8	2.2	5.3	2.6	3.2	2.3	2.7	3.2	2.4	-	2.1	1.8	1.6
Fisher	MO	F	n	2	2	2	2	2	2	2	2	2	2	1	2	2	2
Marten	VO	F	n = 1	54.0	49.1	29.7	38.2	14.6	8.5	18.0	12.6	17.3	9.1	17.3	8.7	20.9	12.2
Marten	MO	F	Mean	51.5	46.0	31.4	36.6	11.3	7.4	14.4	9.6	13.1	7.4	–	6.5	15.1	10.5
Marten	MO	F	SD	0.5	2.6	1.5	1.0	0.6	0.1	0.1	1.2	1.2	0.5	–	0.0	0.7	1.1
Marten	MO	F	n	2	2	2	2	2	2	2	2	2	2	0	1	2	2
Marten	MO	H	n = 1	57.5	49.0	31.3	38.2	17.5	9.6	15.9	9.9	15.5	8.4	–	9.0	17.1	12.2
Badger	VO	F	n = 1	56.0	55.0	23.0	36.0	16.0	9.0	23.0	9.0	25.0	14.0	25.0	13.0	14.0	12.0
Badger	VO	H	n = 1	59.0	44.0	30.0	33.0	15.0	8.0	19.0	10.0	21.0	10.0	20.0	9.0	18.0	10.0
Badger	MO	F	n = 1	53.0	61.0	20.0	28.0	13.0	7.0	16.0	11.0	18.0	13.2	19.0	11.0	19.0	11.0

Appendix B—Data forms

SURVEY RECORD FORM

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. or m?)

(use another sheet if necessary)

Vegetation type (s) ____

Date installed (or run) ________________ Date terminated ___________________

Type of bait or scent ____

Name, address, and phone of investigator ____________________________

____

____

Page ______ of ______

Snow Tracking Form

Observer ____________________________________ Date ______________

Sample Unit Number ______ Days Since Last Snow ___________

Survey Area ____

Comments ____

Time	Distance from Start	Canids	Felids	Mustelids	Prey Species	Habitat	STQ*	Notes

* Describe the Snow Tracking Quality (STQ) using the chart on the following page.

Snow Tracking Quality

Snow tracking quality (STQ) refers to the ability of the snow to preserve an identifiable foot print and trail. Records of STQ are kept to verify adequacy of a track survey. If, at the end of the day, snow quality over much of the route has been inadequate (mostly 1s and 0s) to record and identify prints, the route may have to be resurveyed another day.

STQ should be rated every time a change in quality occurs. The rating refers to the section of the route just travelled and refers to conditions at the time of observation, not conditions at the time the print was made. STQ integrates two factors: conditions at the time the track was made and weather conditions since tracks originated. Clear tracks which rated high originally may be disintegrating by the time the observer finds them. During the course of a day, STQ usually deteriorates, especially as the sun melts the snow.

When STQ is between two categories, give a decimal rating to indicate intermediate conditions, i.e, 3.7. Averaged ratings may be given when conditions vary over short distances; use a "V" for variable, i.e. 3.2V. When conditions vary continually, i.e. when descending a mountain slope or on a fast warming day, record the STQ frequently. Conditions often vary dramatically from one compass aspect to another.

Description of STQ Ratings

<u>Rating 4</u>: Best; every footprint registers, and detail within prints is very clear. Species identification is essentially absolute based on track details.

<u>Rating 3</u>: Good; every print registers, but details are weak, perhaps obscured by snow falling into print. Print details usually visible in microtopographic sites, e.g., tree wells and shadows. Identification is based on track details, but gait patterns offer needed support.

<u>Rating 2</u>: Acceptable; some prints fail to register, and footprint details, if present, are visible only in microtopographic sites. Identification based primarily on gait patterns.

<u>Rating 1</u>: Poor; many prints do not register. Track details lacking. Identification is essentially by gait patterns, and may be possible only in microtopographic sites.

<u>Rating 0</u>: - Unacceptable; target species does not leave enough prints to identify gait patterns left in trails.

Snow Surface Quality Ratings Summary

Rating	Prints	Detail	Detail Location	Gait Patterns	Identification
4	every print registers	clear within print	all locations	distinctive	by tracks, essentially absolute
3	every print registers	weak, snow obscured	details in microtopographic sites	gain importance	by prints and gaits
2	some do not register	no details in open	only in microhabitats	important	by gaits, clues from details
1	many do not register	no details	no details	sole clue	by gaits
0	most prints do not register	no detail	no detail	not complete	not possible

TRACK OBSERVATION FORM

Species Observed ____________________ Number Observed ________

Date __________ Time __________ Observers ____________________

Location ____________________ **Road Number** __________

Sec. ______ T ______ R ______ UTM's __________ , __________

Elev. __________ Aspect __________ **Photos Taken? Yes** ______ No ______

Habitat ____

Topography __________________ Tracking Surface __________________

Notes ____

____

Measurement units are **cm** or **in** (mark out the units **NOT** used)
M1, M2, M3 refer to sequential measurements on one trail, i.e. 3 strides or 3 right prints.

Gait	M1	M2	M3	Mean	STD
Stride					
Group					
Straddle					
Center					
Trough					

Photograph Record		
Film and ASA	Roll Number	**Frames**

	Length					Width				
Prints	M1	M2	M3	Mean	STD	M1	M2	M3	Mean	STD
Front										
Hind										
Metatarsal										

Comments and Drawings (make drawings on the back of this form)

SPECIES DETECTION FORM

Please complete each field after a survey has detected either lynx, wolverine, fisher, or marten, and send a copy to your state's Natural Heritage Division (addresses in Chapter 1) and other appropriate entities. The meaning of each code is explained on the following page. It is important to coordinate with the State Wildlife Agency/Natural Heritage Program within your State to assure uniform codes are used for federal lands, parks, private lands, counties, etc.

1. **SPEC** ____________
2. **DATE** ____________
3. **STATE** _____
4. **CO** ____
5. **LOC** ____
6. **QUAD** ________________
7. **QUADNO** ______________

8. **OWN** ________

8a. **FOR/PARK** ____________

8b. **DISTRICT** ____________

9. **RNG** __
10. **TWN** __
11. **SEC** ___
12. **QSEC** ___
13. **SIXTHSEC** ______
14. **M** ___
15. **Z** ___
16. **UTM_N** ______________________
17. **UTM_E** ____________________
18. **OBS** ____________________________________
19. **SVTP** __
20. **STA_NO** ________
21. **TR_NO**
22. **ELEV** __
23. **COMMENTS** ____

____

CODES FOR THE SPECIES DETECTION FORM

1. **SPEC** - Species; 1 letter: L = lynx, W = wolverine, F = fisher, M = marten.
2. **DATE** - Date; year, month, day; e.g., Jan. 12, 1994 = 19940112.
3. **STATE** - State; use 2-letter postal abbreviation, e.g., MT, OR.
4. **CO** - County; use 2-letter code, e.g., AP=Alpine, HU=Humboldt
5. **LOC** - Locale; the most specific names possible using names found on USGS maps, e.g., Grizzly Creek. 20 characters.
6. **QUAD** - Name of USGS topographic quad showing survey area; if >1, use additional sheets, e.g., Ship Mountain. 20 characters.
7. **QUADNO** - USGS quad number utilizing latitude and longitude identification system.

*8. **OWN** - Landowner. 4-letter code, e.g., USFS, NPS, BLM, CA, PVT.

8a. **FOR/PARK** - National or State Forest or Park name. 3 characters.

8b. **DISTRICT** - Subdivision of Forest or Park (e.g., Ranger District if "OWN" = USFS. 3 characters.

9. **RNG** - Range. 3-characters.
10. **TWN** - Township. 3-characters.
11. **SEC** - Section. 2-characters.
12. **QSEC** - Quarter section. 2 characters.
13. **SIXTHSEC** - Sixteenth section. 2 characters.
14. **M** - Meridian. 1-character.
15. **Z** - UTM zone. 2-characters.
16. **UTM_N** - UTM-north coordinate; 7-characters.
17. **UTM_E** - UTM-east coordinate; 6-characters.
18. **OBS** - Observer; last name, first name, middle initial of survey crew leader. 20 characters.
19. **SVTP** - Survey type: SNSS = snow-tracking survey (searching); SNSB = snow-tracking survey (at bait); TRPL = track plate; CAMR = camera (35-mm or 110).
20. **STA_NO** - Station number of detection (if camera or track plate). 2 characters.
21. **TR_NO_** - Number of snow transect where detection occurred. 2 characters.
22. **ELEV** - Elevation at detection site. 5 characters.
23. **COMMENTS** - 30 Characters.

* Each state will need to develop 2-3 character codes for specific forests, parks, private landowners and districts therein.

Appendix C—Photographic Interpretation

The best means to verify the identity of a track is to augment data collected from the field with laboratory analysis of photographs or casts. Measuring tracks and trails from photographs presents two types of problems: those dealing with scale conversion and those dealing with parallax. Photographs that include a rigid, marked scale, preferably a ruler, are easiest to measure. A set of calipers or dividers can be used to span the object being measured and then moved to the ruler where the distance can be measured. However, when direct measurements are not visible on the scale, the procedure is more complex.

A Photo Interpretation Sheet is provided to help with the procedure. First, list each item to be measured, for example, length, width, interdigital pad length. Then, rate the item as to the quality of measurement. If quality is poor, do not use that measurement for critical decisions on species identity. Record the true size of the scale object that was placed next to the track in the photograph in the "Scale Size" (SS) column. The scale object is then measured in the photograph and listed under the Scale Image (SI) column. Next calculate the scaling ratio (R) by dividing the Scale Size by the Scale Image (SS/SI), and record this in the Ratio column. Measure the Item Image (II) in the photograph, and record it. To get the Real Size (RS) of the item, multiple the Ratio (R) by the Item Image (II). A computer spreadsheet will facilitate calculations. Also note that the final units of the measurement will be the same as the original units used to measure the scale object.

Always use the scale object closest to the item to be measured to reduce parallax problems. Any errors in measurement will be increased because the Item Image is multiplied by a ratio greater than 1, thereby multiplying the error. For long items, such as a trail, there should be a scale at both ends, and it is best to have a continuous scale alongside the item. If a scale is present only at the ends, linear interpolation may have to be used for items between the scales. Note, however, that the parallax problem is not linear, and some error may be introduced.

Photo Interpretation Sheet

Quality ratings:

Excellent

Very Good

Good

Poor

Species Suspected:	Photo Identification:
Date photos taken:	Identified by:
Date measured:	Measurement units: cm in.

Item	Scale Size **SS**	Scale Image **SI**	Ratio (SS/SI) **R**	Item Image **II**	Real Size **RS=R*II**	Quality	Comments

Additional details and comments:

Example

Photo Interpretation Sheet						Quality ratings: Excellent, Very Good, Good, Poor	
Species Suspected: Fisher			Photo Identification: Fisher				
Date photos taken: Feb. 4, 87			Identified by: Rezendes				
Date measured: Apr. 20, 1994			Measurement units: in.				
Item	Scale Size **SS**	Scale Image **SI**	Ratio (SS/SI) **R**	Item Image **II**	Real Size **RS=R*II**	Quality	Comments
Length	3	15.31	0.196	10.3	2.0	G	
Width				10.9	2.1	G	
Interdigital				6.5	1.3	G	
Length							
Interdigital				8.3	1.6	G	
Width							

Additional details and comments: TRACK IN FLUFFY SNOW, TOES NOT CLEAR

Figures

Figure 1—Right front foot of a wolverine. Note the 1-3-1 spacing of toes, chevron-shaped interdigital pad, and metacarpal pad. (Utah) Photograph by D. Hall.

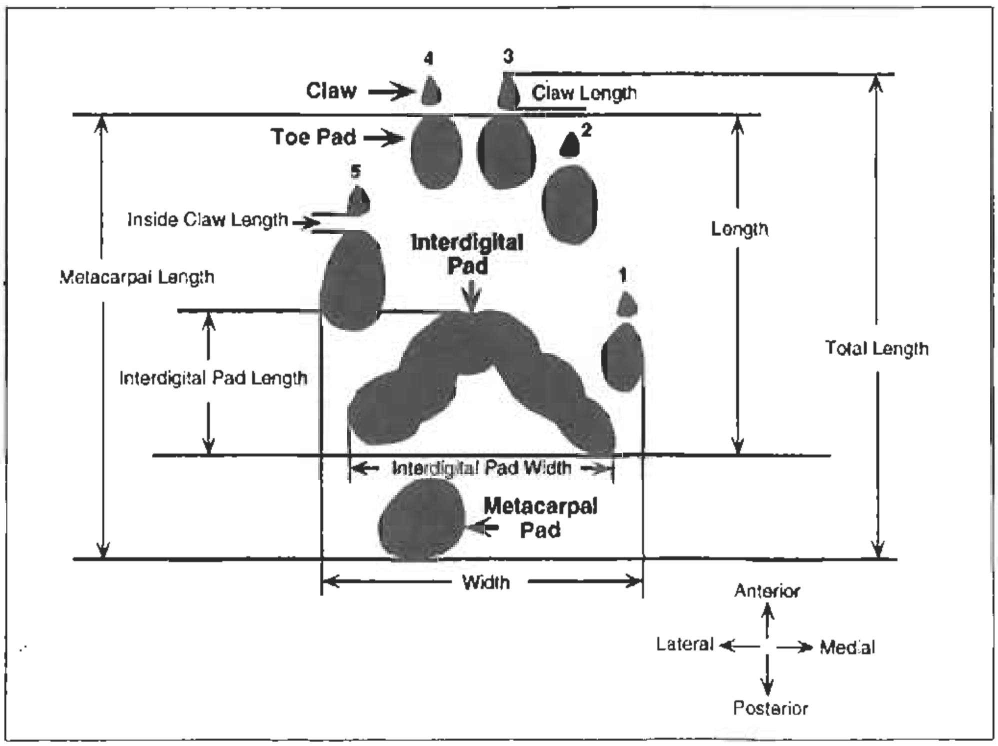
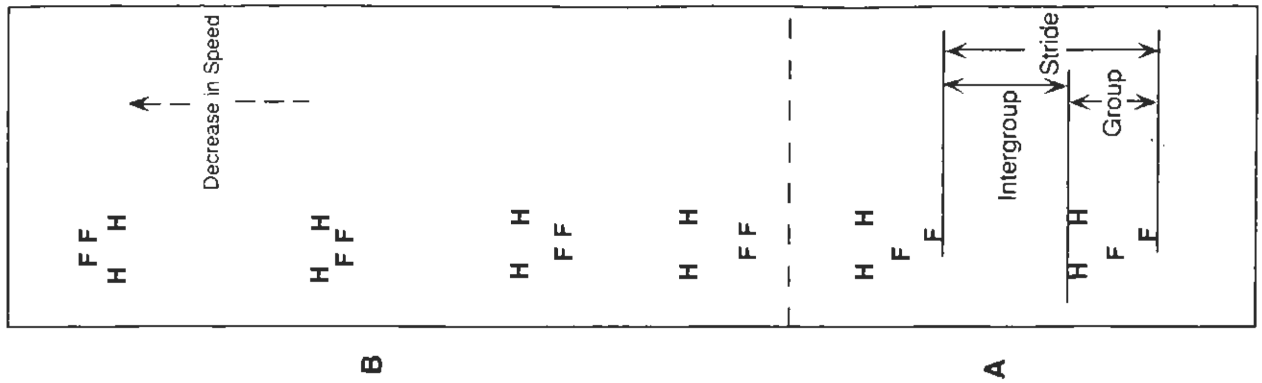
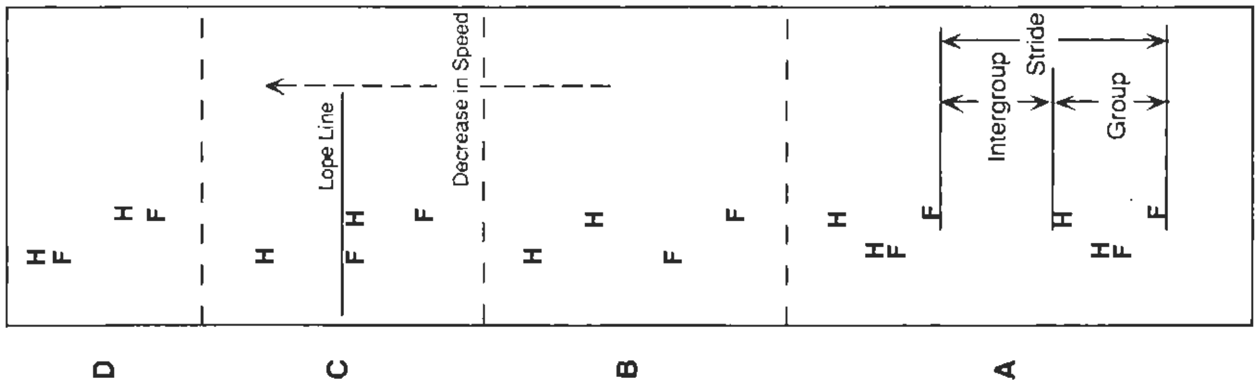
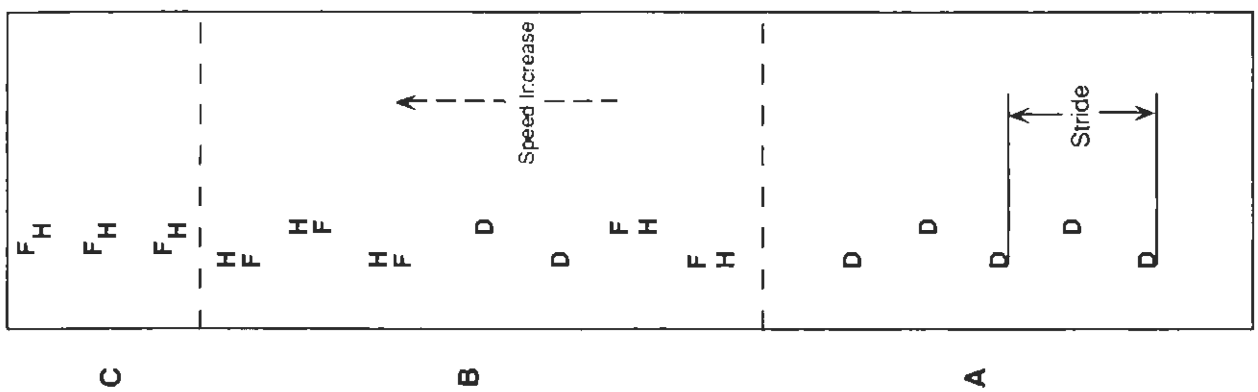


Figure 2—Morphology of the left front footprint of a wolverine and measurements commonly recorded from carnivore tracks


Decrease in Speed
Stride
Intergroup
Group
A
B


Decrease in Speed
Lope Line
Stride
Intergroup
Group
A
B
C
D


Speed Increase
Stride
A
B
C

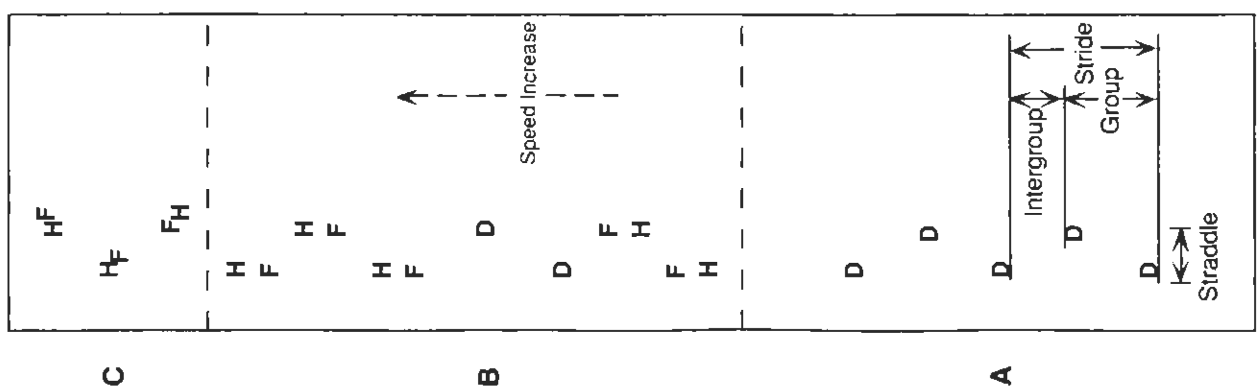

Speed Increase
Stride
Group
Intergroup
Straddle
A
B
C

Figure 3—Walking trail patterns. (A) Walking trail pattern with direct registry; hind feet imprint on top of front prints, only hind prints show. (B) Trail of an animal walking at an increasing speed from bottom to top of figure. At a slow walk, the hind print registers posterior to the front print. At a faster walk, the hind print registers anterior to the front print. As speed increases, the hind print registers farther anterior to the front print. (C) The walking trail of this animal shows no concern for stealth, and the front and hind prints register almost randomly. D = direct registration of hind on front print, F = front print, H = hind print. Direction of travel is from bottom to top of figure.

Figure 4—Trotting trail patterns. Trotting trail patterns appear the same as those of walking patterns, except the stride is longer and straddle may be narrower. (A) Normal trotting trail pattern with direct registry; hind feet imprinting on top of front prints, only hind prints show. (B) Trail of an animal trotting at an increasing speed from bottom to top of figure. At slow trot, the hind print registers posterior to the front print. At a faster trot, hind print registers anterior to the front print. As speed continues to increase, the hind foot registers farther anterior to the front foot. (C) Trail of an animal trotting with the axis of its body at an angle to the direction of travel; in this case the head is to the left. The side trot causes all front feet to register on one side and all hind feet to register on the other side of the line of travel. D = direct registration of hind on front print, F = front print, H = hind print. Direction of travel is from bottom to top of figure.

Figure 5—Galloping trail patterns. (A) Common "C-shaped" galloping pattern known as a rotatory gallop. Distinct group and intergroup patterns during the period when the animal's feet leave the ground are evident. (B) Common "Z-shaped" galloping pattern known as a transverse gallop. The pattern indicates a relatively fast speed with the hind prints well forward of the front prints. In the sequence from B through D, the speed of the animal is decreasing. (C) As speed decreases, hind prints register more posterior and closer to the front print (lope line); when the hind print is posterior to the "lope line," the pattern is known as a lope. Lopes may be either rotatory or transverse. (D) This pattern represents a still slower transverse lope. The loping gait is still a gallop, but it is a slow gallop. F = front print, H = hind. Direction of travel is from bottom to top of figure.

Figure 6—Bounding trail patterns. (A) Bounding pattern showing distinct group and intergroup patterns during the period when the animal's feet leave the ground. The pattern where the front prints are at an angle to the line of travel is known as a half bound. (B) Full bound pattern (front prints are perpendicular to the line of travel) in which the speed is decreasing. At higher speeds hind prints overstep the front prints. F = front print, H = hind. Direction of travel is from bottom to top of figure.

Figure 7—Lynx trail showing walking and bounding gaits. Direction of travel is from the bottom to the top of the photograph. The trough formed by hair dragging is evident. The lynx was walking in the lower portion of the photograph and changed to a 3× bound (or jump). (Colorado) Photograph by J. Halfpenny.

Figure 8—Fisher walking trail. Note hind prints registering on top of front prints. (Massachusetts) Photograph by P. Rezendes.

Figure 9—Marten trail showing 2× gait. Note that the tracks are at an angle to the direction of travel. (Wyoming) Photograph by J. Halfpenny.

Figure 10—Wolverine trail showing 3× lope with partial registry. (Alaska) Photograph by N. Lederer.

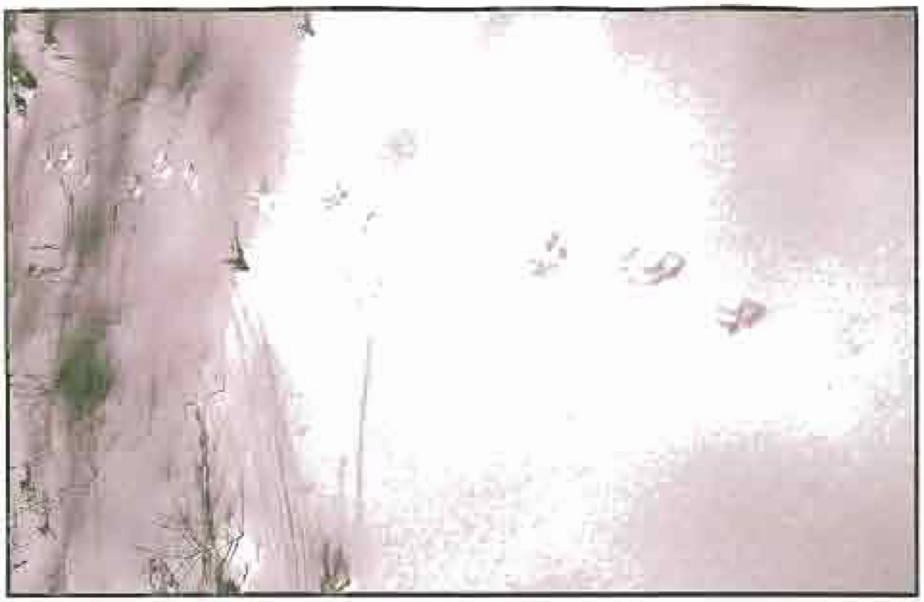


Figure 11—Fisher 3× lope, showing the intergroup distance between groups of four prints. The snow is relatively hard, and the fisher is not sinking deeply. (Massachusetts) Photograph by P. Rezendes

Figure 12—Fisher trail showing 4× lope. The front prints can be differentiated by the presence of a metacarpal pad. (Massachusetts) Photograph by P. Rezendes.

Figure 13—Fisher trail showing transition between gaits. The lower group of tracks is a 3× lope, and at the top the fisher is using a 2× gait. (Massachusetts) Photograph by P. Rezendes.

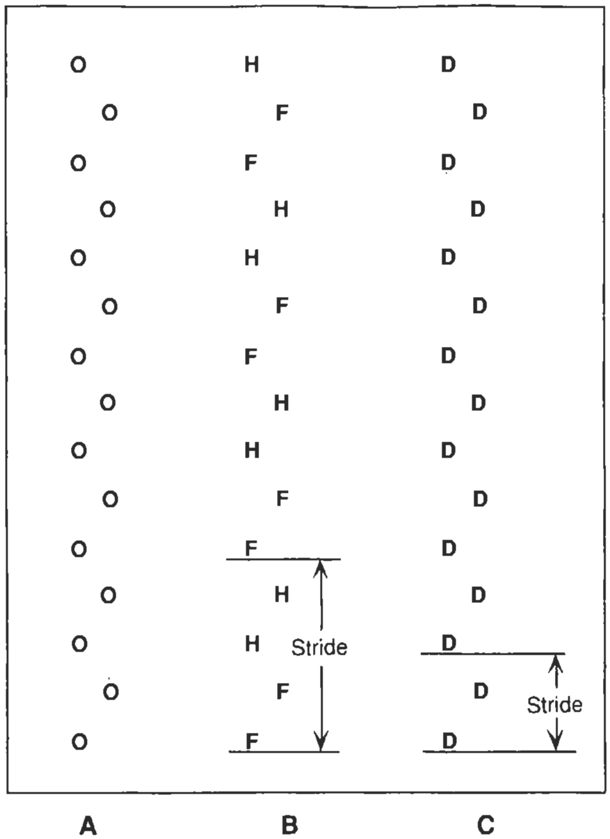


Figure 14—Potential error in gait identification and stride distance when a transverse gallop is mistaken for a walk. (A) Indistinct prints in trail. (B) Transverse gallop producing same pattern as in A. (C) Walk producing the same pattern as in A. O = print hole in snow, F = front print, H = hind print, D = direct registry of front and hind prints. Direction of travel is from bottom to top of figure.

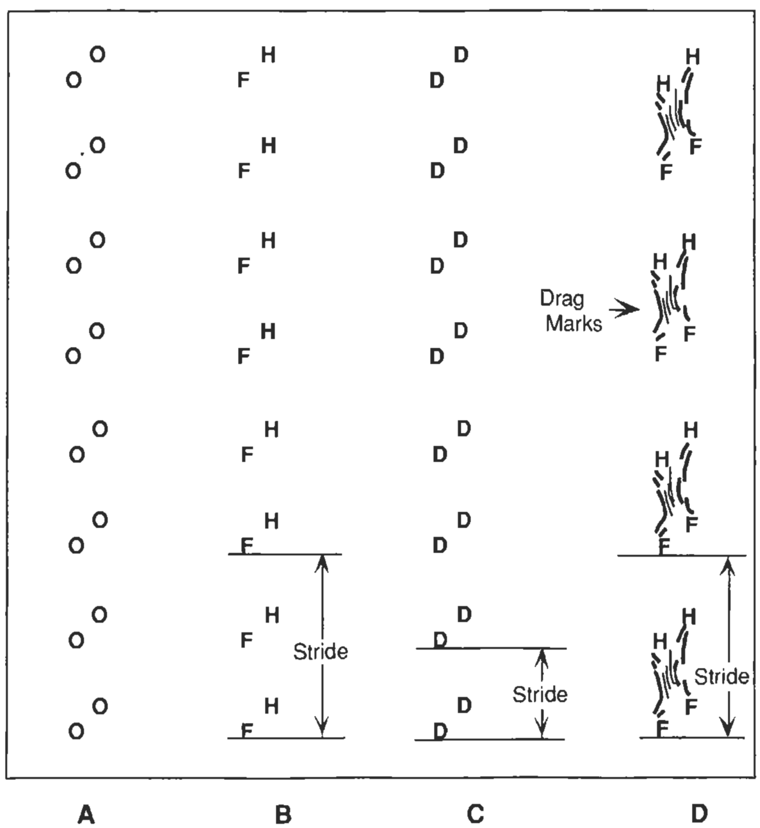


Figure 15—Potential error in gait identification and stride measurement when a side trot, a lope, and a gallop are confused. (A) Indistinct prints in trail. (B), (C), and (D) are a side trot, lope, and fast gallop, respectively, that produce the same pattern as in A. Drag marks indicate a fast gallop, if present. O = print hole, F = front print, H = hind print, D = direct registry of front and hind feet. Direction of travel is from bottom to top of figure.

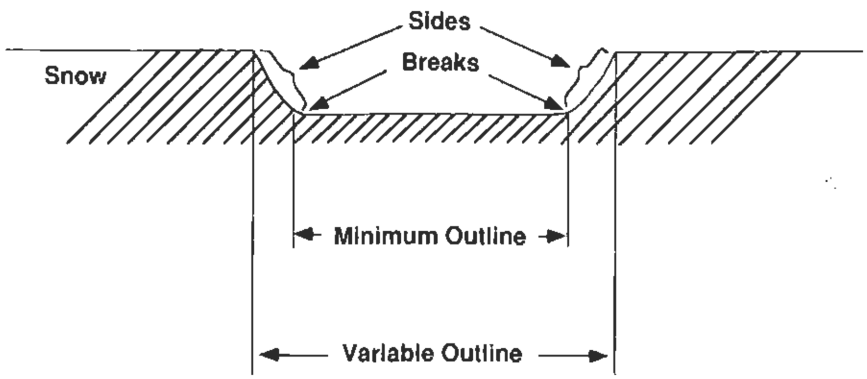


Figure 16—Profile of a track indentation showing increase in size due to sinking into a soft substrate (after Fjelline and Mansfield 1989), and the difference between minimum and variable outline track measurements.

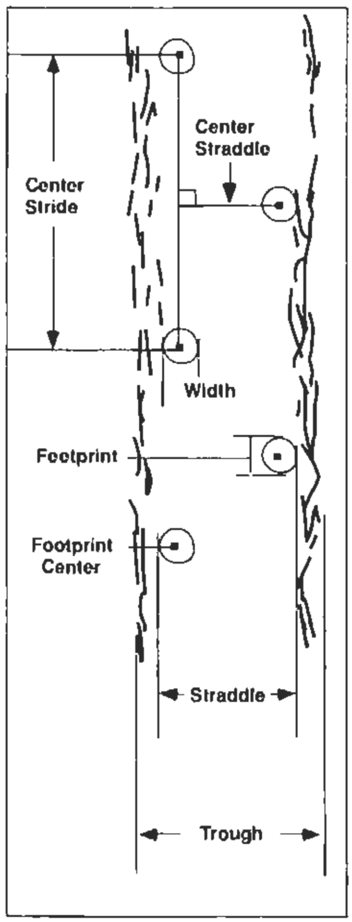


Figure 17—Features used to characterize and measure carnivore trails. The center of the footprint (round circle) is indicated by a square. Wavy lines are hair drag-marks.

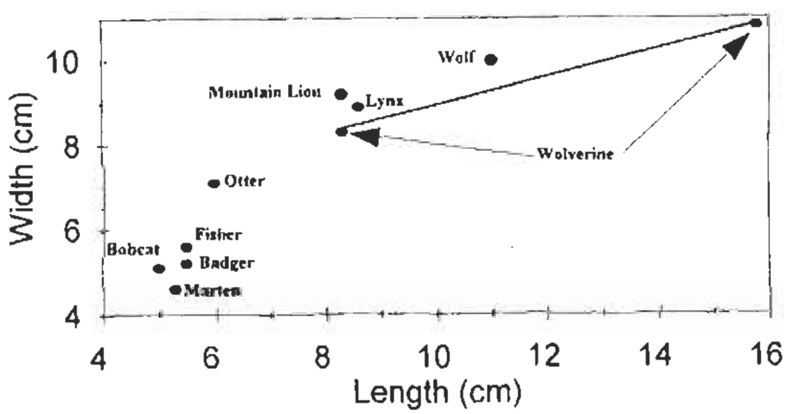


Figure 18—Typical size of prints for selected carnivores. The line indicates the range of values for wolverine attributed to variation in sex, age, and measurement. These sources of variation have not been reported for the other species.

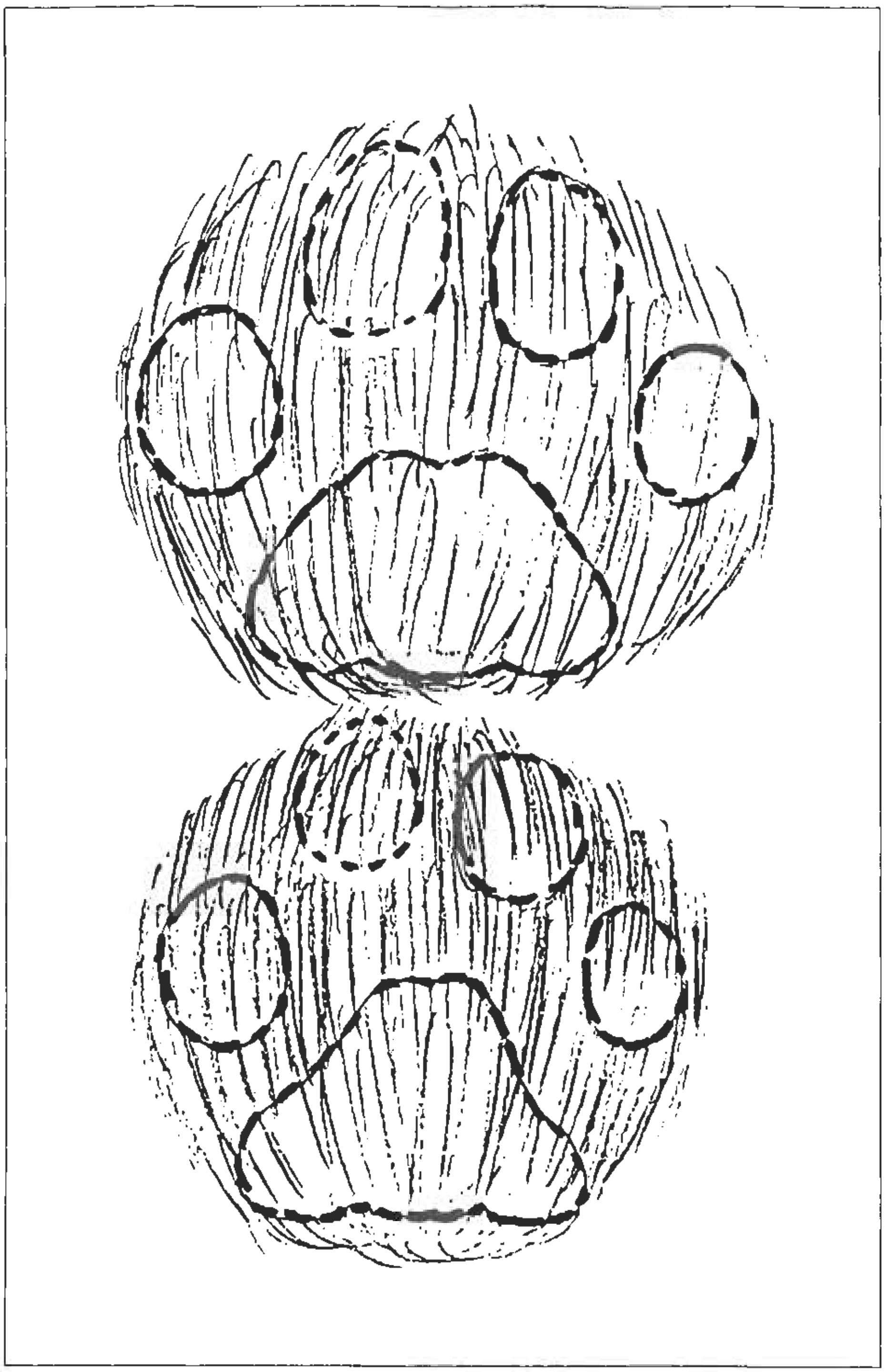


Figure 19—Typical life-size right front and hind footprints of a lynx. Prints will vary in size by sex, age, geographic area, and snow conditions. See text for discussion of interdigital pad size.

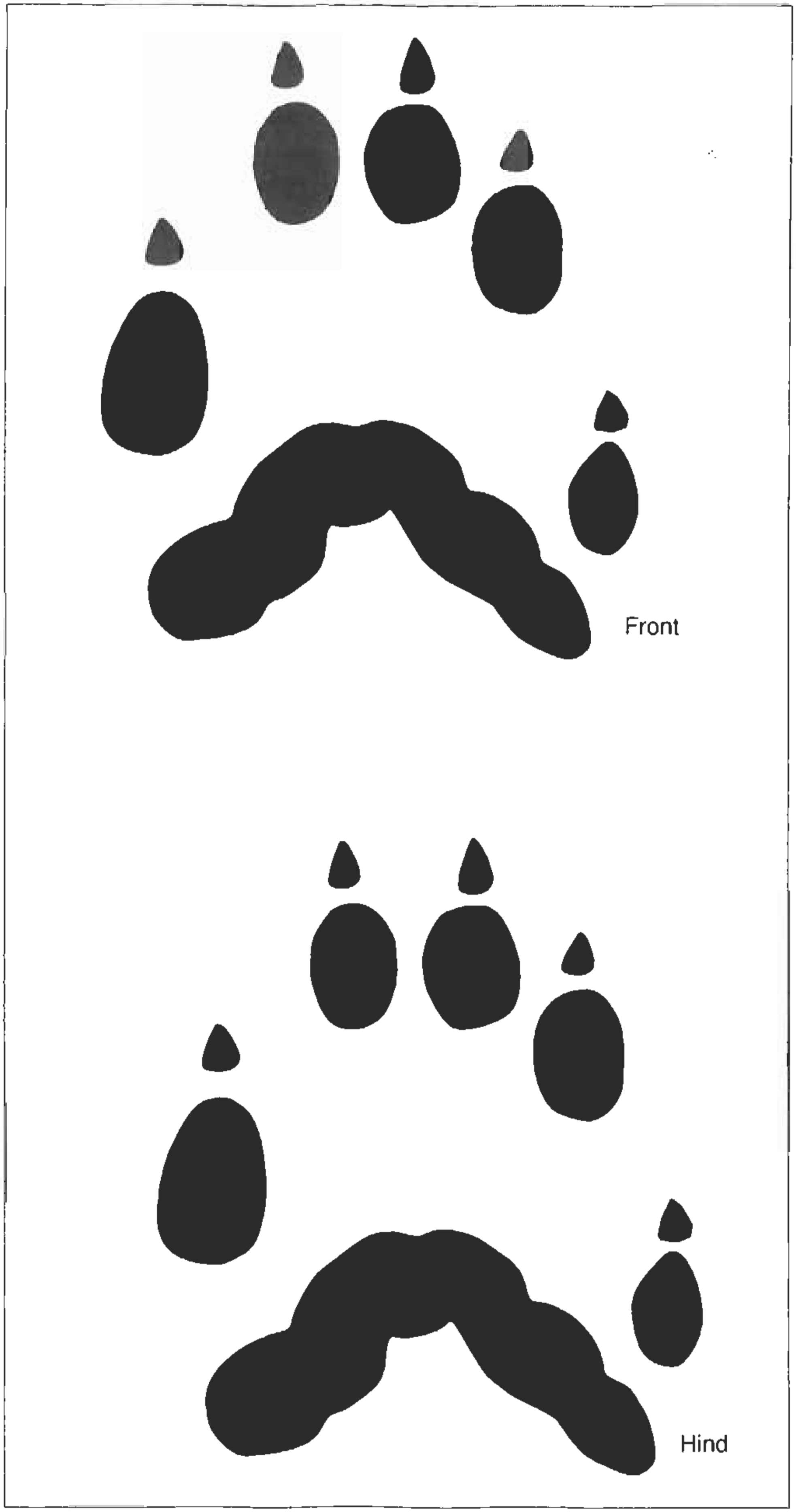


Figure 20—Typical life-size left front and hind footprints of a wolverine. Prints will vary in size by sex, age, geographic area, and snow conditions, so use these only as a general reference.

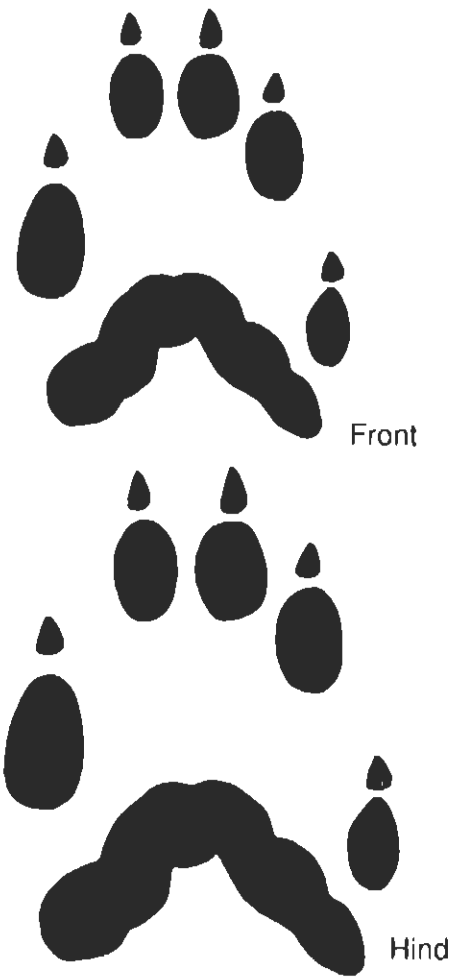


Figure 21—Typical life-size left front and hind footprints of a fisher. Prints will vary in size by sex, age, geographic area, and snow conditions, so use these only as a general reference.

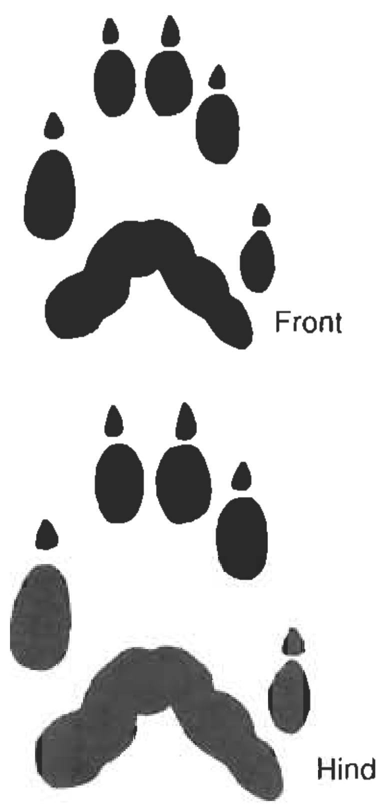


Figure 22—Typical life-size left front and hind footprints of a marten. Prints will vary in size by sex, age, geographic area, and snow conditions, so use these only as a general reference.

Figure 23—Lynx illustrating hairiness of underside front of foot. Toe and interdigital pads are obscured by hair. (Colorado) Photograph by J. Halfpenny.

Figure 24—Lynx trail on wet, semi-firm spring snow. The lynx has sunk only a bit into the snow, and drag marks are evident. A folding ruler provides scale. (Colorado) Photograph by J. Halfpenny.

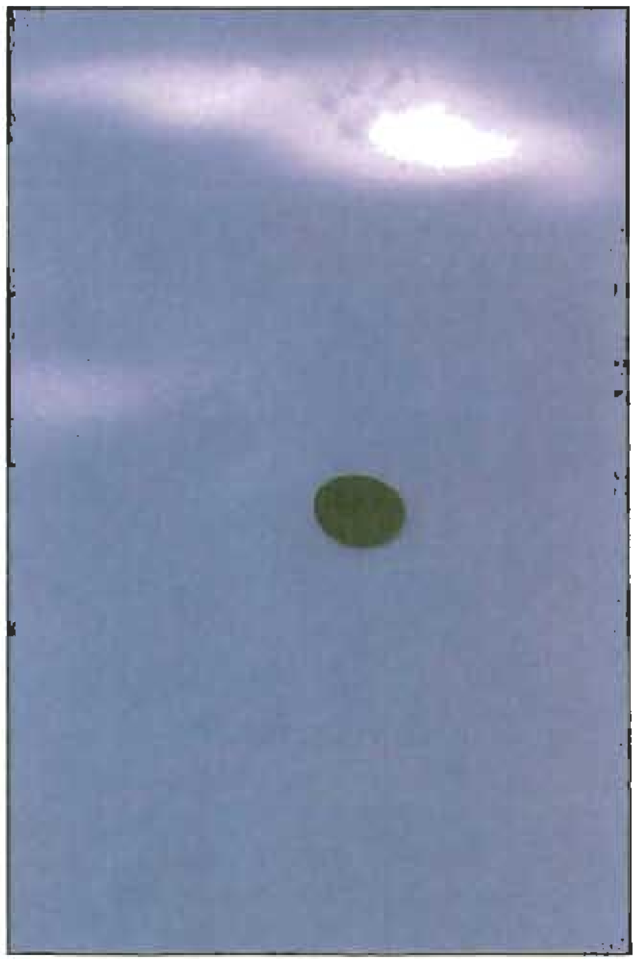


Figure 25—Lynx trail on spring snow. In late spring, when melting and freezing produce a hard surface and when the winter coat of hair is starting to wear off the feet, lynx tracks may show individual toes. Note the larger front feet. (Wyoming) Photograph by B. Thompson.

Figure 26—Front foot of an adult lynx. Note that hair covers most, but not all, of the toe and interdigital pads. The interdigital pad may register clearly, but will represent a relatively small proportion of the footprint. Note also the concave outline of the rear of the interdigital pad, created by the posterior extension of the lateral lobes of the interdigital pad. Photograph by S. Morse.

Figure 27—Front left print of an adult male lynx. Note the posterior extension of the lateral lobes of the interdigital pad and the relatively small size of the pad. Photograph by S. Morse.

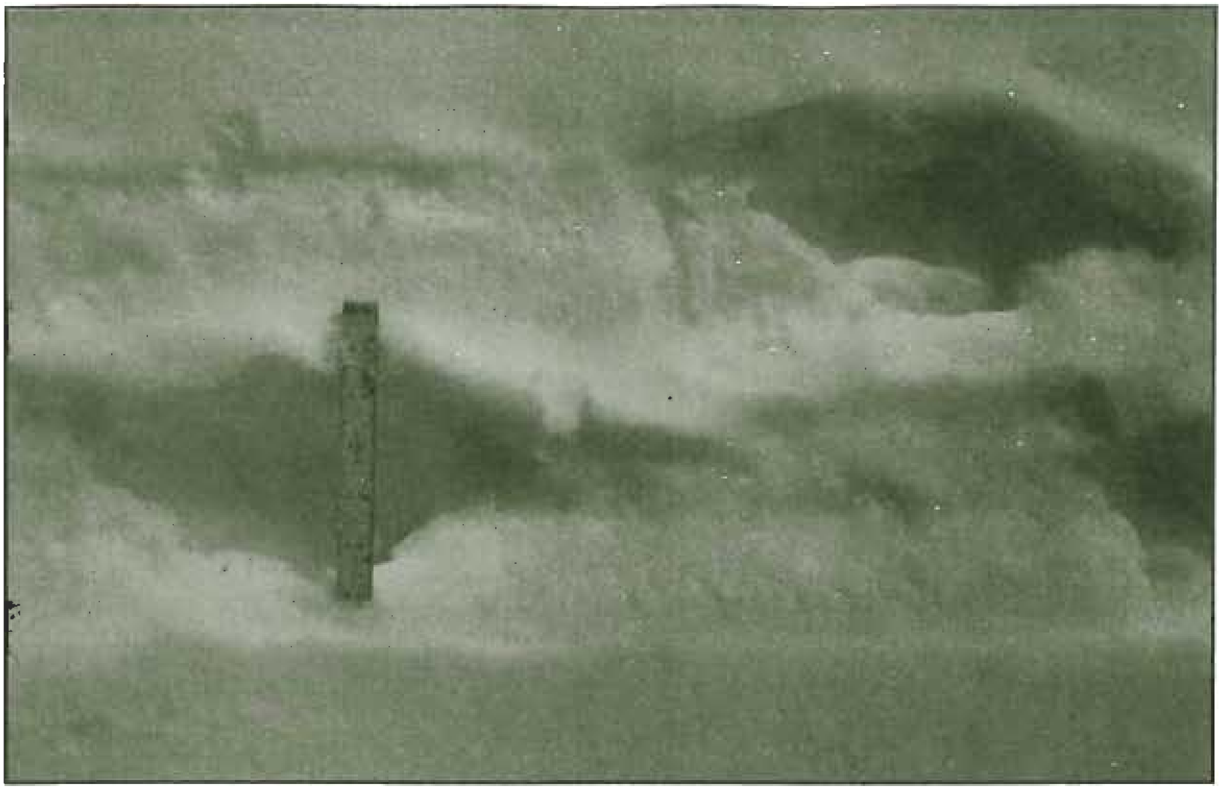


Figure 28—Trail of a lynx. Note how hair obscures details of track and produces a trough in the snow. (Colorado) Photograph by J. Halfpenny

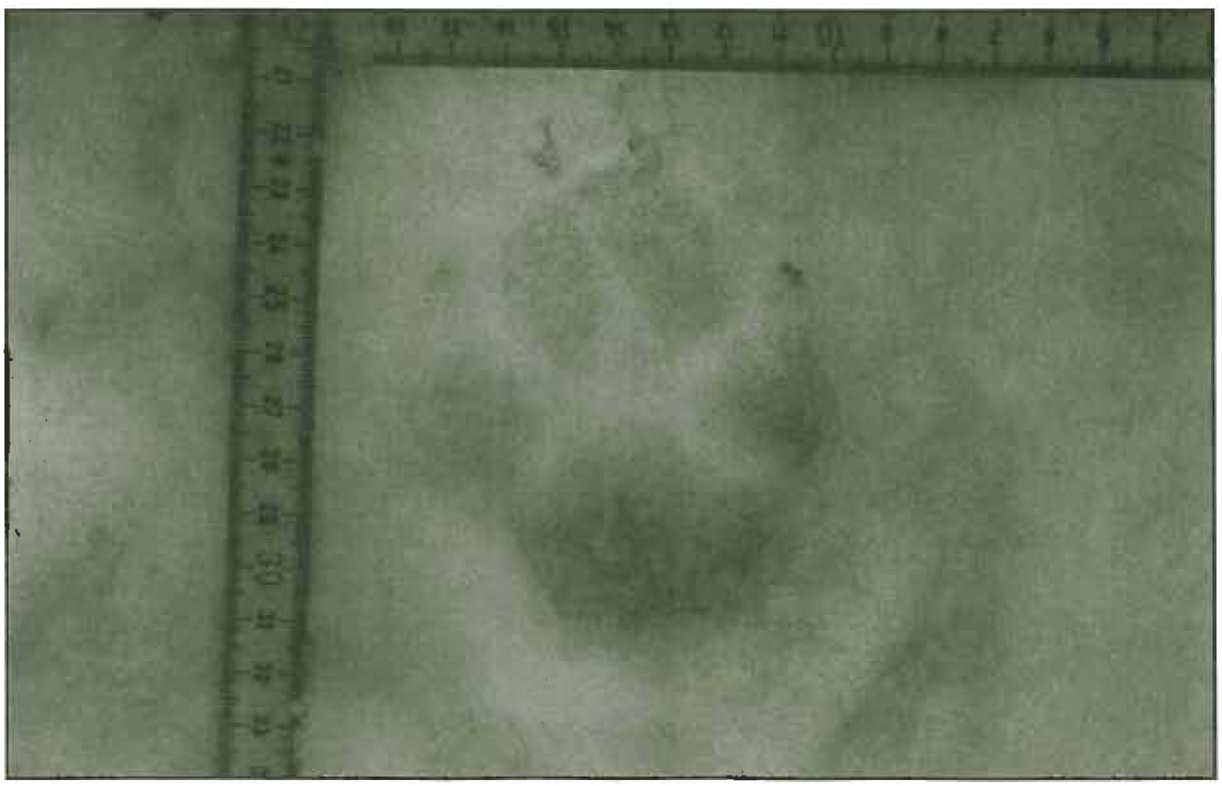


Figure 29—Wolf track. Note claw marks, symmetrical toe size and position, rectangular shape, and single lobe on the anterior edge of the interdigital pad. (Minnesota) Photograph by J. Halfpenny.

Figure 30—Bobcat track. Note small size, distinct pads, and the double lobe on the anterior edge of the interdigital pad. (Wyoming) Photograph by J. Halfpenny

Figure 31—Left front foot of an adult male bobcat. Note the bilobate anterior edge of the interdigital pad, asymmetrical position of the toes, slightly larger toe 2 (toe 1 does not show in the print of a felid), and toe 3 is the most anterior toe. Photograph by S. Morse.

Figure 32—Bobcat tracks (on left) and lynx track (on right). Note the extreme size difference and the fact that the bobcat track has a relatively large interdigital pad. The bilobate anterior edge of the interdigital pad is evident in the top bobcat track. Photograph by S. Morse.

Figure 33—Mountain lion track. Note large size, teardrop-shaped toe pads, and the distinct edges to pads. The bilobate anterior edge of the interdigital pad appears blunt in this photograph. (Colorado) Photograph by J. Halfpenny.

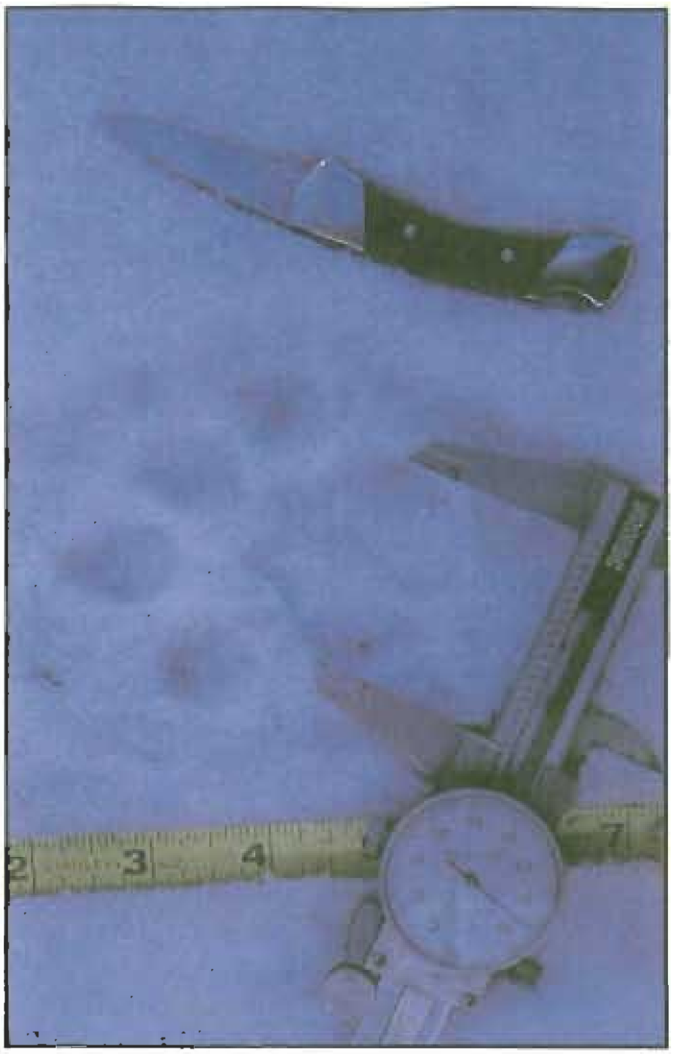


Figure 34—Front footprint of an adult female mountain lion. Note the bi-lobed anterior edge of the interdigital pad, asymmetrical positioning of toes, and third toe slightly advanced beyond the edge of the other toes. Posterior edge on the interdigital pad appears straight to slightly concave. Photograph by S. Morse.

Figure 35—Hind (left) and front (right) feet of an adult male mountain lion. Note tear-drop shaped toes. The big toe and lead toe (number 3) are on the medial side of the foot. The interdigital pad of each foot is relatively large, and the space between toes and interdigital pads relatively small. The posterior edge of the interdigital pad of the hind foot appears straight while that of the front foot appears slightly concave with the lateral lobes of the interdigital pad extending slightly posterior of the center lobe. In some mountain lion prints, the center pad extends posterior to the lateral pads (Smallwood and Fitzhugh 1989). Photograph by S. Morse.

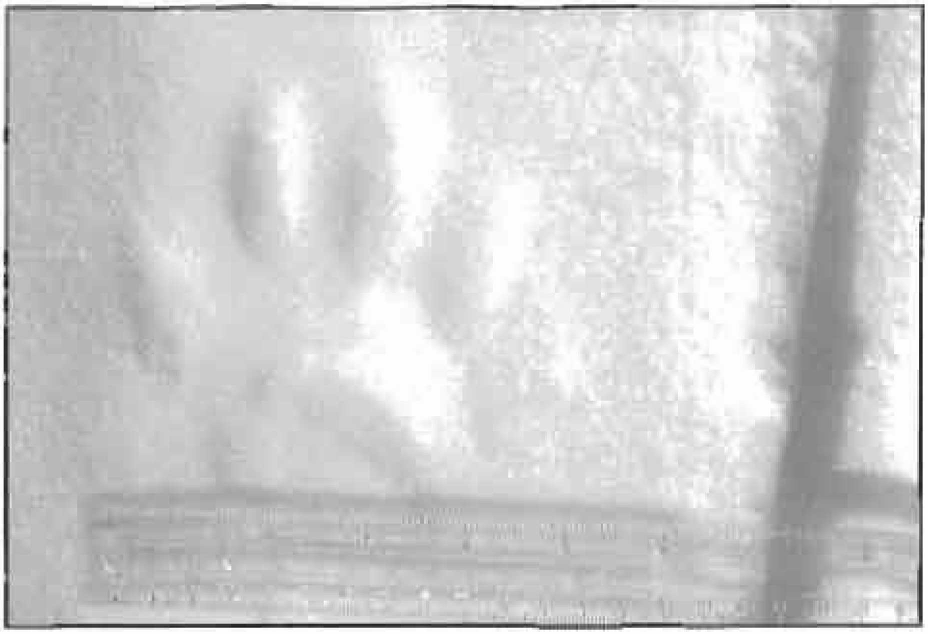


Figure 36—Wolverine print. Note the medial toe is very faint. The toe prints show some elongation from melting. (Montana) Photograph by N. Bishop.

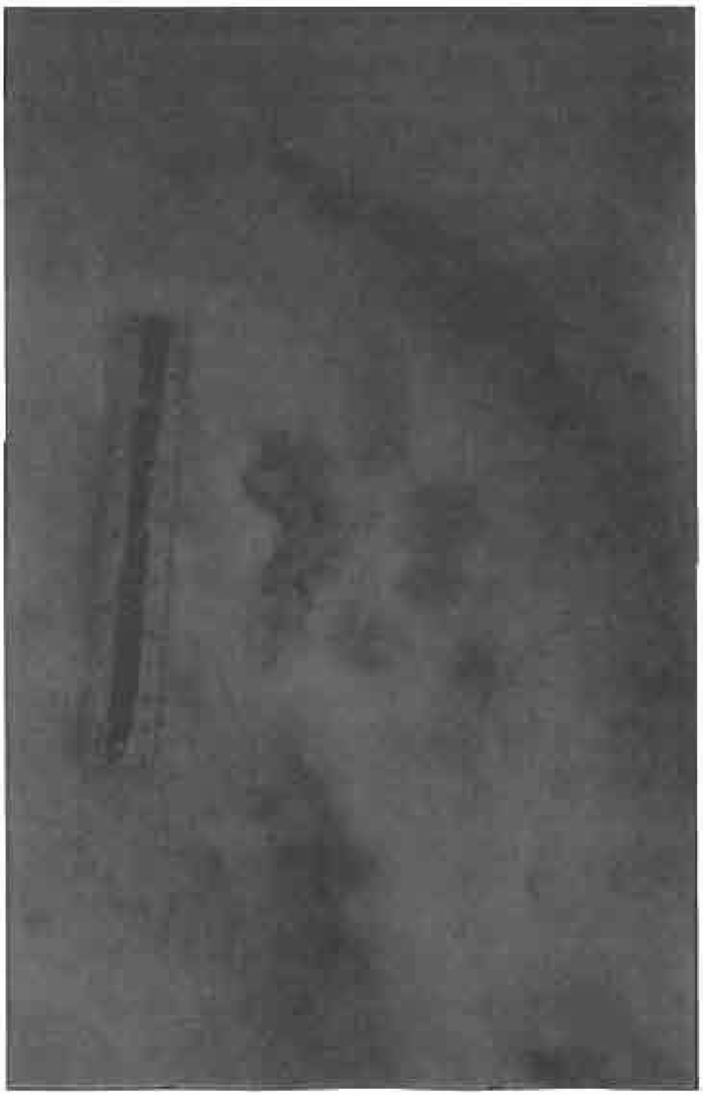


Figure 37—Wolverine print from left foot showing only four toes. The medial toe is absent, but the size, 1-3 spacing of toes, and chevron identify this as a wolverine track. (British Columbia) Photograph by J. Halfpenny.

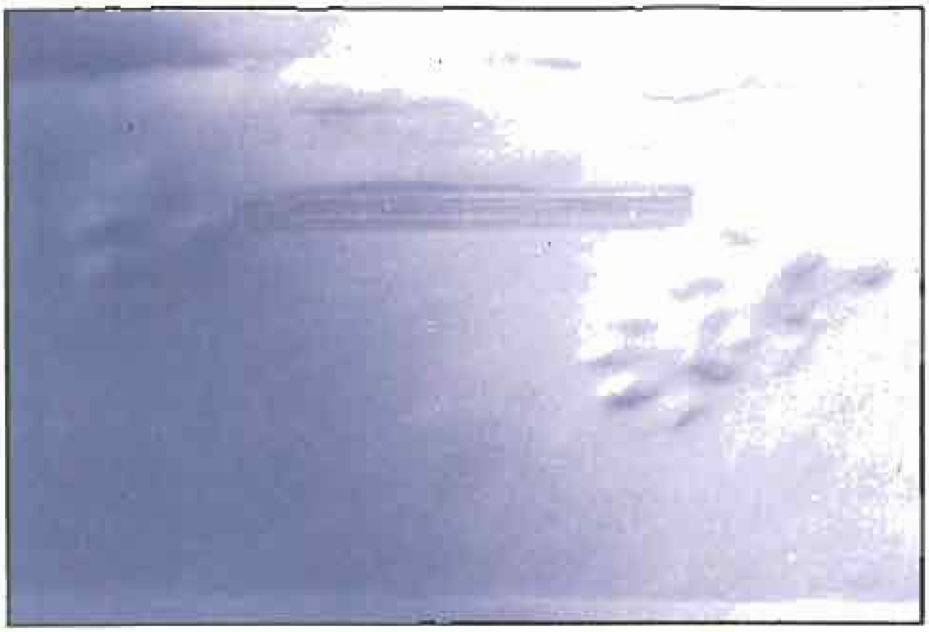


Figure 38—Wolverine print with metacarpal pad. Note that the front print appears longer because of the metacarpal pad. (Montana) Photograph by N. Bishop.

Figure 39—Wolverine left hind print. This print appears long because the haired heel registered. (Alaska) Photograph by N. Lederer.

Figure 40—Wolverine showing a 3× lope extending into a full gallop. The tracks beside the wolverine are probably those of a coyote. (Idaho) Photograph by J. Copeland.

Figure 41—Wolverine trail in deep snow showing a 3× lope. Note the drag marks and the depth the animal has sunk. (Montana) Photograph by R. Thompson.

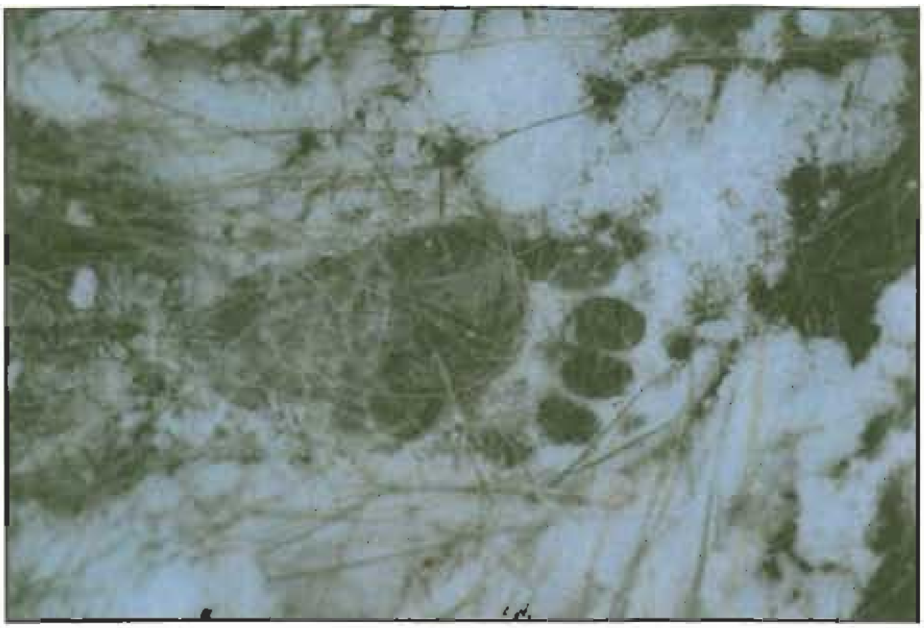


Figure 42—Hind print of a black bear. (Montana) Photograph by J. Halfpenny.

Figure 43—Front (left) and hind prints of a river otter, in mud. Note the presence of webbing. (Colorado) Photograph by J. Halfpenny.

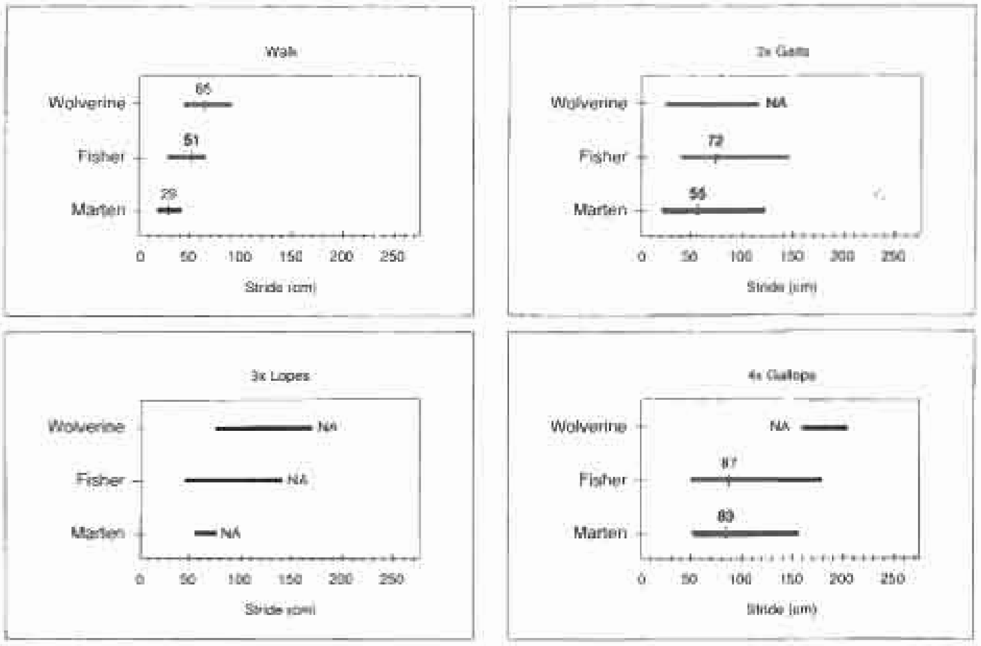


Figure 44—Mustelid stride lengths for walk, 2× gait, 3× lope, and 4× gallop. Bars represent ranges; number above bars represent most typical stride lengths where sufficient data were available. (NA = a typical value for the gait is not available)

Figure 45—Fisher tracks. Note the asymmetrical placement of toes and the chevron-shaped interdigital pad. (Massachusetts) Photograph by P. Rezendes.

Figure 46—Front foot of a fisher. (Massachusetts) Photograph by W. Zielinski.

Figure 47—Left front print of a badger, in mud. Claws do not always show this clearly. (Wyoming) Photograph by J. Halfpenny.

Figure 48—Raccoon prints. The hind foot (left) shows the well-developed, naked heel. Note that toes are long, slender, and slightly bulbous at the tips. (Texas) Photograph by J. Halfpenny.

Figure 49—Front foot of a marten. (Yukon) Photograph by W. Zielinski.

Figure 50—Left front print of a marten. Note the medial or little toe, chevron-shaped interdigital pad, and metacarpal pad. (Colorado) Photograph by J. Halfpenny.

Figure 51—Marten track showing four toes. Prints are on hard snow in the early spring. (Colorado) Photograph by J. Halfpenny.

Figure 52—Right hind print of a marten. The haired heel of the marten has not registered. (Colorado) Photograph by J. Halfpenny.

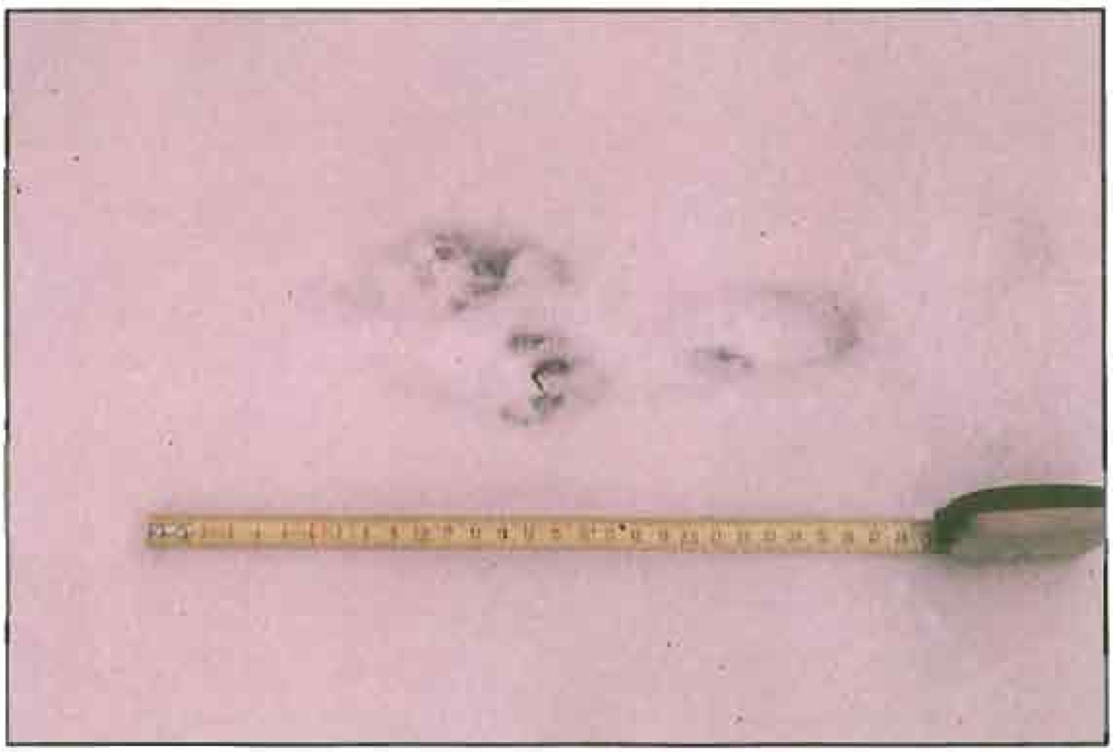


Figure 53—Marten tracks (California). Photograph by W. Zielinski.

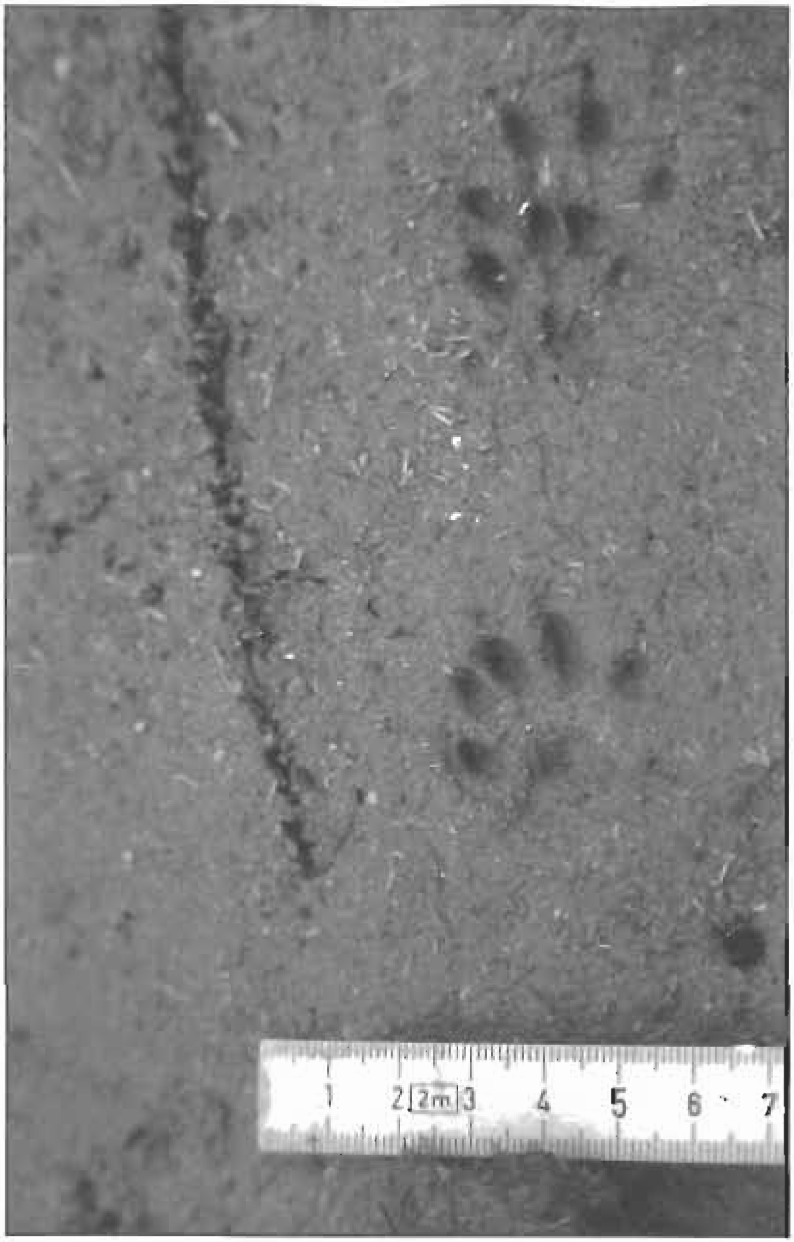


Figure 54—Mink tracks in mud. The top print is an imperfect register of a hind print on a front print. Note small size of prints and mustelid characteristics, including 1-3-1 spacing and chevron-shaped interdigital pad. (Montana) Photograph by J. Halfpenny.

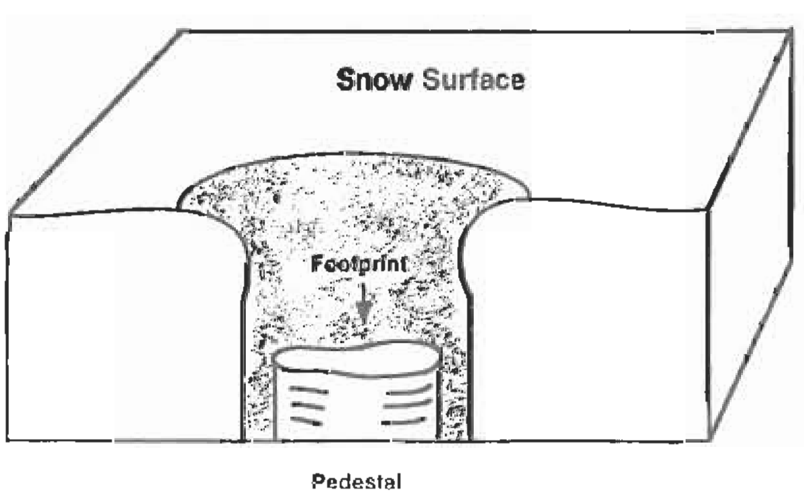


Figure 55—Pedestal method for determining size and shape of a footprint covered with light snow. Snow is carefully excavated around the track. Then with bare fingers the remaining snow up to the hard edge of the print is carefully excavated so as not to damage the track. See text for complete description.