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.

[1]Carnivore Ecologist, A Naturalist's World, P.O. Box 989, Gardiner, MT 59030-0989

[2]Wildlife Biologist, Western Ecosystems, Inc., 905 West Coach Road, Boulder, CO 80302

[3]Wildlife Habitat Specialist, Morse and Morse Forestry and Wildlife Consultants, RFD 1 Box 263, Jericho, VT 05465

[4]Wildlife Biologist, USDA Forest Service, Malheur National Forest, Prairie City Ranger District, P.O. Box 337, Prairie City, OR 97869

[5]Photographer, Bearsden Rd, Star Route, South Royalston, MA 01331

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 enough 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*

Characteristic	Family				
	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 3× 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		Width		Interdigital length		Interdigital width	
	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	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)	Length n	Width Mean (SD)	Width n	Interdigital length Mean (SD)	Interdigital length n	Interdigital width Mean (SD)	Interdigital width 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 use 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 you 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.

1. 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 1 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 1 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.

*Naney, 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).*

						--- Interdigital ---		---- Toe 1 -------		----- Toe 2 ------		------- Toe 3 ------		----- Toe 4 -------		----- Toe 5 -------	
Species	Method	Foot	Statistic	Length	Width	Length	Width	Length	Width	Length	Width	Length	Width	Length	Width	Length	Width	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

Rating 4: Best; every footprint registers, and detail within prints is very clear. Species identification is essentially absolute based on track details.

Rating 3: 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.

Rating 2: Acceptable; some prints fail to register, and footprint details, if present, are visible only in microtopographic sites. Identification based primarily on gait patterns.

Rating 1: Poor; many prints do not register. Track details lacking. Identification is essentially by gait patterns, and may be possible only in microtopographic sites.

Rating 0: - 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

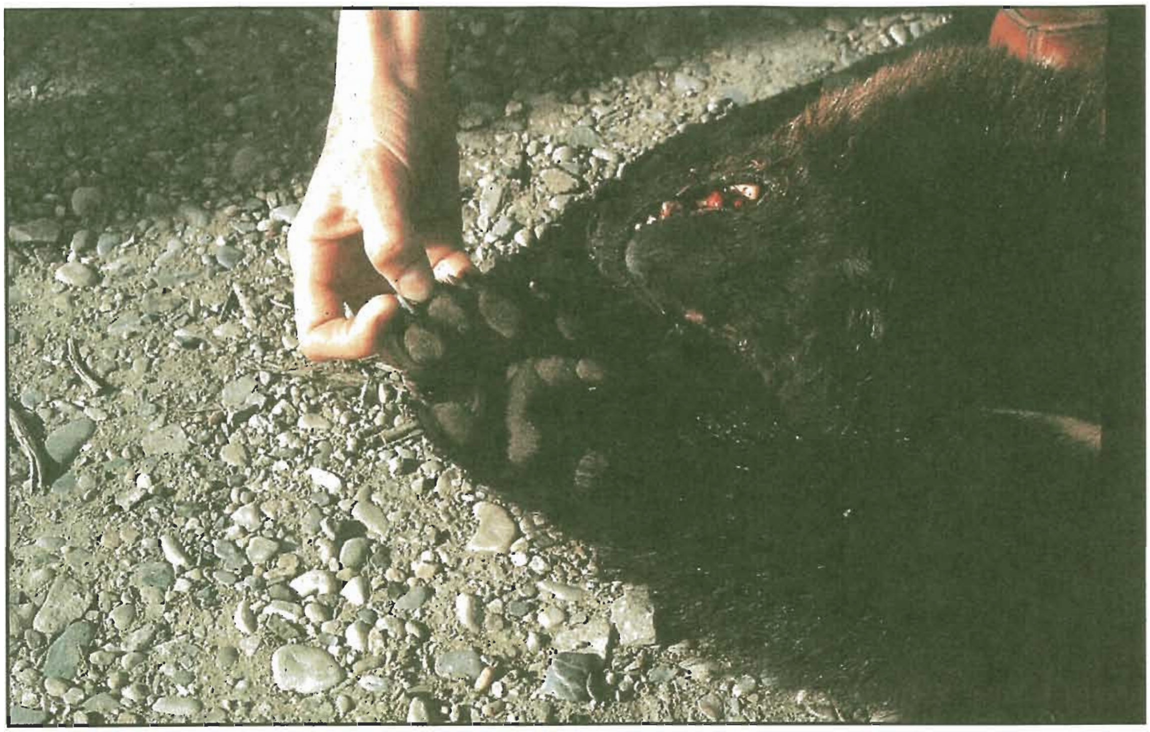


Figure 1—Right front foot of a wolverine. Note the 1-3-1 spacing of toes, chevron-shaped interdigital pad, and metacarpal pad. (Utah) Photograph by D. Hall.

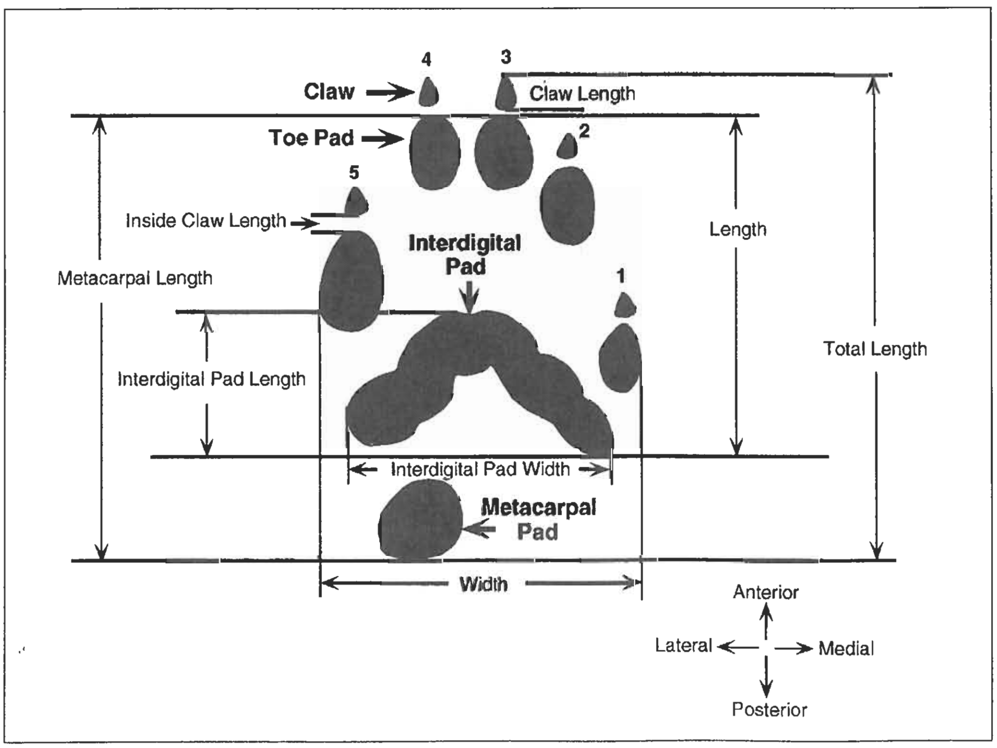
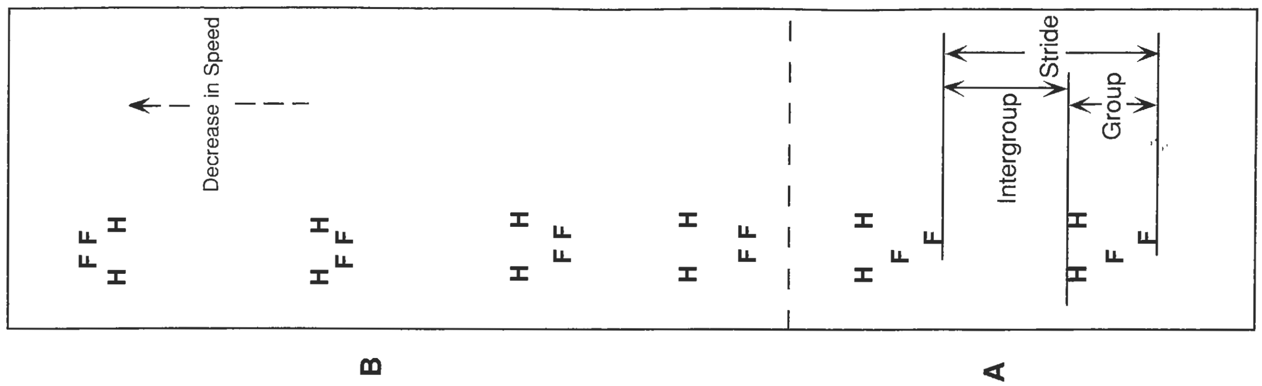
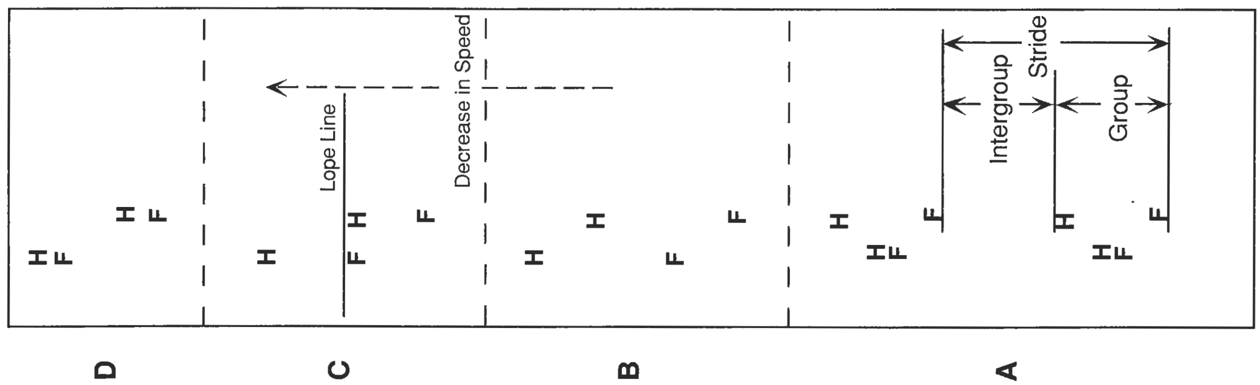
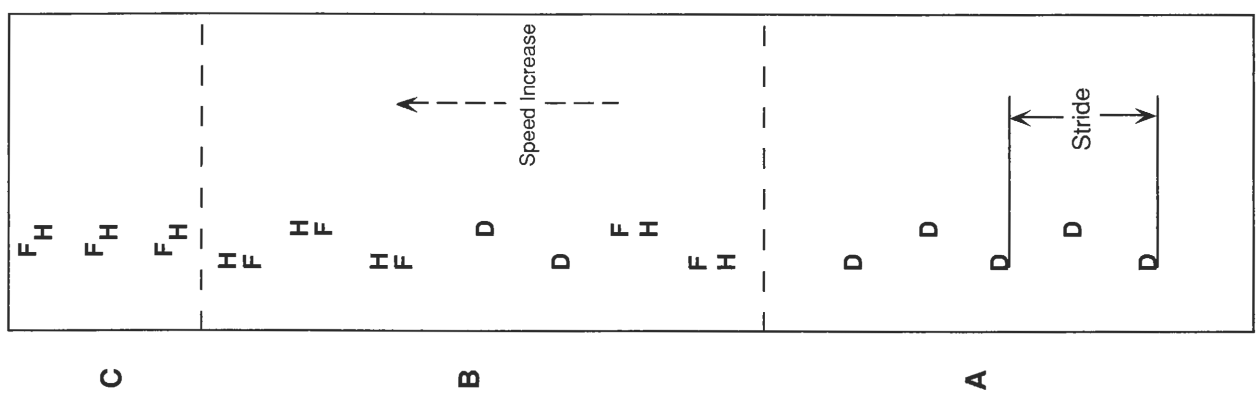


Figure 2—Morphology of the left front footprint of a wolverine and measurements commonly recorded from carnivore tracks.


Decrease in Speed
Stride
Intergroup
Group
B
A


Decrease in Speed
Lope Line
Stride
Intergroup
Group
D
C
B
A


Speed Increase
Stride
C
B
A

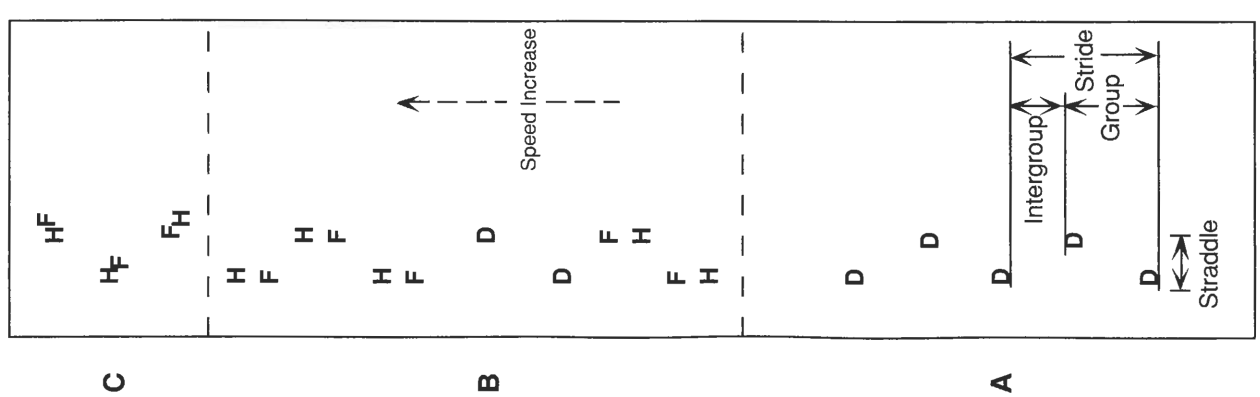

Speed Increase
Stride
Intergroup
Group
Straddle
C
B
A

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.

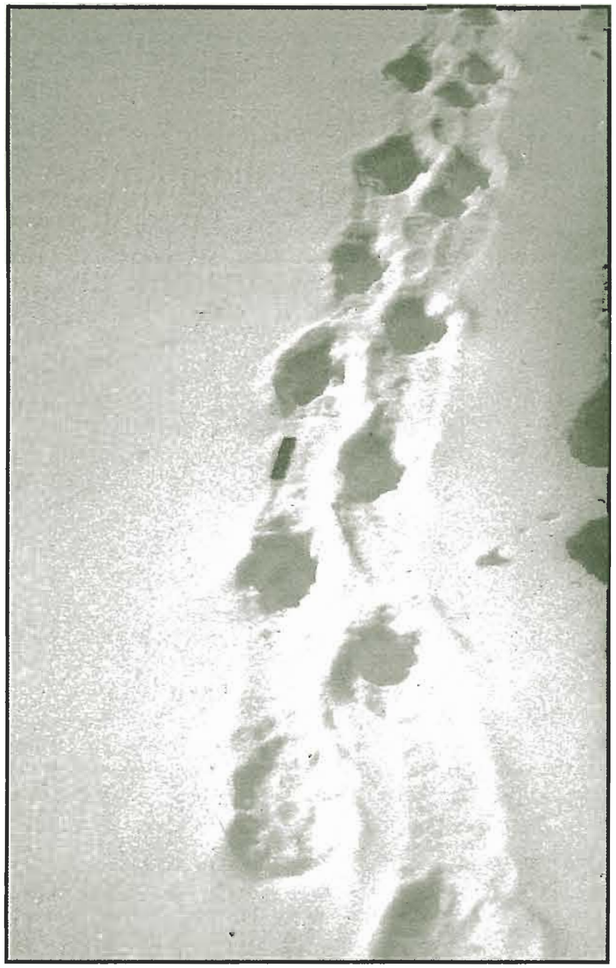


Figure 7—Lynx trail showing walking and bounding gaits. Direction of travel is from the bottom to the top of the photograph. The trough formed by hair dragging is evident. The lynx was walking in the lower portion of the photograph and changed to a 3× bound (or jump). (Colorado) Photograph by J. Halfpenny.

Figure 8—Fisher walking trail. Note hind prints registering on top of front prints. (Massachusetts) Photograph by P. Rezendes.

Figure 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 10—Wolverine trail showing 3× lope with partial registry. (Alaska) Photograph by N. Lederer.

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 12—Fisher trail showing 4× lope. The front prints can be differentiated by the presence of a metacarpal pad. (Massachusetts) Photograph by P. Rezendes.

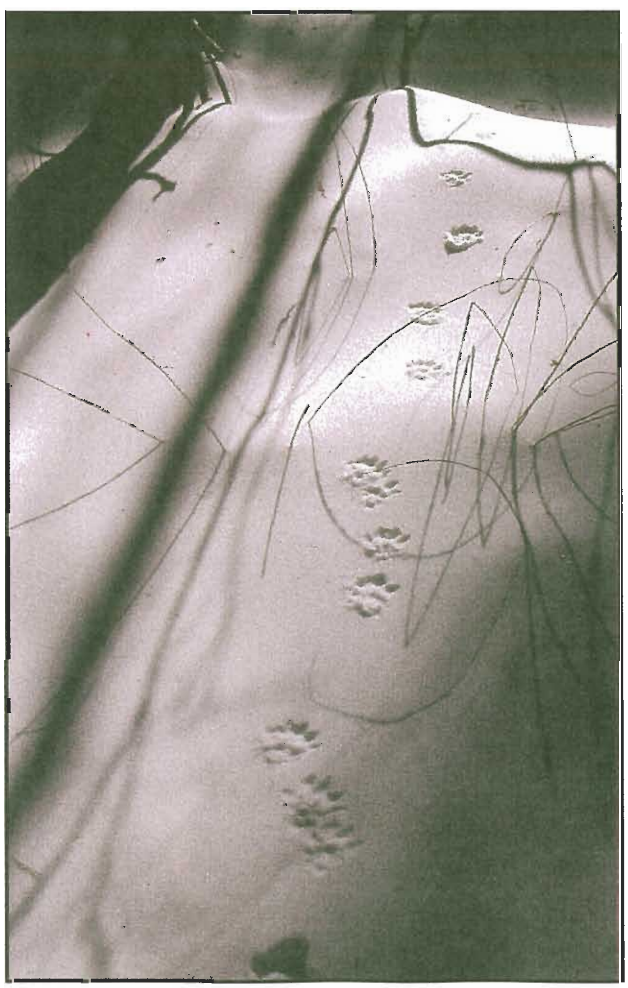


Figure 13—Fisher trail showing transition between gaits. The lower group of tracks is a 3× lope, and at the top the fisher is using a 2× gait. (Massachusetts) Photograph by P. Rezendes.

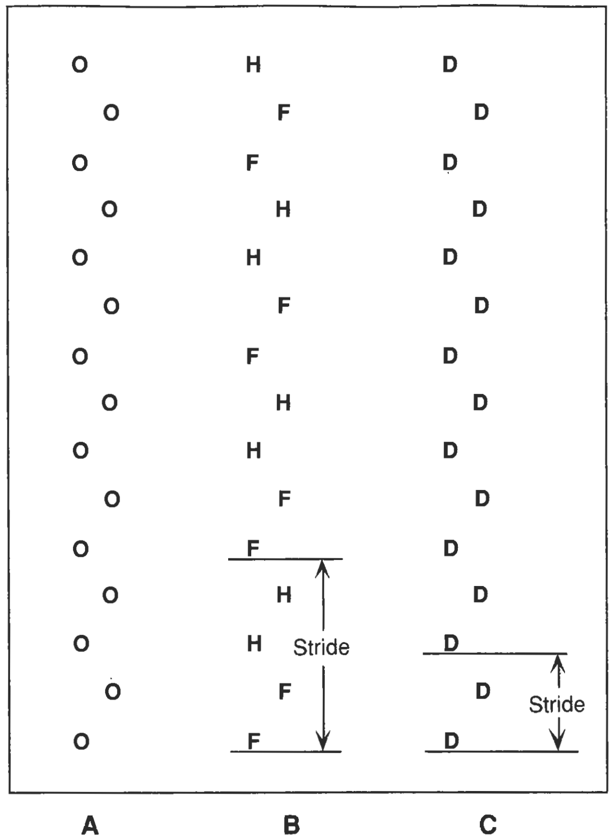


Figure 14—Potential error in gait identification and stride distance when a transverse gallop is mistaken for a walk. (A) Indistinct prints in trail. (B) Transverse gallop producing same pattern as in A. (C) Walk producing the same pattern as in A. O = print hole in snow, F = front print, H = hind print, D = direct registry of front and hind prints. Direction of travel is from bottom to top of figure.

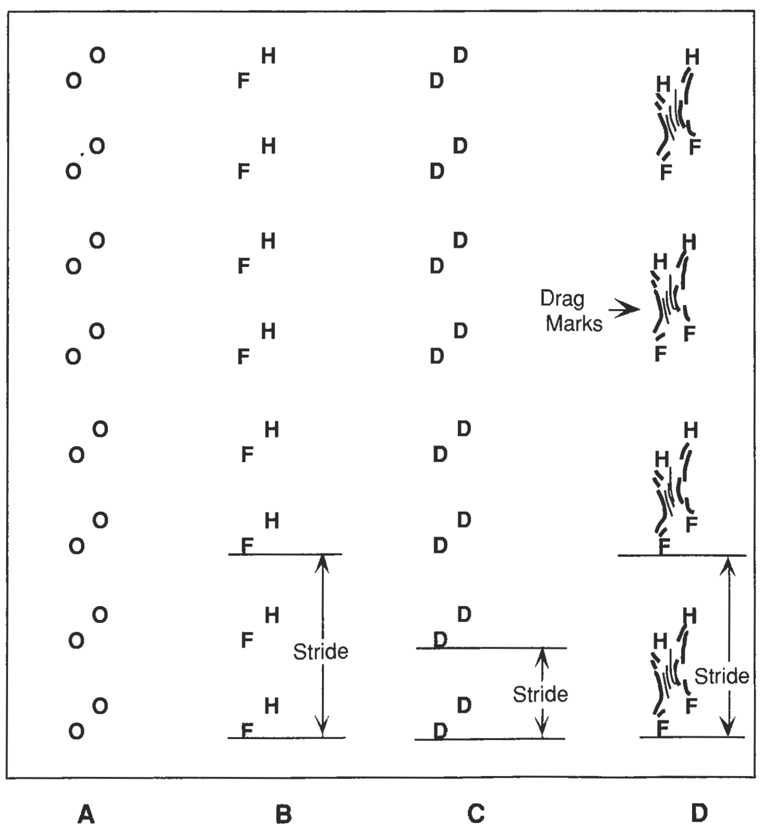


Figure 15—Potential error in gait identification and stride measurement when a side trot, a lope, and a gallop are confused. (A) Indistinct prints in trail. (B), (C), and (D) are a side trot, lope, and fast gallop, respectively, that produce the same pattern as in A. Drag marks indicate a fast gallop, 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.

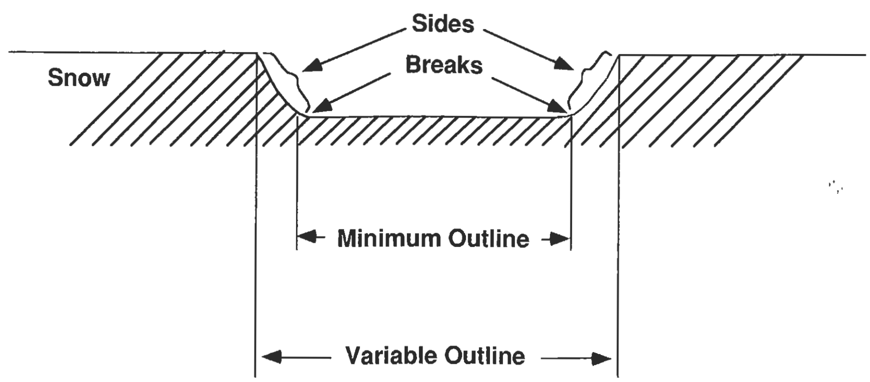


Figure 17—Features used to characterize and measure carnivore trails. The center of the footprint (round circle) is indicated by a square. Wavy lines are hair drag-marks.

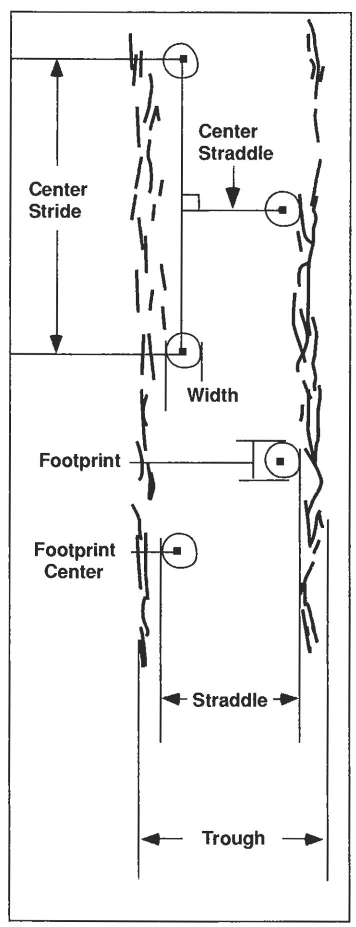
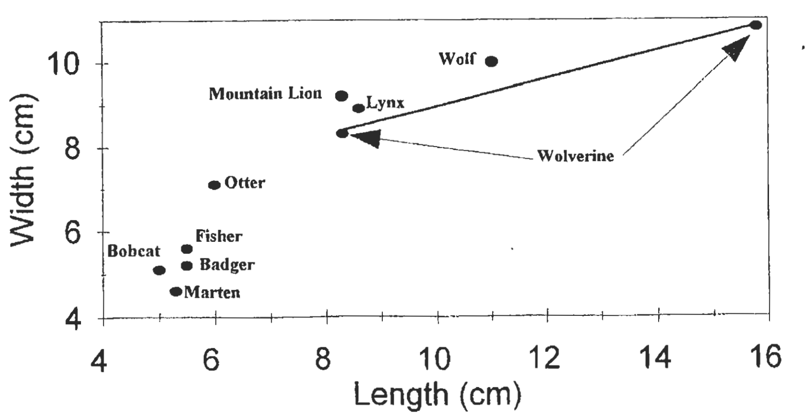


Figure 18—Typical size of prints for selected carnivores. The line indicates the range of values for wolverine attributed to variation in sex, age, and measurement. These sources of variation have not been reported for the other species.



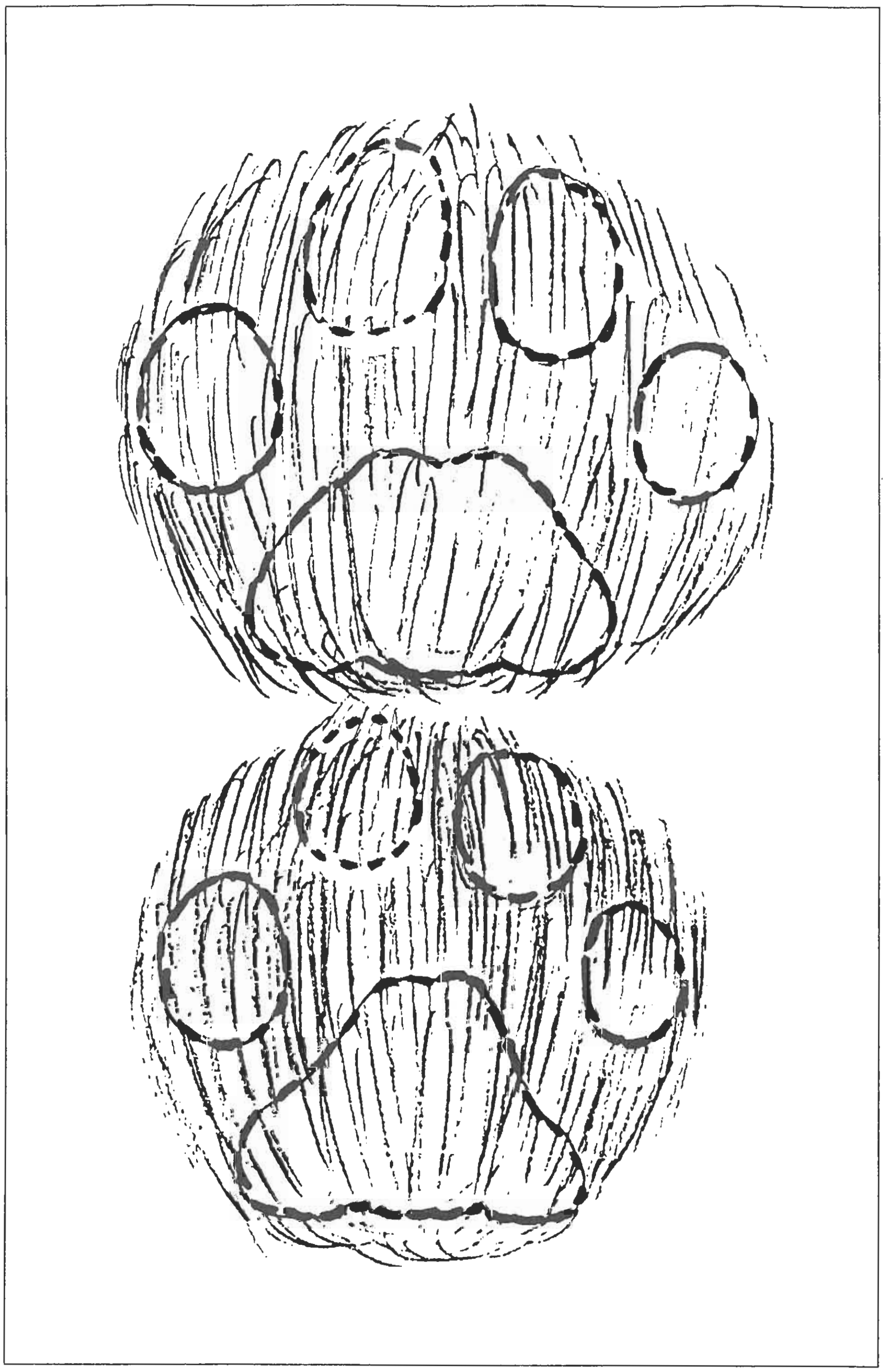
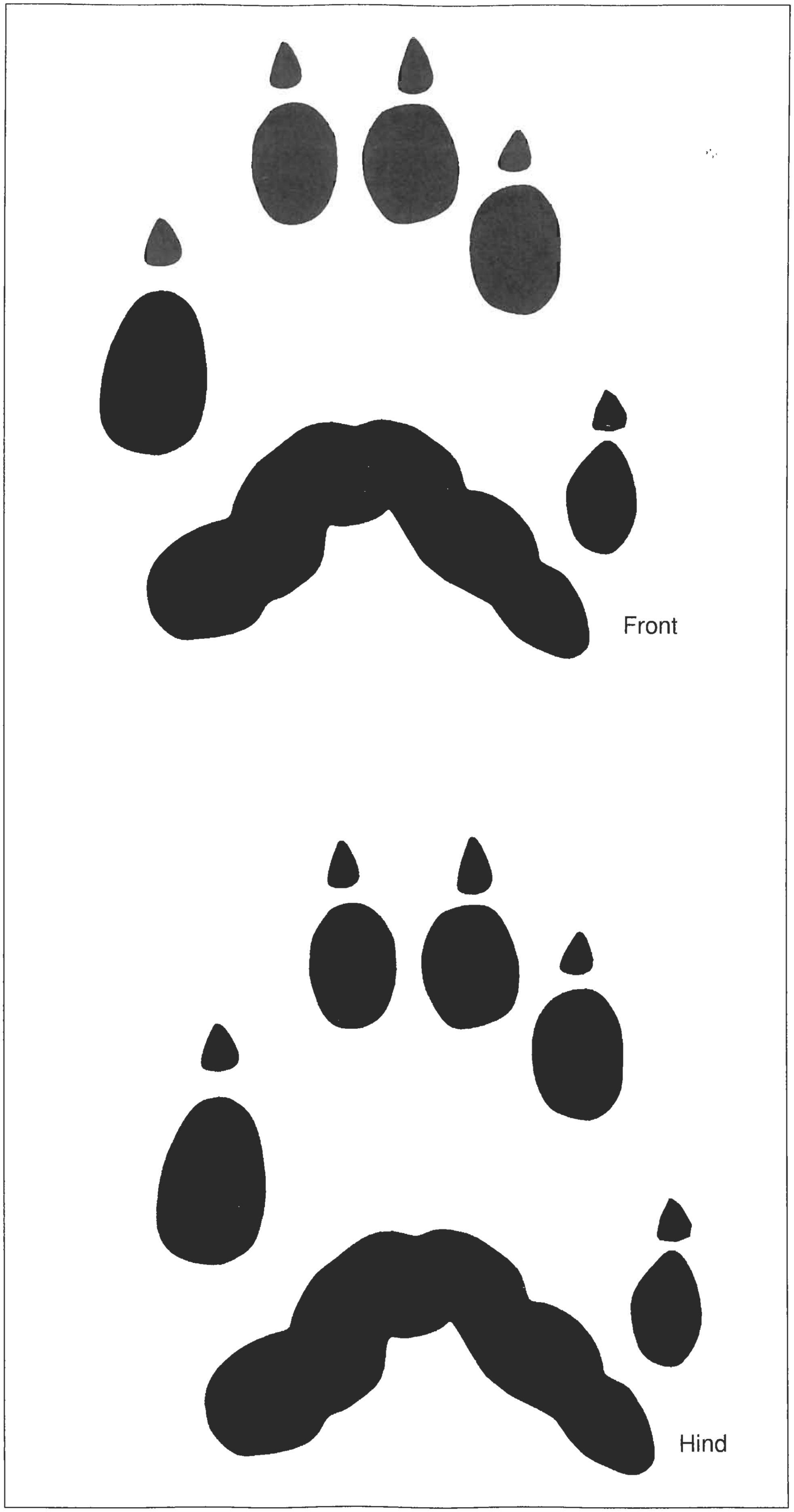


Figure 19—Typical life-size right front and hind footprints of a lynx. Prints will vary in size by sex, age, geographic area, and snow conditions. See text for discussion of interdigital pad size.

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.



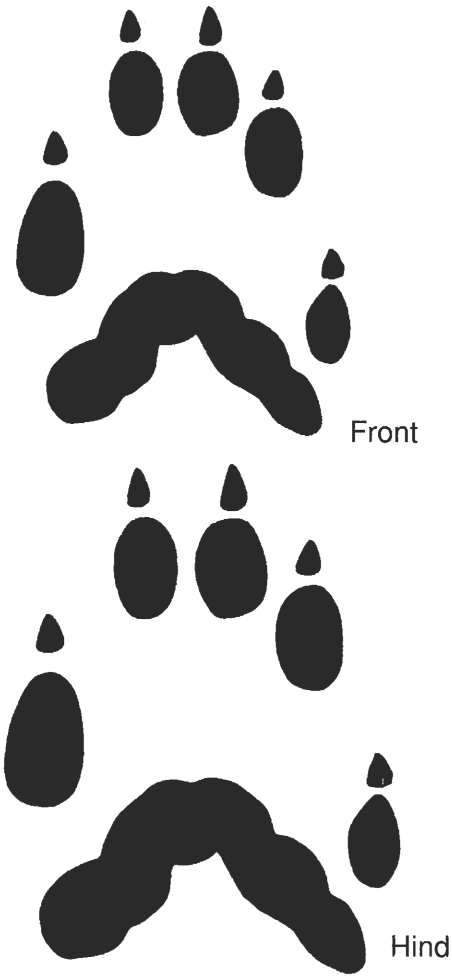


Figure 21—Typical life-size left front and hind footprints of a fisher. Prints will vary in size by sex, age, geographic area, and snow conditions, so use these only as a general reference.

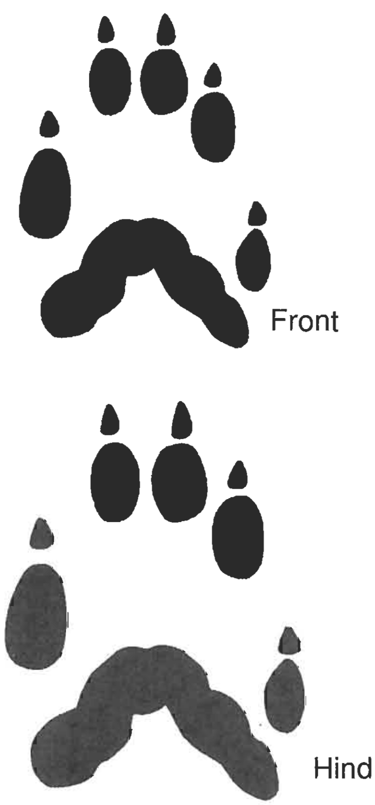


Figure 22—Typical life-size left front and hind footprints of a marten. Prints will vary in size by sex, age, geographic area, and snow conditions, so use these only as a general reference.

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.

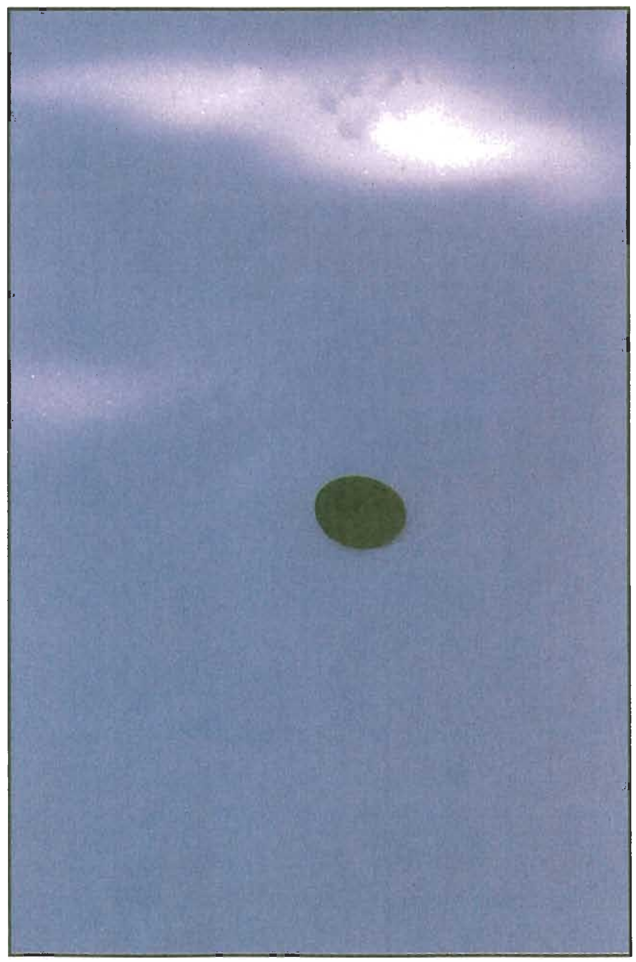


Figure 25—Lynx trail on spring snow. In late spring, when melting and freezing produce a hard surface and when the winter coat of hair is starting to wear off the feet, lynx tracks may show individual toes. Note the larger front feet. (Wyoming) Photograph by B. Thompson.

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.

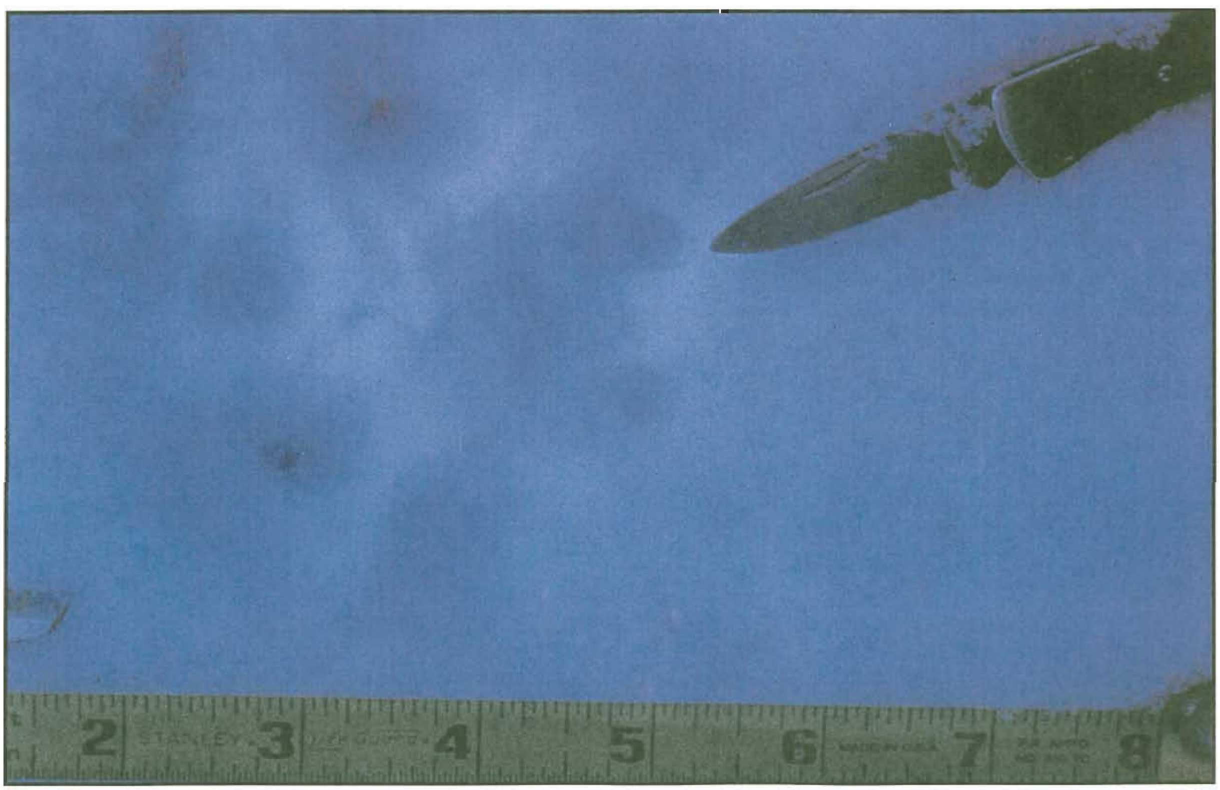


Figure 27—Front left print of an adult male lynx. Note the posterior extension of the lateral lobes of the interdigital pad and the relatively small size of the pad. Photograph by S. Morse.

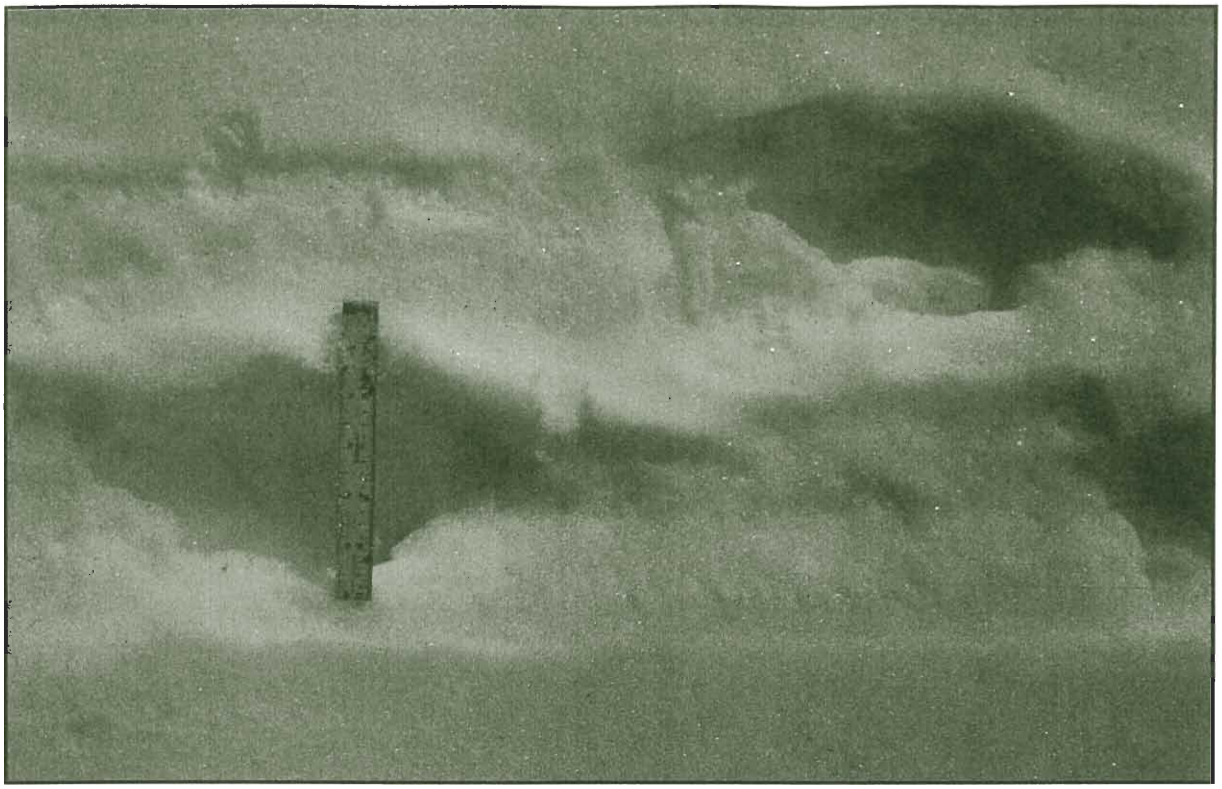


Figure 28—Trail of a lynx. Note how hair obscures details of track and produces a trough in the snow. (Colorado) Photograph by J. Halfpenny

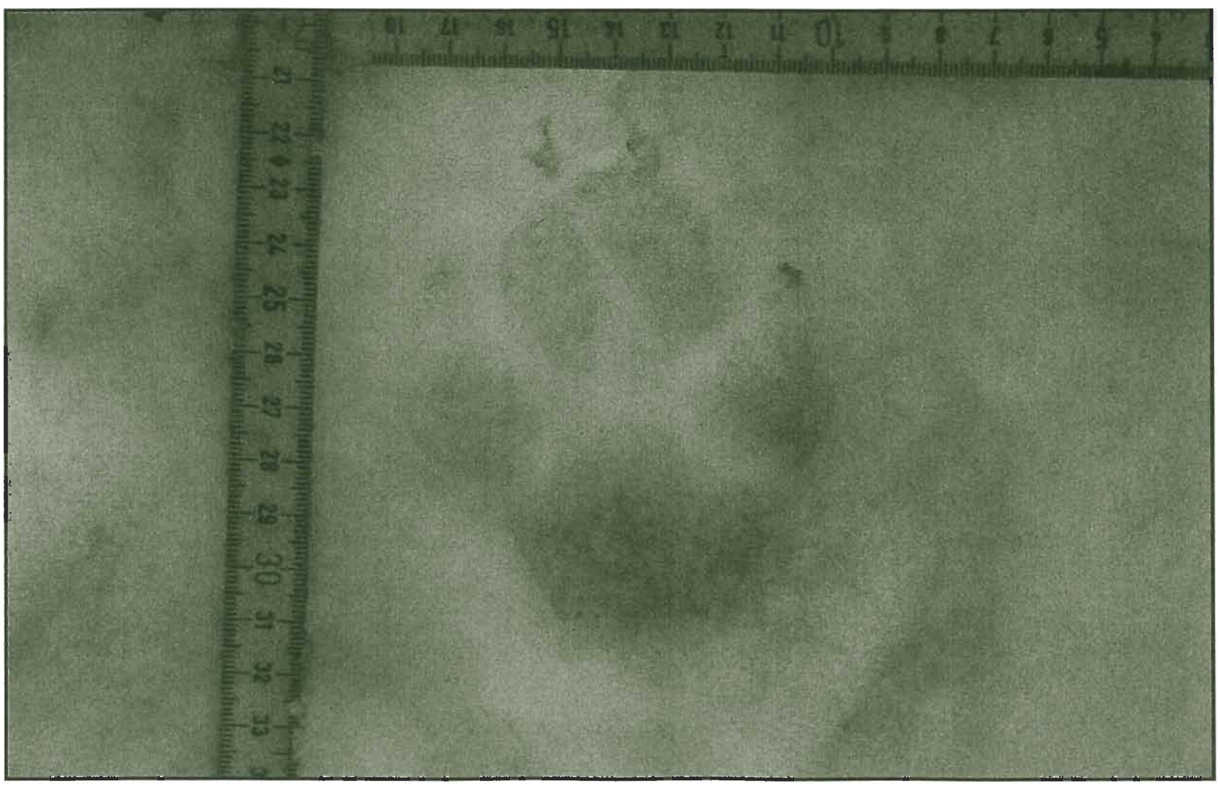


Figure 29—Wolf track. Note claw marks, symmetrical toe size and position, rectangular shape, and single lobe on the anterior edge of the interdigital pad. (Minnesota) Photograph by J. Halfpenny.

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.

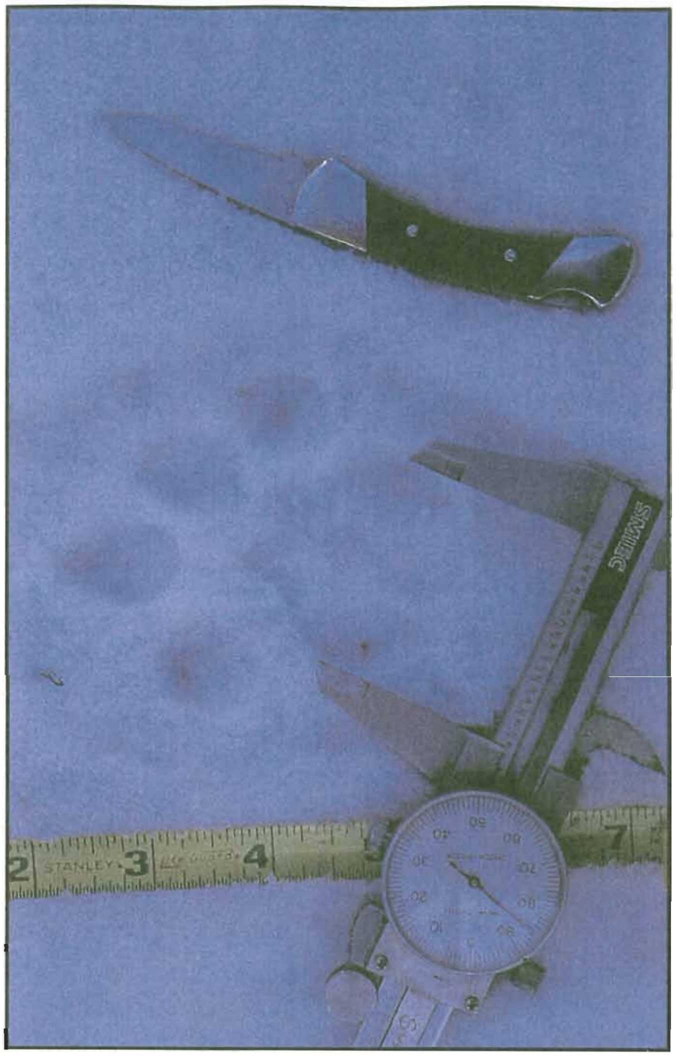


Figure 34—Front footprint of an adult female mountain lion. Note the bi-lobed anterior edge of the interdigital pad, asymmetrical positioning of toes, and third toe slightly advanced beyond the edge of the other toes. Posterior edge on the interdigital pad appears straight to slightly concave. Photograph 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.

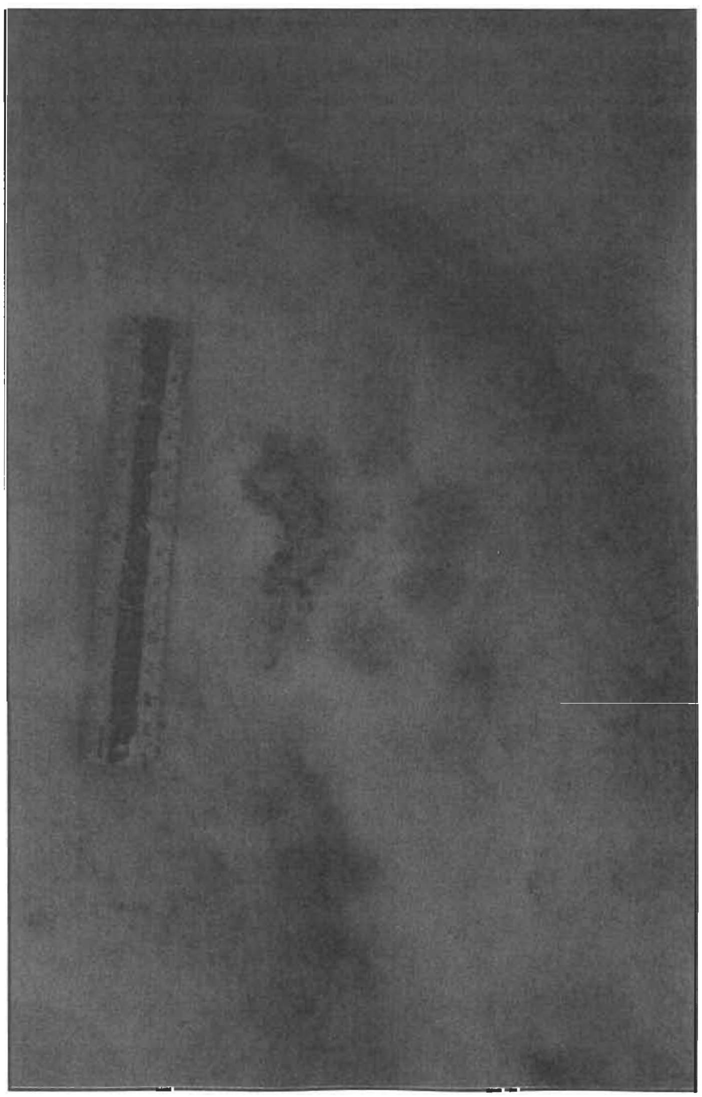


Figure 37—Wolverine print from left foot showing only four toes. The medial toe is absent, but the size, 1-3 spacing of toes, and chevron identify this as a wolverine track. (British Columbia) Photograph by J. Halfpenny.

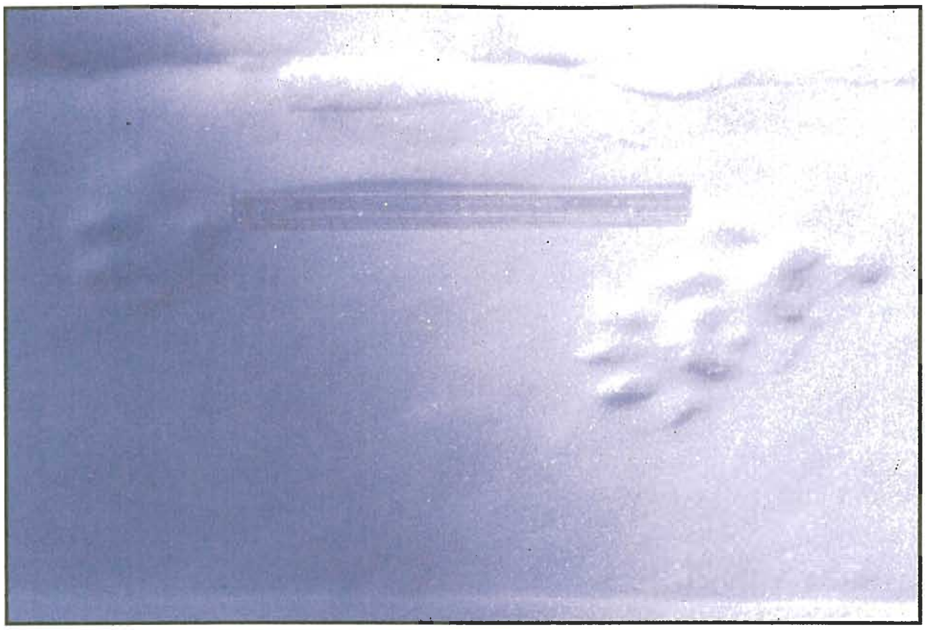


Figure 38—Wolverine print with metacarpal pad. Note that the front print appears longer because of the metacarpal pad. (Montana) Photograph by N. Bishop.

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.

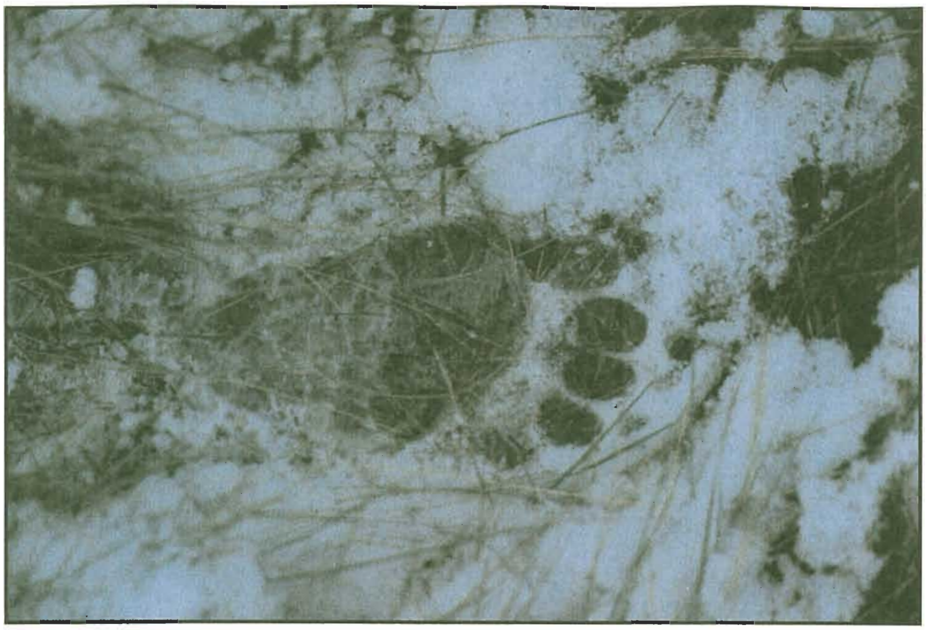
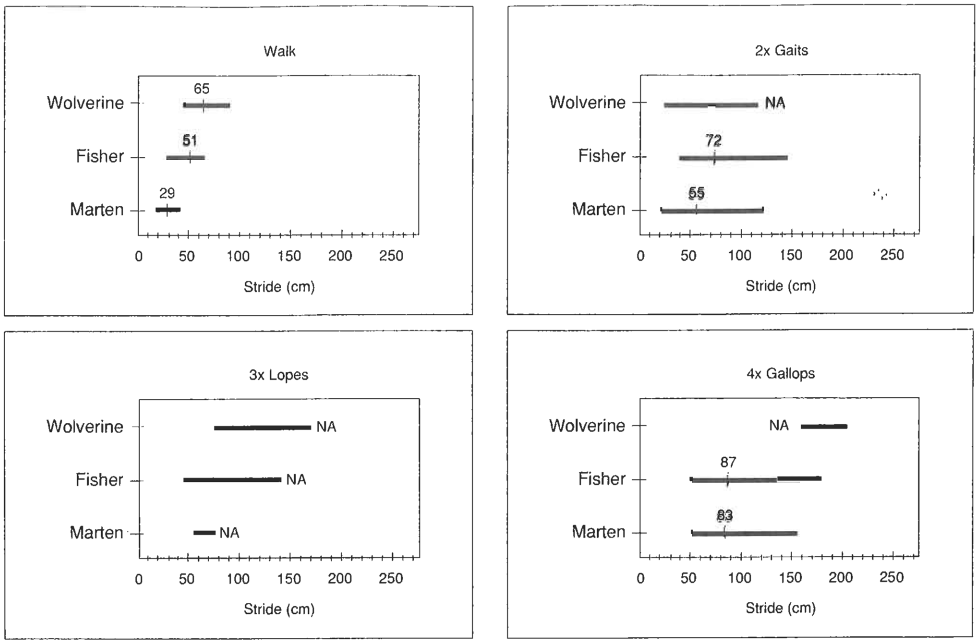


Figure 42—Hind print of a black bear. (Montana) Photograph by J. Halfpenny.

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).



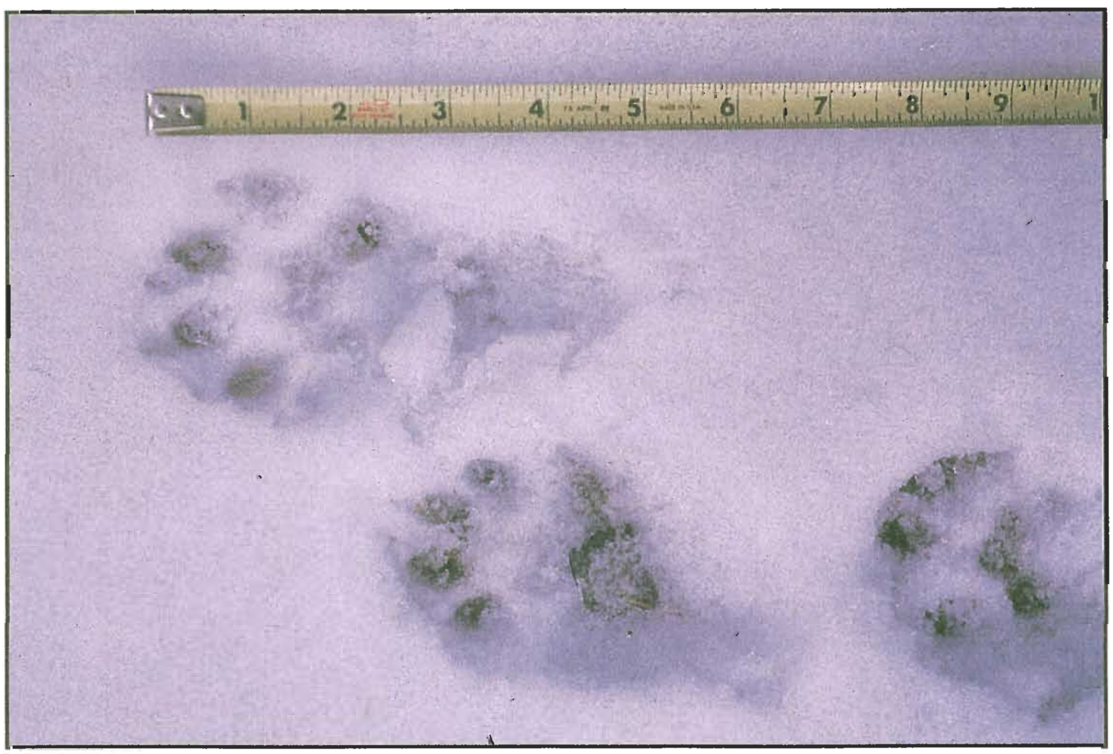


Figure 45—Fisher tracks. Note the asymmetrical placement of toes and the chevron-shaped interdigital pad. (Massachusetts) Photograph by P. Rezendes.

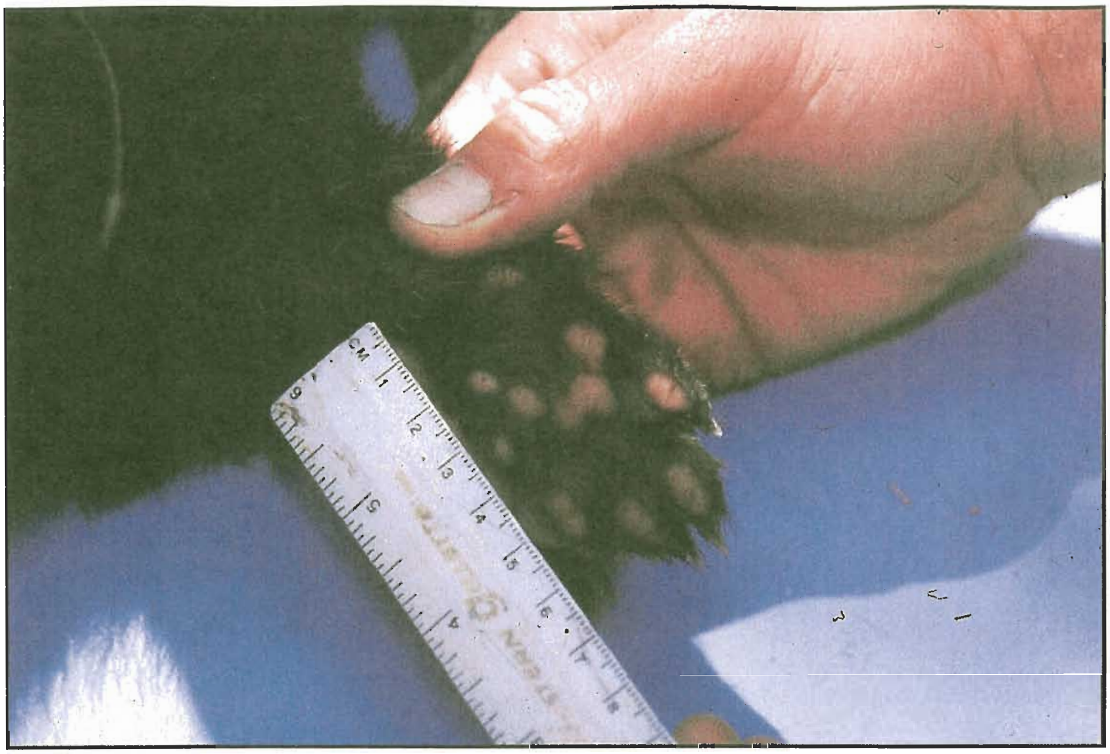


Figure 46—Front foot of a fisher. (Massachusetts) Photograph by W. Zielinski.

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.

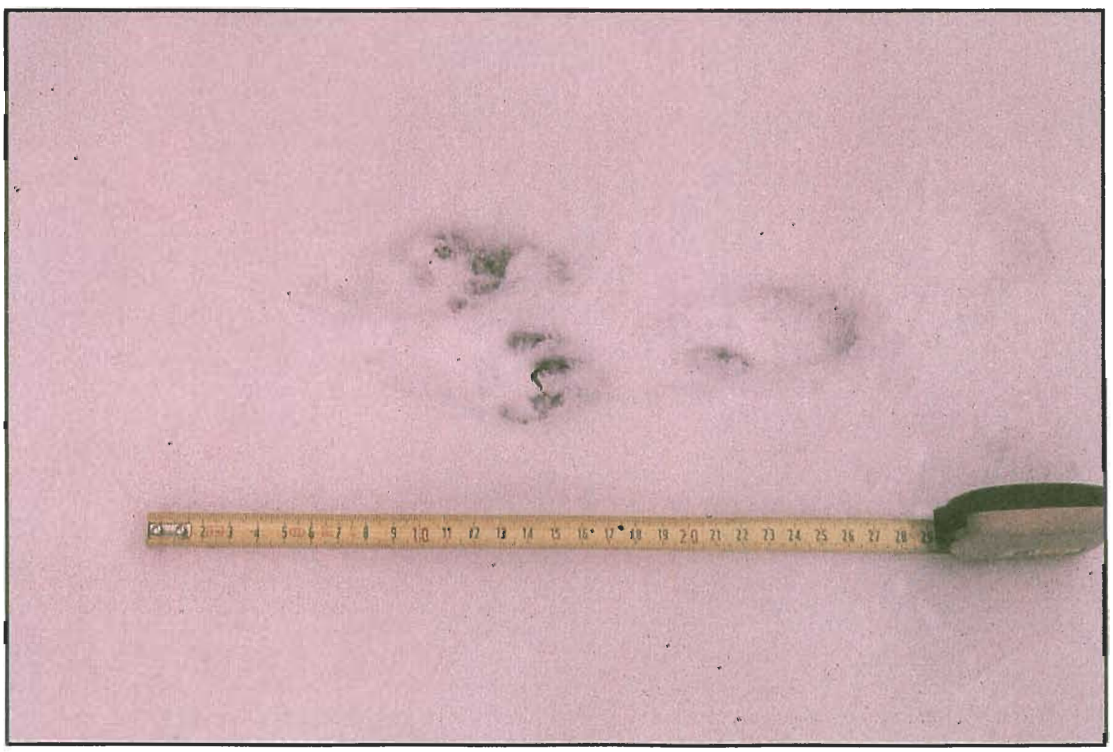


Figure 53—Marten tracks (California). Photograph by W. Zielinski.

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.

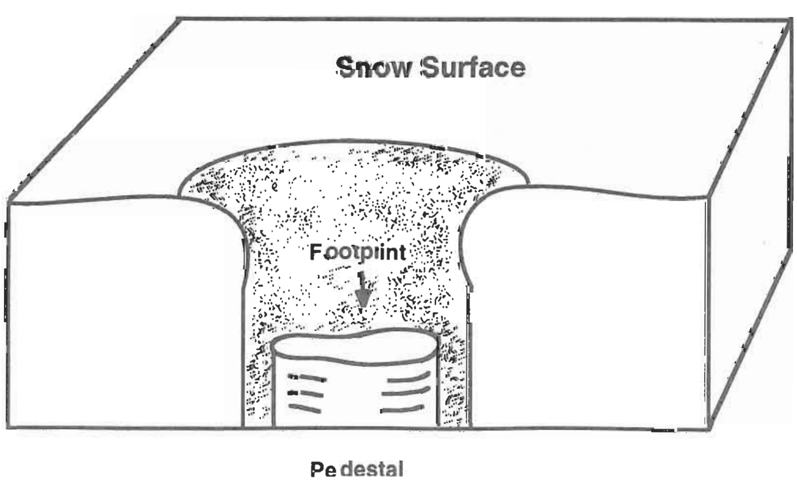


Figure 55—Pedestal method for determining size and shape of a footprint covered with light snow. Snow is carefully excavated around the track. Then with bare fingers the remaining snow up to the hard edge of the print is carefully excavated so as not to damage the track. See text for complete description.