2000

Effectiveness of covered track plates for detecting American marten

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Effectiveness of Covered Track Plates for Detecting American Marten

By

Jacob Scott Ivan

B. S., Purdue University, 1997

presented in partial fulfillment of the requirements for the degree of

Master of Science

The University of Montana

2000

Approved by:

Chairperson

Dean, Graduate School

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Dean
I assessed the effectiveness of covered track plates for detecting American marten in western Montana by 1) estimating the probability of detecting marten when they are present on a survey unit (POD$_{su}$), 2) estimating the probability of detecting a particular individual that resides on a survey unit (POD$_{ind}$), and 3) assessing the behavior of marten near track plates. Additionally, I tested the validity of deriving POD$_{su}$ from latency to detection (LTD; average amount of time elapsed before a detection occurs on a survey unit).

During the summers of 1998 and 1999, I radio-collared and branded the toe pads of 1-2 marten on each of 10 10.44-km$^2$ survey units. I located marten daily during 12-day survey periods. Concurrently, I deployed track plates in each survey unit as per the USFS protocol. In addition, I monitored a subset of track plates within each unit using automated telemetry systems (ATS) designed to log the presence of marten that approached a track plate.

Radio locations indicated that all collared marten were present on their respective survey units and could have been detected by plates. I estimated POD$_{su}$ as the ratio of survey units on which marten were detected to survey units where marten were known to exist (POD = 0.70, $n = 10$, 95% CI: 0.42 - 0.98). Similarly, I estimated POD$_{ind}$ as the ratio of branded animals detected to the number of branded animals in the study area (POD$_{ind}$ = 0.067 - 0.133, $n = 15$, 95% CI: 0.00 - 0.31). Data from ATSs indicated that 2 of 8 marten approached track plates, but never entered. POD$_{su}$ derived empirically was lower than that derived from LTD (0.977).

Track plates seem to work acceptably well in areas where marten densities are relatively high. However, because POD$_{ind}$ is low, track plates may not work as reliably in areas with low marten density. Changes to track plate design or deployment procedure may be needed to reduce avoidance behavior and make plates more conducive to visitation by marten. More research is needed to determine how POD varies with marten density, home range size, behavior, and environmental variables.
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INTRODUCTION

American marten (Martes americana) are part of an assemblage of secretive mammals referred to as mid-level forest carnivores. They share this distinction with fisher (Martes pennanti), wolverine (Gulo gulo), and lynx (Lynx canadensis). Recently, considerable scientific and management effort has been invested in studying forest carnivore ecology and distribution, especially in the western United States (Ruggiero et al. 1994a). The project described here is one such study that focused on testing methods for gathering accurate distributional data on American marten. In the following pages, I present a background of marten physiology and ecology and outline the importance and specific objectives of this study.

Description

The American marten is a mid-sized member of the family Mustelidae. It is characterized by a long, slender body with a bushy tail, relatively short legs, and a triangular-shaped head with a pointed muzzle (Clark et al. 1987). Marten have sleek, dense fur that varies from blond or grayish brown to dark chocolate. They have a distinctive cream to bright orange throat patch that is often interspersed with darker markings creating a unique pattern for each individual. Marten have relatively large, pentadactyl feet which enable them to navigate efficiently
over deep, soft snow (Raine 1983). They also have semi-retractable claws and exhibit more arboreal behavior than other Mustelids (Clark et al. 1987).

Male marten are 560 to 780 mm in length and generally weigh between 500 and 1250 g. Females are 500-600 mm in length with a body mass of 380-850 g (Clark et al. 1987, Buskirk and Ruggiero 1994). Both sexes have an abdominal gland and scent mark by dragging their bellies over logs, branches, and other structures. Presumably, this behavior is associated with breeding, but its exact function is unknown (Clark et al. 1987).

Energetics

Marten are subject to several energetic limitations. Their cylindrical shape produces a high surface to volume ratio, which results in a tremendous loss of heat for their size. Their lean stature restricts fat reserves to <5% of their body weight (Buskirk and Harlow 1989). Furthermore, they live in a climate where the ambient temperature falls below their lower critical temperature (16°C) for several months of the year (Buskirk et al. 1988). Thus, marten have a high basal metabolic rate (Harlow 1994).

Marten compensate for these limitations in a variety of ways. First, they forage daily (except during severe weather; Buskirk et al. 1988) for several small, high-protein meals; large meals cannot be assimilated efficiently
because marten possess a relatively small gut (Harlow 1994). Second, during resting periods marten may enter torpor (Buskirk et al. 1988, Harlow 1994). However, this torpor is very shallow and daily energy savings are only an estimated 4% (Buskirk et al. 1988, Harlow 1994). Third, marten may cope with energetic constraints by adjusting activity bouts to prey activity and abundance. Thus, marten are generally crepuscular, although they have been characterized as nocturnal and diurnal, depending on season, geographic region, and prey availability (Zielinski et al. 1983, Clark et al. 1987, Foresman and Pearson 1999). Marten can also combine fat and protein catabolism during fasting bouts in such a manner as to maximize fat reserves and muscle tone while minimizing water loss (Harlow and Buskirk 1991, Harlow 1994). If necessary, marten can survive and maintain normal activity for several days without food or water, although they may lose a significant amount of mass (24%) during such an event (Buskirk and Harlow 1989, Harlow and Buskirk 1991). Finally, marten can behaviorally decrease their energetic costs during resting periods via selection of rest sites.

During winter, marten generally rest in subnivean spaces to take advantage of the insulative properties of snow (Wynne and Sherburne 1984, Spencer 1987, Buskirk et al. 1989, Buskirk and Ruggiero 1994, Chapin et al. 1997b, Gilbert et al. 1997). Subnivean rest sites are often
associated with stumps, snags, tree cavities, squirrel middens, or some form of coarse woody debris (CWD; Spencer 1987, Buskirk et al. 1989, Fager 1991, Chapin et al. 1997b, Gilbert et al. 1997, Raphael and Jones 1997). The low thermal conductance of these substrates minimizes heat loss compared with that lost through contact with rocks or soil. (Buskirk et al. 1989). Resting against these substrates may also prevent a marten’s body heat from melting the surrounding snow, which would dampen fur and compromise its insulative value (Buskirk et al. 1989). During warmer periods or in areas with more temperate climates, marten often use elevated rest sites. Many authors report tree cavities, snags, branches, and mistletoe brooms as frequently used rest sites under such conditions (Wynne and Sherburne 1984, Spencer 1987, Buskirk et al. 1989, Chapin et al. 1997b, Raphael and Jones 1997, Tomson 1999).

**Diet**

Marten are very opportunistic and have a highly varied diet depending on season and geographic region. Over much of its distribution, however, red-backed voles (*Clethrionomys gapperi*) are a staple prey item that provide marten with the several small, high protein meals they require each day (Buskirk and Ruggiero 1994, Martin 1994). *Microtus* sp. are also heavily preyed upon where they are available and may be preferred over *Clethrionomys* (Buskirk

To a lesser degree, marten feed on chipmunks (*Tamias* sp.), jumping mice (*Zapus* sp.), ground squirrels (*Spermophilus* sp.), grouse (*Bonasa* sp.), Ptarmigan (*Dendragapus* and *Lagopus* sp.), small birds, cottontails (*Sylvilagus* sp.) and carrion, although these items may be seasonally or locally important (Weckwerth and Hawley 1962, Koehler and Hornocker 1977, Bateman 1986, Snyder and Bissonette 1987, Thompson and Colgan 1990, Martin 1994). Shrews (*Sorex* sp.) and deer mice (*Peromyscus* sp.) are generally avoided by marten (Buskirk and Ruggiero 1994). However, in areas where typically preferred food items are less available, such as Vancouver Island, these species may be used extensively (Nagorsen et al. 1989).

**Reproduction**

Marten breed from late June through early August in response to photoperiod changes (Hawley 1955, Clark et al. 1987, Mead 1994). They exhibit 1-4 periods of receptivity
during the breeding season, each lasting 1-4 days. Ovulation is induced by copulation (Mead 1994). Once fertilization occurs, embryonic development is suspended and implantation is delayed until February or March. The post-implantation period is 27-28 days; therefore parturition occurs in March or April. Average litter size is 2.7-3.0 (range 1-5; Mead 1994).

Parturition occurs in "natal dens" (Ruggiero et al. 1998), which are generally located at or below ground level (but see Wynne and Sherburne 1984) and tend to be associated with snags, large diameter trees, hollow logs, slash piles, and squirrel middens (Ruggiero et al. 1998). Dens used for kit rearing are referred to as maternal dens, and, like natal dens, they tend to be near the ground. However, in temperate areas maternal dens are often found in elevated structures (Raphael and Jones 1997). Females may use several maternal den sites and may move kits between them several times during the denning period (Wynne and Sherburne 1984, Jones et al. 1997). Females are most likely to be away from the den during early nighttime hours, and den attendance by females decreases as kits become older (Henry et al. 1997). Males often visit den sites, but there is no evidence they aid in kit rearing. Their presence at dens corresponds directly with the breeding season and they scent
mark frequently suggesting that mating is their primary motive (Jones et al. 1997).

Kits are weaned in late June or early July, approximately six weeks after parturition (Hawley 1955, Wynne and Sherburne 1984, Clark et al. 1987, Mead 1994, Jones et al. 1997). They reach adult body size in 3 (females) to 4 (males) months (Hawley 1955), and become independent in late August or early September (Wynne and Sherburne 1984). Marten are very capable dispersers and have been known to travel up to 40 km during dispersal events (Hawley 1955).

Both males and females are able to breed as yearlings (1.5 years). However, fewer yearling than adult (≥2.5 years) females ovulate (80%-85% vs. 95-100%; Clark et al. 1987, Aune and Schladweiler 1997), and adult females exhibit greater fecundity than yearlings. Peak fecundity is attained at approximately 6 years of age (Mead 1994). Marten reach reproductive senescence at age 12 (Mead 1994).

Home range and Territoriality

Male home ranges are approximately twice as large as those of females (Buskirk and McDonald 1989), and those of non-lactating females tend to be larger than those of lactating females (Katnik et al. 1994). Beyond those distinctions, however, home range sizes are highly variable. Minimum convex polygon (MCP) home range areas for males vary
from $<2 \text{ km}^2$ (Soultiere 1979, Burnett 1981, Tomson 1999) to $>18 \text{ km}^2$ (Bateman 1986, Fager 1991, O’Doherty et al. 1997). The source of this inherent variation is elusive. O’Doherty et al. (1997) and Phillips et al. (1998) found no relationship between home range size and age, season, or year. Similarly, Buskirk and McDonald (1989) found no correlation between home range size and geographic latitude, mean annual temperature range, sampling interval, or number of radio locations. At least part of the variation in home range size is likely due to prey availability and marten density. Thompson and Colgan (1987) reported an increase in home range sizes of marten in Ontario as prey species declined and marten density decreased. Similarly, Soultiere (1979) reported that marten home ranges in Maine were larger in less favorable habitats where marten density was lower.

Marten exhibit intrasexual territoriality (Powell 1994). Thus, overlap in home range between marten of the same sex is much less than expected, whereas overlap among opposite sexes is much greater than expected (Katnik et al. 1994). Powell (1994) suggested that females space themselves to maximize access to food resources; males space themselves to gain access to females. However, Katnik et al. (1994) found that male home range size is not different than expected based on body size. Further, and Katnik et al. (1994) and Phillips et al. (1998) did not document any
shift or expansion in home range during the breeding season. Thus, male territory spacing may be closely tied to metabolic requirements, just as it is in females.

**Distribution and Habitat Use**

Historically the range of marten extended from eastern Canada to Alaska and south through the fingers of boreal forest that reach into California, New Mexico, the Great Lakes, and New England (Gibilisco 1994). However, during the early 20th century, heavy exploitation and concurrent loss of significant amounts of habitat due to logging caused a reduction in many marten populations and a coincident contraction of its overall range (Thompson 1991, Buskirk and Ruggiero 1994, Gibilisco 1994). These changes have caused some populations, such as those found on the Olympic Peninsula in Washington or the Coastal range of California, to become disjunct (Gibilisco 1994, Lyon et al. 1994). Other populations in the central Rocky Mountains have become isolated due to natural climatic changes since the Pleistocene that have resulted in montane islands separated by wide, arid valleys. Local extirpation of such populations may not be ameliorated by re-colonization (Gibilisco 1994). This phenomenon has led to the absence of marten from the Tobaccoroot Mountains of southcentral Montana (Gibilisco 1994).
Within their range, marten are generally associated with contiguous tracts of mature, coniferous forest (Buskirk and Powell 1994, Buskirk and Ruggiero 1994). Species composition of these forests appears to be inconsequential, but structural characteristics are crucial (Buskirk and Powell 1994, Buskirk and Ruggiero 1994, Raphael and Jones 1997). Abundant snags, downed logs, and tree cavities typical of mature stands provide protection from terrestrial predators (Hodgman et al. 1997). Coarse woody debris provides access to subnivean rest sites as well as prey species that reside in the subnivean space (Hargis and McCullough 1984, Corn and Raphael 1992, Buskirk and Powell 1994, Thompson and Colgan 1994). Large diameter trees furnish marten with well-protected and well-insulated natal and maternal dens (Thompson and Harested 1994, Ruggiero et al. 1998). The above-mentioned characteristics also provide excellent habitat for important prey species (i.e. red-backed voles). Younger successional stages may have larger small mammal populations, but these are typically non-preferred species. Furthermore, lack of protection from predation and the lack of access to the subnivean zone in younger forests limit the extent to which marten can use small mammal populations in them (Thompson and Curran 1995, Coffin et al. 1997).
Riparian areas may also be key components of marten habitat (Buskirk and Powell 1994, Buskirk and Ruggiero 1994). Spencer et al. (1983) suggested that riparian areas are important for foraging; Buskirk et al. (1989) indicated that they may be valuable in rest site selection. Jones et al. (1997) hypothesized that riparian areas were significant because their topography and hydrology predispose them to having large trees, large snags, and numerous downed logs. It remains unclear whether riparian areas are important to marten because they prefer to be near water, because their favored prey species prefer riparian areas, or because riparian areas impart indirect benefits to marten via influence on structural characteristics of a stand. Nevertheless, riparian areas seem to be significant components of marten habitat in the western U. S.

Many authors have indicated that canopy closure (30-60%) is also an important attribute of marten habitat (Koehler and Hornocker 1977, Spencer et al. 1983, Hargis and McCullough 1984, Buskirk and Ruggiero 1994, Thompson and Harestad 1994). The closed canopy typical of mature forests may protect marten from avian predation (Clark et al. 1987, Thompson 1994, Thompson and Harestad 1994). However, overall structural complexity of a stand may override canopy closure. In Maine, Chapin et al. (1997a) found that marten selected areas that were decimated by spruce-budworm
(Choristoneura fumiferana) and were nearly devoid of canopy. Sturtevant et al. (1996) also cited heavy use of defoliated stands by marten in Newfoundland. Despite the absence of a dense canopy, these forests provided adequate prey, vertical structure for predator avoidance, and abundant CWD.

The literature is replete with work on the effects of timber harvesting on American marten, and most studies indicate a negative impact. Thompson (1988, 1994) showed that marten densities in Ontario were up to 90% less in logged areas compared to uncut areas. Marten that did inhabit logged forests (3-40 years since logging) tended to be non-resident dispersers, were less productive, and had a higher daily mortality (both trapping and natural) than marten residing in uncut forests (Thompson 1994). Hargis and Bissonette (1997) found a similar pattern in Utah. Marten density decreased as fragmentation due to clear-cutting (1-5 years since cutting) and/or natural processes increased across their study sites. They never caught any marten in sites that were 25-42% unforested. Furthermore, marten in the unfragmented sites had higher body weights, higher over-winter survival, were more productive, and were in better condition than those in fragmented areas. Marten in harvested areas of Maine made almost exclusive use of large, residual blocks of forest (>27 ha) that tended to be close to continuous forest (Chapin et al. 1998). These
marten rarely established a home range that was >20% clearcut 1-14 years earlier (Chapin et al. 1998).

Avoidance of recently clear-cut (0-25 years since cutting) areas by American marten is well-documented (Soultiere 1979, Steventon and Major 1982, Spencer et al. 1983, Snyder and Bissonette 1987, Bissonette et al. 1991, Thompson and Harestad 1994). Marten may avoid clearcuts because they lack the overhead cover and/or structural complexity needed to protect them from predation (Buskirk and Powell 1994). Clearcuts also tend to be deficient in coarse woody debris, which is essential for winter foraging (Corn and Raphael 1992). Furthermore, prey species in clearcuts (e.g. *Peromyscus maniculatus*) may not be as desirable as species present in residual stands (Thompson and Colgan 1994, Hargis and Bissonette 1997).

Despite the generally inhospitable nature of clearcuts and other sparsely vegetated openings, many authors have indicated that marten are willing to travel short distances (≤200 m) across them (Koehler and Hornocker 1977, Soultiere 1979, Hargis and McCullough 1984, Snyder and Bissonette 1987, Fager 1991). In doing so, marten generally cross quickly and forage little (Koehler and Hornocker 1977, Soultiere 1979, Snyder and Bissonette 1987, Thompson and Harested 1994). Islands of cover interspersed throughout an opening greatly increase the likelihood that a marten will
traverse the area, which it does by "hopping" from island to island (Hargis and McCullough 1984, Bissonette and Broekhuizen 1995).

Use of clearcuts and natural meadows appears to be greatest in the summer when deciduous vegetation provides some cover from avian predation, and seasonal foods such as invertebrates and berries are readily available. (Koehler and Hornocker 1977, Steventon and Major 1982, Buskirk and Powell 1994, Thompson 1994). Marten may also forage on booming small mammal populations that arise in clearcuts shortly after harvesting. However, they tend to hunt along the edge of a harvested area in such situations, making only occasional, short forays into the opening itself (Snyder and Bissonette 1987, Chapin et al. 1998).

Conservation

In 1976, Congress passed the National Forest Management Act (NFMA). This legislation and its associated regulations require that a diversity of native wildlife be maintained on lands within the National Forest System (National Forest Management Act 1976, Ruggiero et al. 1994:1). Due to the range constriction and local population declines discussed earlier, the American marten is one of several species that has received considerable attention with regards to NFMA regulations. Many national forests in the western U.S. list marten as a "sensitive species", which explicitly expresses
concern for the persistence of marten populations on those forests (Buskirk and Ruggiero 1994, MacFarlane 1994, Zielinski and Kucera 1995b). Unfortunately, marten are very elusive in nature and tend to occur at low densities even in areas where they are relatively abundant. Thus, monitoring marten populations or even assessing presence/absence of marten in a given area is difficult (Lyon et al. 1994, Zielinski and Kucera 1995b).

Detection Methods

Numerous methods have been employed in the past to survey for marten and other forest carnivores. These include habitat surveys, harvest data, hair snags, livetrapping, snow tracking, track plates, and remote camera systems (Thompson 1988, Bull et al. 1992, Raphael 1994). However, a lack of large-scale coordination between management entities regarding survey methods and survey effort has made it difficult to draw meaningful interpretations about forest carnivore distribution (Foresman and Pearson 1998). In an effort to ameliorate this problem, the U. S. Forest Service (USFS) recently published standardized survey protocols for gathering distributional data on forest carnivores using snow tracking, track plates, and remote camera systems (Zielinski and Kucera 1995a). Other potential survey methods mentioned above were omitted due to lack of necessary knowledge.
(habitat surveys assume habitat suitability is known), presence of confounding factors (harvest data are influenced by pelt price, socioeconomic conditions, weather, trapper effort, and access), invasiveness and intensity of effort involved (livetrapping), or difficulty in detecting and identifying target species (hair snares; Thompson 1988, Zielinski and Kucera 1995b).

Snow tracking, track plates, remote cameras, and their associated protocols differ with regards to 1) the season in which they can be used, 2) the amount of training required, 3) the cost of labor and materials, 4) difficulty in identifying target species, and 5) species for which they are best suited (Zielinski and Kucera 1995b, Foresman and Pearson 1998). No method is superior to the others in all situations, and all share a considerable shortcoming; failure to detect a species in a given area cannot be interpreted as "absence". All that can be concluded definitively is that the species was not detected (Zielinski and Kucera 1995b). Information regarding the probability of detecting a target species if it indeed occurs in an area is needed to resolve this shortcoming and enhance the utility of these methods (Lyon et al. 1994, Ruggiero et al. 1994b, Zielinski et al. 1997). With an estimate of probability of detection (POD) for each survey technique, lack of detection could be interpreted as absence with some degree of
confidence. Furthermore, estimates of POD would greatly enhance current efforts to use these survey methods in a monitoring capacity (Zielinski and Stauffer 1996).

As monitoring tools, snow tracking, track plates, and remote cameras are used to estimate the proportion ($P$) of survey units that are occupied by a target species. This proportion is then tracked over time as an index of population trend (Raphael 1994). However, $\hat{P}$ should be corrected for bias resulting from the failure to detect target species in survey units where they actually exist (Raphael 1994). Knowledge of POD is required to make this adjustment. If POD is close to one, then little or no adjustment will be needed because target species present on a given survey unit stand a very good chance of being detected. However, if POD is $<1$, $\hat{P}$ should be adjusted accordingly by dividing by POD.

Currently, bias adjustments are derived from a model that defines probability of detection as a function of latency to detection (LTD; Azuma et al. 1990, Zielinski and Stauffer 1996), which is defined as the average time elapsed (days or visits to a survey unit) before a target species is detected. This model assumes that if mean LTD is small relative to the length of the survey, then the probability of overlooking a resident of a survey unit should be low and POD should be high. Conversely, if mean LTD is close to the
maximum number of survey days, then the likelihood of missing individuals is higher, and POD should be lower (Zielinski and Stauffer 1996). However, the validity of this function is unknown. Empirically deriving POD would allow for a direct bias adjustment (\( \hat{p}/\text{POD} \)) and could be used to validate the model currently used to make such an adjustment.

Information regarding the probability of detecting a given individual (\( \text{POD}_{\text{ind}} \)) on a survey unit could prove useful as well. With such information one could calculate the number of individuals that might reside on a survey unit despite failing to obtain a detection. Assuming individuals are detected independently of one another, multiplying the complement of \( \text{POD}_{\text{ind}} \) by itself \( n \) times yields the probability \( (i) \) of not detecting any of the \( n \) individuals \( ([1 - \text{POD}_{\text{ind}}]^n = i) \). By choosing an acceptably low value for \( i \), one can solve for \( n \), the maximum number of individuals likely to be present on an "unoccupied" survey unit \( (n = \ln[i]/\ln[1 - \text{POD}_{\text{ind}}]) \). For example, if \( \text{POD}_{\text{ind}} \) is 0.60, and the accepted probability of failing to detect all individuals is set at 0.10, one could assume that no more than 3 marten are likely to be present on any "unoccupied" survey unit \( (n = \ln[0.10]/\ln[1 - 0.60]) \). Alternatively, the number of individuals occupying a saturated survey unit (i.e. all available area is occupied) could be extrapolated based on
home range sizes typical of a given area. Then one could calculate the probability of failing to obtain a detection on a saturated survey unit and use this as a gauge of the utility of the method in that area. For example, if $\text{POD}_{\text{ind}} = 0.10$, and there are likely to be a maximum of 10 marten on a fully occupied survey unit, the chances of not obtaining a detection in the best of circumstances (full occupancy) is $i = [1 - 0.10]^{10} = 0.35$. Such a priori calculations may be useful during the planning phase of the survey process.

Although none of the survey methods described by Zielinski and Kucera (1995a) are superior for all occasions, covered track plates may be the most practical technique from a management perspective. Of the three survey methods, track plates are the least expensive to implement (Foresman and Pearson 1998); they have high detection rates (Barrett 1983, Bull et al. 1992) and short LTD (Foresman and Pearson 1998) compared to other methods; identification of different species is relatively easy (Barrett 1983, Zielinski and Kucera 1995b); their use is independent of weather conditions (Bull et al. 1992); and they have been recommended as the preferred method of detection for fisher and marten (Zielinski 1995). Thus, I focused on assessing the efficacy of covered track plates for detecting American marten, the most abundant and readily studied of the forest carnivores. Specifically, my objectives were to 1) estimate
the probability of detecting American marten on survey units where they were known to exist (POD\textsubscript{su}), 2) test the model for calculating POD\textsubscript{su} as a function of LTD, 3) estimate the probability of detecting a given individual known to reside on a survey unit (POD\textsubscript{ind}), and 4) assess marten behavior in the vicinity of track plates. This final objective was adopted because marten are detected more rapidly by open (no cover) vs. covered track plates and have been observed to approach, but not enter covered plates (Foresman and Pearson 1998). Any avoidance behavior marten might exhibit toward covered plates would significantly influence the probability of detection.

**STUDY AREA**

I defined the study area by five 2\textsuperscript{nd}-3\textsuperscript{rd} order drainages along the east front of the Bitterroot Range in western Montana (Fig. 1). All drainages run in an easterly direction and cover 25 km north to south. Each encompasses approximately 30-60 km\textsuperscript{2}. Elevations of the valley floors range from 1100 m at the mouth of the canyons to 1900 m at the upper reaches. Ridges extend up to 2850 m. Shear rock walls are common, and slopes routinely exceed 50\%. Ridges that separate each drainage are generally above tree line. Approximately half of the study area lies within the Selway-Bitterroot Wilderness; the remainder lies within an essentially roadless area of the Bitterroot National Forest.
Figure 1. Study area in the Bitterroot Mountains, western Montana. Study area lies adjacent to the Idaho – Montana border (green line) 26 km south of Missoula and 13 km north of Hamilton.
Average minimum and maximum January temperatures on the study area are -9°C and 0°C, respectively. Average minimum and maximum July temperatures are 8°C and 29°C, respectively. Total annual precipitation is 50-100 cm. Average total snowfall is 250 - 450 cm, and snow generally covers the area from late November through April. Much of the remaining annual precipitation falls as rain in May and June (Western Regional Climate Center, unpublished data 1999).

Douglas-fir (*Pseudotsuga menziesii*) climax series (Pfister et al. 1977) are typical of the lower reaches of each drainage, but may be found on southern exposures at higher elevations. Common Douglas-fir habitat types include blue huckleberry (*Vaccinium globulare*, PSME/VAGL), snowberry (*Symphoricarpos albus*, PSME/SYAL), ninebark (*Physocarpus malvaceus*, PSME/PHMA), and twinflower (*Linnaea borealis*, PSME/LIBO; Pfister et al. 1977). Mid-elevation, relatively moist areas are dominated by the grand fir (*Abies grandis*)/twinflower (ABGR/LIBO) habitat type. Subalpine fir (*Abies lasiocarpa*)/menziesia (*Menziesia ferruginea*, ABLA/MEFE) and subalpine fir/bear grass (*Xerophyllum tenax*, ABLA/XETE) habitat types are common in the upper reaches of each drainage, but may also be encountered at lower elevations on north aspects. Vertical structure for the
majority of the study area is old forest multi-strata (O'Hara et al. 1996)

Structural characteristics vary considerably within each drainage depending on elevation and aspect (see Appendix A). However, structural and vegetative characteristics are generally similar across drainages, and marten presence has been documented in all of them via previous track plate and remote camera surveys (Foresman and Pearson 1998).

Within each of the 5 drainages, I delineated 2 10.44-km² survey units as per the USFS survey protocol (Zielinski et al. 1995; Fig. 2). However, survey units did not follow township and range designations as suggested. Instead, the eastern boundary of the first survey unit in each drainage was established to bypass "non-marten" habitat common to the lowest reaches of the canyons. The second survey unit was placed adjacent to the western border of the first. Survey units were centered and aligned with the creek. Survey unit boundaries generally extended from ridgeline to ridgeline.

**METHODS**

**Marten Capture**

I live-trapped marten over several short periods (3-11 days) from June 1-mid August 1998 and 1999. Trapping activities were delayed until June 1 to decrease stress on lactating females. Females caught prior to July 1 (weaning
Figure 2. Delineation of 10.44-km² survey units (red squares) in relation to drainages of the Bitterroot Mountains, western Montana. A • indicates position of a covered track plate.
date) were released immediately without anesthesia or handling. I generally trapped the first (lower) survey unit in a given drainage until I successfully captured a marten, then moved to the second (upper) survey unit before conducting track plate surveys in each unit (see below).

During a trapping session, I set 16-24 traps (Tomahawk No. 105, Tomahawk Live Trap Co., Tomahawk, Wisconsin, USA) along an east-west, 1-km transect centered in the survey unit. By arranging traps in the center of each unit, I maximized my chances of capturing individuals that would remain on their respective survey units during the 12-day period that track plates were deployed (see below). Each trap was set in a "cubby" constructed of bark, logs, and other debris. Cubbies fully encased each trap offering captured marten protection from weather, concealment from people, and a dark environment, which may reduce stress and deter escape attempts (Bull et al. 1996). I baited traps with a mixture of sardines, chicken, and trapping lure during the 1998 field season. However, chicken and trapping lure are the baits recommended in the track plate protocol (Zielinski 1995). To eliminate any bias in "trap response" due to use of similar baits during trapping and survey sessions, I trapped marten using beef scraps instead of chicken during the 1999 field season.
I generally checked traps twice daily. Young of the year were released upon capture. Adult marten were immobilized with an intramuscular injection of ketamine hydrochloride (0.1 ml @ 100 mg/ml) and xylazine (0.25 ml @ 20 mg/ml; Tomson 1999). Small animals (<700 g) were given 75% of the standard dose. All adults and one juvenile were sexed, weighed, and examined for overall condition. I marked the toe and/or interdigital pads on the front feet of each marten with a unique combination of heat brands, which allowed me to identify individuals from tracks. Brands were small (2-mm wide) circles, which minimized both trauma to the animal and the potential to confuse them with natural scars. Brands were superficial in nature, did not break the skin, and healed over completely in approximately 3 weeks. I obtained a track from each animal immediately after branding to serve as a reference for comparison with tracks collected later from track plates (Fig. 3). In addition to the above procedures, the first animal captured in each survey unit was also fitted with a 40-g radio collar (ATS Corporation, Isanti, Minnesota, USA). These were adjusted so that I could fit one finger between the collar and the animal (Bull et al. 1996). After handling, animals were usually returned to the trap for 30-60 min to allow them to recover completely from the anesthesia before they were released (Bull et al. 1996).
Figure 3. Examples of reference tracks obtained from anesthetized marten shortly after branding. Arrows indicate circular brands. Images are approximately 1.5X normal size.
I live-trapped marten intermittently from January through March 1999, and from November through December 1999 in an effort to retrieve radio collars. I only re-trapped 4 of the 10 survey units trapped during previous summers.

**Track Plates**

I constructed covered track plates according to the "canopy design" described by Zielinski (1995; Fig. 4a). Track plates were comprised of carbon-sooted sheets of aluminum (aluminum flat stock; 20 x 76.2 x 0.1 cm), each with a piece of contact paper (Con-Tact™, Rubbermaid Corporation; 31 x 23 cm) affixed approximately 9 cm from one end. These were housed in a protective enclosure composed of a metal base (galvanized steel flat stock; 28 x 75 x 0.1 cm) and plastic hood (2 sheets 0.33-cm PVC plastic flat stock; 40.5 x 70.5 x 0.2 cm). I baited each plate by positioning a chicken leg or wing behind the contact paper. In the field, I barricaded the rear of the protective housing with rocks, logs, and other debris so that a marten had to walk across the carbon soot then step onto the contact paper to retrieve the bait (Fig. 4b). In doing so, it left detailed prints on the paper (Fig. 5).

I deployed track plates in each survey unit 1-12 days after marten were captured. Following the survey protocol outlined by Zielinski et al. (1995), I distributed 6 track
Figure 4. A) Schematic drawing and parts list for a covered track plate. I used 1/8" PVC plastic flat stock rather 1/16" as suggested here. B) Completed track plate in the field (graphics and text adapted from Zielinski 1995).
Figure 5. Examples of tracks (without brands) collected from covered track plates in A) Kootenai Creek and B) Big Creek drainages, Bitterroot Mountains, western Montana. Tracks were collected during July 1998 and August 1999, respectively. Images are approximately 1X normal size.
plates in two rows of three. Each row was separated by 0.3-0.8 km, depending on topography. Within each row, plates were spaced 0.8 km apart (Fig. 2). No plate was <0.8 km from the survey unit border. Within these general guidelines, plates were situated at micro-sites that maximized the chance of achieving a detection (Zielinski 1995). All track plate sites, along with telemetry stations, were located using GPS (Garmin GPS 45XL, Garmin Corporation, Olathe, Kansas, USA).

I re-visited track plates every other day for 12 days as per the survey protocol (Latency to first detection for marten has been estimated at 3-4 days with an upper confidence limit of 8.4 days, thus 12 days is considered sufficient for detecting marten if they are present in the area [Zielinski et al. 1997, Foresman and Pearson 1998]). On each visit, plates, contact paper, and bait were replaced as needed. When tracks were present, I removed the contact paper and stored it in a polypropylene cover for subsequent analysis.

Telemetry

Concurrent with deployment of track plates on a survey unit, I obtained daily locations of radio-collared marten that were captured in that unit. This allowed me to verify that at least one marten was present and eligible for detection on each survey unit during the 12-day survey.
period. All locations were obtained between 0800 and 1800 h, and all consecutive locations were separated by >15 h ($\bar{X} = 22.67 \text{ h, } SE = 0.22, \text{ range } = 15 - 29$). Azimuths from known positions to a radio-collared animal were taken from the ground using the "direction finding" method outlined by Samuel and Fuller (1996). With the aid of a field assistant, I made a concerted effort to triangulate on collared marten using azimuths obtained simultaneously from two receiving locations. However, the logistical constraints associated with working on the ground in a wilderness often precluded acquisition of simultaneous azimuths. Because I was only interested in whether marten were present on their respective survey units, detailed positional information was not required. Therefore, I accepted azimuth estimates separated by up to 40 min ($\bar{X} = 16.27, SE = 0.86$).

Because of the steep topography, numerous rock outcroppings, and wet conditions, signal deflection was a great concern (Tomkiewicz 1998). To compensate, I always obtained azimuths from ≥3 locations, which aided in the detection of aberrant signals (Samuel and Fuller 1996, Tomkiewicz 1998). Furthermore, azimuths from each location were plotted and evaluated on site to assess the probable position of the animal and to flag "bad" signals. Additional azimuths were obtained as needed. When
determining marten location, I gave greater weight to those azimuths representing the shortest distance between the receiver and the transmitter.

I assessed the error associated with our telemetry procedures by estimating azimuths to collars hidden within the study area. Using GPS, I obtained the exact location of these collars and calculated the accuracy and precision of our azimuth estimates (White and Garrott 1990). I used the SAS program TRIANG2 (White and Garrott 1990) to calculate locations and their associated error polygons, which were imported into a GIS (ArcView 3.2, ESRI Incorporated, Redlands, California, USA) for analysis. I calculated 95% MCP home ranges for each marten using program CALHOME (Kie et al. 1994).

Telemetry Systems

At a subset of the track plates in each survey unit (usually 1-2 plates), I monitored marten behavior using automated telemetry systems (ATS; Fig. 6a). Systems consisted of a radio receiver (Model TR-4, Telonics Incorporated, Mesa, Arizona, USA), a data logger (Hobo State Logger, Onset Computer Corporation, Bourne, Massachusetts, USA), and a receiver-data logger interface unit (see Appendices B and C). These components were housed together in a weatherproof ammunition box (30 x 15 x 18 cm) along with a sealed 12v battery (Power Sonic Model 1270), which
Figure 6. A) Schematic of automated telemetry system used to log presence of radio-collared marten that approach a track plate. B) Automated telemetry system deployed in the field. Signals from radio collars were detected only when marten approached within approximately 5 m of the antenna (graphics for B) adapted from Powell 1993; Zielinski 1995).
powered the system. For an antenna I used 30 m of 12-gauge house wire, one end of which was passed through the ammunition box and connected to the receiver.

In the field, I concealed the ammunition box next to a track plate, and positioned the antenna in a 5-m radius around the plate. I tuned the receiver so that signals emitted by a radio-collared marten were received only when that marten approached to within 0-5 m of the antenna (Fig. 6b). When a signal from a radio-collar was received, low level audio output from the ear-phone jack on the receiver was emitted into the interface unit where it was amplified. This amplified signal was then fed into a timer circuit, which caused relay contacts within the interface unit to close for 3.5-4.0 sec. This closure created an output that was recorded (along with the date and time of this event) by the data logger. Thus, I was able to determine when a radio-collared animal approached to within ca. 5-10 m of a given track plate (5-10 m is an arbitrary, conservative estimate of the distance at which marten perceive the presence of a baited track plate). I compared these data to those gathered from the track plates themselves to determine if marten were reluctant to enter plates.

Through extensive field-tests, I noted that changes in static output related to battery power and other anomalies (possibly lightning strikes) were recorded by ATSs along
with actual visits to track plates. However, these false-positive signals were always of short duration, resulting in closure of the relay for only 3.5-4.0 sec (corresponding to receipt of a single pulse). Actual visits to a plate always resulted in at least two pulses recorded (collars pulsed at 60 pulses/min) and thus lasted for ≥8.0 sec. Therefore, false-positives were eliminated by filtering out events ≤4.0 sec in duration. Using this method, telemetry systems successfully recorded 100% of 112 simulated visits to track plates during test trials. More importantly, 0 false positives were recorded. Field tests also revealed that batteries were capable of running these systems continuously for 3-5 days. To avoid missing events, I switched batteries at each visit to a plate (2 days).

**Habitat Assessment**

To accurately depict my study area and facilitate comparison with other locations, I characterized the habitat in each survey unit as follows. I sampled 6 randomly selected plots in each unit, 3 of which were on the north aspect of the canyon, 3 on the south aspect. On each 15-m radius plot, I measured the dbh of all overstory, midstory, and understory trees. I counted the number of downed logs (diameter > 10 cm, length > 120 cm, decay < 50%) and snags (dbh > 20 cm, height > 1.4 m). I estimated CWD load (kg/m² of woody debris > 1 cm diameter) using Fischer’s (1981a,b,c)
photoguides and noted if squirrel middens were present. Lastly, I determined the habitat type (Pfister et al. 1977) and vertical structure (O’Hara 1996) of the stand containing the plot.

**Analysis**

From each set of tracks collected, I captured (ATI Video Player 4.0, ATI Technologies, Thornhill, Ontario, Canada) the clearest print into a PC and electronically measured (SigmaScan Pro 5.0, SPSS, Incorporated, Chicago, Illinois, USA) the width of interdigital pad 3 (WI3), the length of interdigital pad 3 (LI3), and the length of interdigital pad 4 (LI4; Fig. 7). I then applied the discriminant function developed by Zielinski and Truex (1995):

\[(4.595 \times WI3) + (3.146 \times LI3) + (0.906 \times LI4) - 80.285\]

to determine whether the track was made by a marten (result <0) or a fisher (result >0). Tracks that were not clear enough for this procedure were inspected visually and subjectively assessed as marten or fisher.

**POD survey unit.**—I estimated the probability of detecting marten on a survey unit, given the presence of ≥1 marten (i.e. conditioned on the presence of marten), using

\[\hat{d}_{su} = s/S\]  

(eq.1)

where \(\hat{d}_{su}\) = the estimated conditional probability of
Figure 7. Schematic drawing of a *Martes* foot print (right foot) collected from a sooted track plate. Toe pads are labeled 1-5 beginning with the "thumb"; I1-I4 indicate interdigital pads. H indicates the heal pad. Joining the inner margins of 2 and I3 and the outer margins of 5 and I3, then bisecting the resultant angle forms the ordinate of the cartesian coordinate system. Measurements A, B, and C are entered into the algorithm: $(4.595 \times A) + (3.146 \times B) + (0.906 \times C) - 80.285$. If the solution is $>0$, the track is a fisher; if $<0$ the track is a marten (graphic and text adapted from Zielinski 1995).
detecting marten on a survey unit (POD$_{su}$), $s =$ the number of survey units where marten were detected, and $S =$ the number of survey units where marten were present. Survey units were classified as occupied (marten present) if 1) marten were detected at $\geq 1$ track plate during the survey period, 2) radio-collared marten were located on the corresponding survey unit at least 6 of the 12 survey days, or 3) if $\geq 75\%$ of the activity range (MCP) of radio-collared marten during the survey period fell inside the associated survey unit. I calculated a 95% confidence interval (CI) using $\hat{d}_{su} \pm Z_{a/2} \sqrt{(\hat{d}_{su}/(1-\hat{d}_{su})/n)}$ (Manly 1992).

Test of derivation of POD$_{su}$ from LTD.—To test the legitimacy of deriving POD$_{su}$ from LTD, I used my observed LTD to solve iteratively for $p$, the probability of obtaining a detection on any single visit to a survey unit, using:

$$L = 1/p - vq^v/(1-q^v) \quad \text{(eq. 2)}$$

where $L =$ mean latency to first detection measured in visits to a survey unit, $p =$ probability of detecting marten on any single visit to a survey unit, $q =$ the probability of failing to detect marten on any single visit to a survey unit ($1-p$), and $v =$ the maximum number of visits to the survey unit (6; Azuma et al. 1990, Zielinski and Stauffer 1996). I then converted $p$ into POD$_{su}$ using

$$d_{suL} = 1 - (1 - p)^v \quad \text{(eq. 3)}$$
where \( d_{suL} \) = probability of detecting marten during the survey period (POD\(_{su}\)) as derived from LTD, and \( p \) and \( v \) as defined above (Morrell and Yahner 1995). I tested the equality of \( d_{suL} \) and \( \hat{d}_{su} \) by determining whether the former value fell within the 95% CI of the latter.

**POD individual marten.**—I estimated \( POD_{ind} \), the probability of detecting a given individual on a survey unit, using

\[
\hat{d}_{ind} = \frac{\sum b_s}{\sum B_s} \quad \text{(eq. 4)}
\]

where \( \hat{d}_{ind} \) = the conditional probability of detecting an individual marten (POD\(_{ind}\)), \( b_s \) = number of branded individuals detected on survey unit \( s \), and \( B_s \) = number of branded individuals present on survey unit \( s \). I determined the number of individuals present on a survey unit using the criteria stated above. I calculated a 95% CI for \( \hat{d}_{ind} \) as described earlier.

**Assessment of behavior near track plates.**—I assessed the behavior of marten near track plates using data collected from the ATSs. I determined the average number of visits marten made to a plate before tracks were collected as well as the average cumulative amount of time spent within ca. 5-10 m of a plate before tracks were obtained.

**RESULTS**

**Marten Capture**
I captured 23 marten (18M, 5F) a total of 24 times (2.16 captures/100 trap nights) during the summer field seasons of 1998 and 1999. Mean body weight of adult males was 990.3 g (SE = 31.7, n = 15); adult females averaged 704.0 g (SE = 24.1, n = 5); juvenile males averaged 647.5 g (SE = 27.5, n = 2).

Twelve adult males, 1 juvenile male, and 2 adult females were chemically immobilized. Mean induction time (time between injection and loss of ability to right) was 2.73 min (SE = 0.18, n = 11). Mean down time (time between loss of ability to right and recovery of ability to lift head) was 29.03 min (SE = 2.40, n = 11). I branded 1 or 2 foot pads of all 15 marten that were immobilized. In addition, I fitted 11 adult males and 1 adult female with a radio collar. Only 1 marten, which was not branded or radio-collared, was captured ≥1 during the 3–10 day summer trapping sessions.

During winter trapping sessions, I recaptured 6 (5M, 1F) of 8 individuals that were initially marked (branded and/or radio-collared) during previous summers and targeted for recapture in the winter. Additionally, I captured 10 individuals not captured previously. Trap success was greater in winter (9.17 captures/100 trap nights) than summer (Z = 6.44, P < 0.0001). Body mass of males initially marked during summer (X̄ = 996.0 g, n = 5) was significantly
higher than winter body mass of these same individuals ($\bar{x}_w = 906.3$ g, $n = 5$; Paired $t = 3.52$, $df = 4$, $P = 0.012$). Similarly, body mass of males captured only during summer sessions tended to be higher ($\bar{x}_s = 987.5$ g, $n = 10$) than those captured only during winter sessions ($\bar{x}_w = 930.0$ g, $n = 4$; $t = 1.096$, $df = 12$, $P = 0.147$). Female body mass remained similar between summer ($\bar{x}_s = 725.0$ g, $n = 4$ captured during summer only) and winter ($\bar{x}_w = 708.5$ g, $n = 7$ captured during winter only; 2 sample $t = 0.309$, $df = 9$, $P = 0.382$). Nine individuals were captured 2–6 times during winter trapping periods, which lasted 4–9 days each. No trap or handling-related mortality was observed during any trapping session.

A minimum of 2–7 marten ($\bar{x} = 2.7$, SE = 0.50) were present on each 10.44-km$^2$ survey unit during the summer season. Thus, minimum density on my study area was approximately 0.26 marten/km$^2$ including all age and sex classes as well as possible transients. During winter, I captured 4–7 ($\bar{x} = 4.0$, SE = 1.2) marten on each survey unit; a minimum density of 0.38 marten/km$^2$.

**Telemetry**

I obtained 9–22 independent radio locations ($\bar{x} = 14.3$, SE = 1.2) on each of 12 marten for a total of 170 locations. Mean bearing error to test collars was $-2.33^\circ$ (SD = 23.87$^\circ$,
Mean area of error polygons was 1.91 km\(^2\) (SE = 0.29, \(n = 105\)). Mean 95% MCP home range for males was 3.06 km\(^2\) (SE = 0.72, \(n = 11\)). Home range area for the single radio-collared female was 1.58 km\(^2\).

During 12-day survey periods, I obtained 6-13 (\(\bar{X} = 10.08, \text{SE} = 0.63, n = 12\)) telemetry locations on each collared marten. Although large errors were associated with these locations, my accuracy was sufficient to determine position of a given marten relative to the corresponding 10.44-km\(^2\) survey unit.

All 12 of the radio-collared marten met one or more of the requirements for "presence" on their associated survey unit during the survey period. Two were detected at track plates. The remaining 10 marten were either located within their survey unit \(\geq 6\) of the 12 survey days (\(\bar{X} = 8.42\) days, \(\text{SE} = 0.65, \text{range} = 6-12\) days) and/or \(>75\%\) of their MCP activity range during the 12-day survey period overlapped the corresponding survey unit (\(\bar{X} = 84.30\%, \text{SE} = 9.25, \text{range} = 76-100\%\); Fig. 8). Given that all 12 radio-collared marten met the eligibility requirements for "presence", I assumed the remaining 3 individuals that were captured and branded but not radio-collared were also present and eligible for detection.

**Track Plates**

I collected 46 *Martes* tracks from 19 track plates in 7
Figure 8. Telemetry locations (colored dots) of 12 radio-collared marten during survey periods. MCPs are color-coordinated with telemetry locations. Track plate locations are indicated by a ●. Locations of marten that were detected at track plates via toe brands are indicated by colored triangles.
survey units (Fig. 9). Forty of these were sufficiently
detailed to allow application of the classification
algorithm (Zielinski and Truex 1995), and all were scored as
American marten. The remaining 6 tracks were subjectively
determined to be marten as well.

**POD survey unit.**—I collected marten tracks on track
plates from 7 of 10 survey units where marten were known to
exist (Fig. 9). By equation 1,

\[
\hat{d}_{su} = 7/10 = 0.70 \quad (95\% \text{ CI } = 0.42 - 0.98).
\]

**Test of derivation of POD\(_{su}\) from LTD.**—Average LTD (±
SE) for marten at covered track plates was 4.00 (±0.87) days
or 2.00 (±0.44) visits (\(n = 7\)). Substituting \(L = 2.00\) and \(v = 6\)
into equation 2 yields \(p\) (probability of detection on
any single visit) = 0.467. By equation 3, the theoretical
probability of detecting marten during the survey period is

\[
d_{su} = 1 - (1 - 0.467)^6 = 0.977
\]

which matches the upper limit of the 95\% CI calculated above
for the empirically derived probability of detection (\(\hat{d}_{su}\)).

**POD individual marten.**—Of the 15 marten eligible for
detection, I detected 1-2 at covered track plates (Fig. 8).
I report a range here because I cannot be certain that a
branded individual made the second set of tracks. Healing
of brands, variation in track quality, and differences in
shape between reference (made while animal was anesthetized)
Figure 9. Results of track plate surveys conducted during summers 1998 and 1999. Red squares indicate 10.44-km² survey units. Bold survey units are those in which marten tracks were collected from ≥1 track plate. A ● indicates location of a track plate; track plates monitored by automated telemetry systems (ATS) are indicated by ○. Red symbols indicate plates where tracks were collected or ATSs where marten presence was documented.
and actual tracks compromise my ability to identify individuals with 100% confidence. By equation 3,

\[ \hat{d}_{\text{ind}} = \frac{1}{15} = 0.067 \ (95\% \ CI = -0.060 - 0.193) \]  
\[ \frac{2}{15} = 0.133 \ (95\% \ CI = -0.039 - 0.305). \]

**Assessment of behavior near track plates.**—I collected data from remote telemetry systems stationed at 15 track plates across 7 survey units (Fig. 9). These were set to monitor activity of 8 radio-collared marten. MCPs of all 8 of these individuals encompassed at least one plate that was monitored by an ATS (Fig. 8,9). Data from ATSs indicated that 2 of these marten approached to within 5-10 m of the associated track plate, but never entered to retrieve the bait and leave their tracks. Both individuals approached only once during the 12-day survey period. Duration of each approach was approximately 14.0 and 21.0 sec, respectively. Neither of these two marten were detected at any plate in their associated survey unit.

Both of the marten detected via toe brands (see POD individual above) were radio-collared and potentially monitored by ATSs. One of these individuals used only 1 plate in its survey unit, and this plate was not equipped with an ATS. The other individual used several different plates, one of which was monitored by an ATS. However, the ATS failed to detect this marten, possibly due to poor
connections between the battery and radio receiver, which I discovered after the survey had terminated.

DISCUSSION

Home Range

The home range estimates I reported were likely biased low because I collected relatively few locations (<20) over a short time frame (12-20 days) on most (10/12) individuals. Estimates of MCP home range size increase with number of observations (Bekoff and Mech 1984) and sample duration (Buskirk and McDonald 1989). Most other published estimates are based on >20 locations and/or >20 day sampling duration (e.g. O’Doherty et al. 1997, Phillips et al. 1998). Home ranges on my study area were smaller than most of those reviewed by Buskirk and McDonald (1989), probably due in part to the small number of telemetry locations on which they are based and in part to the moist, productive habitat in which they were located. Within the northern Rockies, the home ranges I observed were greater than those reported by Tomson (1999) in Idaho and Burnett (1981) in Glacier National Park, but much less than those reported by Fager (1991) and Kujala (1993) in southwest Montana. This finding likely reflects the intermediate location of my study area between the more mesic, intact habitats of Tomson (1999) and Burnett (1981) and the more xeric, naturally fragmented habitats of southwest Montana (Gibilisco 1994).
Density

My minimum density estimates (0.26-0.38 marten/km²) were very similar to those recorded by Tomson (1999) in northern Idaho (0.23-0.33 marten/km²). However, they were slightly less than those reported for unharvested forests in Maine (1.2 marten/km², Soultiere 1979; 0.68 marten/km², Phillips 1994) and Ontario (0.8-2.4 marten/km²; Thompson and Colgan 1987, Thompson 1994). Eastern forests that are open to timber harvest and/or trapping support marten densities that are similar (0.4 marten/km² Soultiere 1979; 0.14 marten/km², Katnik et al. 1994, Phillips 1994; 0.08-0.20 marten/km² Thompson 1994) to what I report here.

Latency to Detection

Mean (±SE) LTD for American marten using covered track plates was 4.00 ± 0.87 days (n = 7) for this study. This is comparable to mean LTD values reported by Foresman and Pearson (1998; \( \bar{X} = 3.3 \pm 0.4 \) days, n = 6) for the same study area 3-4 years earlier and to those reported by Foresman and Maples (unpublished data 1996; \( \bar{X} = 4.5 \pm 1.7 \) days, n = 4) for different areas within the same region. Zielinski et al. (1997) reported a similar LTD (\( \bar{X} = 3.39 \pm 2.64 \) days, n = 225 surveys) for 6 years of work throughout California.

POD_{su} and POD_{ind}

I estimated POD_{su} at 0.70 and POD_{ind} at 0.067-0.133.
Confidence intervals around each point estimate are quite large due to small sample sizes \((n = 10\) and \(n = 15\), respectively\) and a small value for \(\text{POD}_{\text{ind}}\) (Ott 1993:367). Despite a lack of precision in these estimates, they do indicate that \(\text{POD}_{\text{su}}\) is fairly high whereas \(\text{POD}_{\text{ind}}\) is quite low. These results are intuitively appealing because I expected the probability of detecting any of several marten that may reside on a survey unit to be much higher than the probability of detecting a particular individual.

An adequate \(\text{POD}_{\text{su}}\) suggests that track plates are useful for determining presence of marten in localized areas, especially if they occur at densities at or above what I report here. Thus track plate surveys can be a very important and cost effective tool for determining whether a proposed management activity could potentially impact a given marten population. Surveys conducted after the implementation of the management initiative could provide an assessment of the effect on marten distribution.

\(\text{POD}_{\text{ind}}\) does not appear to be high enough to yield useful information regarding the maximum number of marten that may reside on a survey unit when detection does not occur. For example, given my estimate, there is a 50% chance of not obtaining a detection when there are 5 marten present on a survey unit \(((1-0.133)^5)\). The chance of failing to detect marten drops to 12% when 15 marten reside on a survey unit.
This may be an acceptably low probability of failure, but one could assume that ≤15 marten reside on a 10.44-km$^2$ area simply based on typical density and home range sizes. Given my home range estimates, no more than 9 marten (3M, 6F) probably occur on any given survey unit. The probability of failing to obtain a detection on a fully occupied survey unit is $(1-0.133)^9 = 0.28$, which is not overwhelmingly low.

Low POD$_{ind}$ indicates that track plates may not perform well in areas where only 1 or a few marten are present on any given survey unit (i.e. areas with low marten density). This extrapolation is most likely to hold in areas where marten occur at low densities, but home range sizes are typical of high density areas. Given that home range size is driven largely by energetic requirements (Katnik et al. 1994, Phillips 1994, Powell 1994), regions where resources are not limiting, but human activities such as trapping or timber harvesting maintain low marten densities may meet this condition. Phillips (1994) reported such a situation for lactating females in low and high-density populations in Maine.

However, in areas where marten occur at low densities, they typically occupy larger home ranges (Thompson and Colgan 1987, Phillips 1994). In this case, it is difficult to predict how track plates will perform. Given a larger home range, a single marten on a survey unit will have an
increased number of track plates within its territory, and its chances of encountering a plate will be higher. Also, if low density and large home ranges are a result of low resource levels, marten in low-density areas are more likely to be food-stressed when they encounter track plates and may be more prone to enter and retrieve the bait. POD\textsubscript{ind} in such situations may be higher than I indicated above. However, whether a detection occurs depends entirely on the behavior of a few individuals rather than on the behavior of several marten. Chances are greater that occupancy will go unnoticed simply because all of the individuals present may avoid track plates. This is less likely in areas where 5-10 marten occur within a given survey unit.

More work is needed to clarify how POD\textsubscript{ind} and POD\textsubscript{su} vary with marten density. If there is a direct, positive relationship between POD and marten density, then the threshold density below which track plates perform too poorly to be practical should be identified. Additionally, if a direct positive relationship exists, it would have important implications for using track plate surveys in a monitoring capacity. If track plate performance deteriorates as marten populations decline, other avenues for gathering trend data should be explored.

**Test of Derivation of POD\textsubscript{su} from LTD**

I observed a potential disparity (subject to sample
size considerations) between the observed \( \hat{POD}_{su} (\hat{d}_{su} = 0.70, 95\% \text{ CI: } 0.42 - 0.98) \) and that derived from the mean LTD estimate (\( d_{su} = 0.977 \)). Foresman and Pearson (1998) and Foresman and Maples (unpublished data 1996) conducted remote camera surveys concurrent with track plate surveys in the same region as my study from April - June 1995, and May - September 1996, respectively. The ratio of survey units where marten were detected by track plates to those where marten were detected by either track plates or cameras produces an estimate of \( POD_{su} \) from their data. Combining their datasets with mine does not change the estimated \( POD_{su} \) appreciably (\( \hat{d}_{su} = 0.739, n = 23, SE = 0.09 \)). However, it imparts greater precision on the estimate (95\% CI: 0.56 - 0.92), which provides further evidence of a discrepancy between empirically and theoretically deriving \( POD_{su} \).

If this inconsistency exists, it is likely rooted in the calculation of mean LTD, which is based exclusively on survey units where detections occurred. Ignoring information from units where detections did not occur produces a mean LTD that is biased low. Subsequently, the value for \( POD_{su} \) derived from mean LTD is inflated. If one could account for detections that would have occurred had a survey lasted long enough, mean LTD would be unbiased and \( POD_{su} \) derived from LTD may be more reflective of the empirically derived value. For example, in my study, I
failed to obtain a detection on 3 occupied survey units during 12-day survey periods. Suppose that marten would have been detected on these units on day 13 had I not terminated the survey. My mean LTD would have been 6.7 days or 3.35 visits \((n = 10)\). Using equations 3 and 4, \(p = 0.15\) and \(d_{suL} = 0.68\). This more closely matches my point estimate of 0.70 and falls well within the 95% CI.

**Assessment of Behavior Near Track Plates**

Six of the 8 marten that were monitored by automated telemetry systems were either never detected or were noted to have approached a track plate without entering. This finding strengthens the suggestion made by Foresman and Pearson (1998) that marten may be reluctant to enter covered track plates. It also implies that in part, \(POD_{su}\) is <100% and \(POD_{ind}\) is very low due to the reluctance of marten to use covered plates rather than a failure to encounter them. Trap-shyness is unlikely to be the cause of this avoidance behavior given that I recaptured a high percentage (75%) of previously marked individuals during winter trapping periods. Furthermore, several animals captured during winter trapping sessions were recaptured up to 5 times over short (up to 9 days) periods. Other authors have reported high incidence of recaptures as well (Hawley 1955, Weckwerth 1957, Koehler and Hornocker 1977, Thomson 1999). Perhaps different baits and/or lures would prove more enticing to
marten. I found that beef and beef suet seemed to attract marten more efficiently during trapping sessions compared to chicken. I conducted no formal test of this, however. Possibly more care should be taken to cover up any human scent that may be present at the track station. Also, track plates which incorporate "see through" wire mesh (Zielinski pers. comm.) to block off the back may allow more light to penetrate the plate and thus make them more conducive to visitation by marten.

Further Considerations

Numerous extraneous variables undoubtedly influence both $\text{POD}_{su}$ and $\text{POD}_{\text{ind}}$. As discussed above, marten density and/or home range size have the potential to impact POD. Accordingly, anything that influences these 2 parameters has the potential to indirectly impact POD. Also, individual behavior can have a tremendous influence on POD. Marten differ in levels of curiosity, hunger, and wariness, all of which affect their behavior near plates. These latter factors are important to recognize, but quantifying and accounting for them in a survey will prove very difficult if not impossible.

Aside from density, home range, and behavior, several environmental variables could influence both $\text{POD}_{su}$ and $\text{POD}_{\text{ind}}$. Season is likely important as marten are often 2-3 times more difficult to trap in the summer than in the
winter (Hawley 1955, Raphael 1994). If their response to track plates is similar, it follows that $POD_{su}$ and $POD_{ind}$ should be much higher in the winter. Bull et al. (1992) found that detection rates for remote cameras and track plates were lower in the summer and recommended winter surveys for marten in Oregon. Weather (Nottingham et al. 1989), habitat (Nottingham et al. 1989), and human activity (i.e. trapping; Andelt et al. 1985), have been shown to influence carnivore movements and detection rates at scent stations. These probably influence detection of marten at track plates as well. Marten have been shown to reduce foraging activity during inclement weather (Buskirk et al. 1988), which would decrease their chances of encountering track plates during such periods. Density and home range size may change with habitat type and disturbance (Phillips 1994, Thompson 1994), which, as discussed earlier, could have unpredictable effects on detection probability. Human activity such as trapping can temporarily or permanently reduce marten densities and influence home range size as well (Phillips 1994). Topography may impact POD also. Plates placed in elevated areas with consistent wind currents may attract animals more efficiently than those placed in relatively low-lying, stagnant areas.

Ideally, more work should be conducted to quantify how POD varies with the above-mentioned factors. In the
meantime, researchers should control for such variables to the degree possible by conducting surveys during the same period and in the same fashion from year to year. If a given year is characterized by environmental variables that deviate from normal (e.g. exceptionally cold or rainy weather), then interpretation of distributional data should be modified accordingly.

Conclusions

I described here the first POD estimates derived empirically for American marten and covered track plates. Covered track plates work acceptably well for detecting marten if they are present at relatively high densities (0.26-0.38 marten/km²) on a survey unit. However, the probability of detecting a particular individual was very low, indicating that they may not perform as well in areas where marten occur at low densities. While the estimates reported here are useful, they suffer from lack of precision and lack of control for numerous extraneous variables. Compared to other populations in the northern Rockies, my marten population is typical in terms of home range size and density. However, my population has never been subjected to logging or other human-imposed habitat disturbance, and trapping pressure in recent years has been minimal. Replication of this study is needed to verify results. More work is needed to elucidate how POD_{su} and POD_{ind} vary with
marten density, geographic region, season, weather, bait, habitat disturbance, topography, and other variables that may prove important.

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Provincial Museum of Alberta, Edmonton, Alberta, Canada.


Appendix A. Mean (SE) downed logs/ha, coarse woody debris load (kg/m²), overstory dbh (cm), overstory stems/ha, basal area (m²/ha), snags/ha, and % of plots with squirrel middens for study area in the Bitterroot Mountains, western Montana, 1998-1999.

<table>
<thead>
<tr>
<th></th>
<th>Lower Survey Units</th>
<th></th>
<th>Upper Survey Units</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LOGS</td>
<td>CWD</td>
<td>OVER</td>
<td>OVER</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>dbh</td>
<td>stems</td>
</tr>
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<td>North</td>
<td>575</td>
<td>5.0</td>
<td>27.4</td>
<td>486</td>
</tr>
<tr>
<td>Aspect</td>
<td>(92)</td>
<td>(0.6)</td>
<td>(2.7)</td>
<td>(100)</td>
</tr>
<tr>
<td>South</td>
<td>287</td>
<td>2.8</td>
<td>40.7</td>
<td>192</td>
</tr>
<tr>
<td>Aspect</td>
<td>(75)</td>
<td>(0.7)</td>
<td>(3.3)</td>
<td>(32)</td>
</tr>
<tr>
<td>Total*</td>
<td>482</td>
<td>4.7</td>
<td>37.1</td>
<td>306</td>
</tr>
<tr>
<td></td>
<td>(46)</td>
<td>(0.4)</td>
<td>(1.8)</td>
<td>(34.1)</td>
</tr>
</tbody>
</table>

\(n = 15\) 15-m radius circular plots used to calculate values for each elevational-aspect combination.

\(\text{Downed logs} >120\ \text{cm in length,} >10\ \text{cm in diameter, and} <50\%\ \text{decayed.}\)

\(\text{Coarse woody debris} >1\ \text{cm in diameter as determined by Fischer 1981a,b,c.}\)

\(\text{Snags} >1.4\ \text{m high and} >20\ \text{cm dbh.}\)

\(n = 60\) plots used to calculate values for all elevation-aspect combinations.
Appendix B. Parts list for interface units used in automated telemetry systems that logged the presence of martens at track plates in the Bitterroot Mountains, western Montana, 1998-1999. Labels correspond to schematic on following page. Parts list provided by Eric Gabriel, Stevi Electronics, 321 Main, Stevensville, Montana, USA, (406) 777-2733, gabe@bitterroot.net.

<table>
<thead>
<tr>
<th>LABEL</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>J1, J2</td>
<td>1/8&quot; mono jack</td>
</tr>
<tr>
<td>J3</td>
<td>5.0 mm X 2.0 mm coaxial jack</td>
</tr>
<tr>
<td>RE1</td>
<td>SPST 5 volt reed relay, 250 ohm coil</td>
</tr>
<tr>
<td>SW1</td>
<td>SPST switch</td>
</tr>
<tr>
<td>IC1</td>
<td>LM741 opamp</td>
</tr>
<tr>
<td>IC2</td>
<td>LM555 timer</td>
</tr>
<tr>
<td>Q1</td>
<td>2N2222 silicon transistor</td>
</tr>
<tr>
<td>R1</td>
<td>1K ohm ½ watt resistor</td>
</tr>
<tr>
<td>R2</td>
<td>20 M ohm ½ watt resistor</td>
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<tr>
<td>R3</td>
<td>100K ohm ½ watt resistor</td>
</tr>
<tr>
<td>R4-R6</td>
<td>10K ohm ½ watt resistor</td>
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<tr>
<td>R7</td>
<td>330K ohm ½ watt resistor</td>
</tr>
<tr>
<td>C1</td>
<td>0.1uF poly capacitor</td>
</tr>
<tr>
<td>C2</td>
<td>0.1uF tantalum capacitor @ 25 volts</td>
</tr>
<tr>
<td>C3</td>
<td>0.001uF poly capacitor</td>
</tr>
<tr>
<td>C4</td>
<td>10uF tantalum capacitor @ 25 volts</td>
</tr>
<tr>
<td>C5</td>
<td>4.7uF tantalum capacitor @ 25 volts</td>
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<tr>
<td>D1-D4</td>
<td>1 N914 silicon signal diode</td>
</tr>
<tr>
<td>D5</td>
<td>1 N4001 silicon rectifier diode</td>
</tr>
</tbody>
</table>
Appendix C. Schematic for interface units used in automated telemetry systems that logged the presence of marten at track plates in the Bitterroot Mountains, western Montana, 1998-1999. Labels are defined on previous page. Schematic and design provided by Eric Gabriel, Stevi Electronics, 321 Main, Stevensville, Montana, USA, (406) 777-2733, gabe@bitterroot.net.