Use of track plates to detect changes in American marten (*Martes americana*) abundance

by
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Thesis submitted in partial fulfillment of the requirement for the degree of Master of Science in Biology

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July 2000

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ABSTRACT

This study was an attempt to validate the track plate technique as an index of marten abundance. On two 10.5-km^2 sampling units in central Ontario, 35–41 track plate stations were spaced at 400 m in a grid pattern and activated for 2 days immediately prior to, or following, live-trapping sessions. Live-trapping was used to determine the number of individual martens present, referred hereafter as abundance. Surveys were conducted generally 1 month apart, with 13 surveys in area 1 and six in area 2. A track plate index was calculated as the proportion of stations with marten tracks after 1 (TPI-1) and 2 days (TPI-2). Marten abundance ranged between 2 and 8 individuals (~0.2–0.8/km^2) during the study. TPI-1 and TPI-2 averaged (± SD) 8.7 ± 10.1% and 9.1 ± 7.8%, respectively. A regression model incorporating male abundance explained 32.3% of variation in TPI-2 readings ($F_{1,17} = 8.11$, $P = 0.01$) with no additional effect of female abundance ($F_{1,16} = 0.01$, $P = 0.92$). Applying a predictive model to discriminate martens by sex revealed TPI-2 readings of 7.4 ± 6.5% for males and 0.4 ± 0.8% for females over 13 summer and autumn surveys. Male abundance (range = 1–5) explained 61.0% of variation in TPI-2 adjusted for male visits ($F_{1,11} = 17.20$, $P < 0.01$) with no additional effect ($P > 0.05$) of independent variables (e.g., site, total precipitation, and min and max temperature). An analysis of survey power showed that ≥4 replicate TPI-2 surveys would be required during each of 3 sampling occasions to detect annual declines of 30% in male abundance with the probability of committing a Type I and Type II error set at 0.20. Although track plate surveys as designed here were successful in indexing male marten abundance, further research is required to determine how female marten visitations can be increased without increasing male visits further, potentially saturating surveys.

ACKNOWLEDGEMENTS

This project was funded through the Ontario Ministry of Natural Resources with equipment provided by the Department of Biology at Laurentian University and the Quebec Ministry of the Environment. Many people made this project possible so I sincerely apologize if I forget one or two names. Dr. J. -F. Robitaille kept me focussed and provided encouragement throughout the study. Dr. Y. Alarie made valuable suggestions during the onset of the study. Dr. I. D. Thompson provided helpful suggestions concerning the live-trapping of marten. Dr. F. V. Clulow provided helpful advice and encouragement and never failed to enlighten me on all topics under the sun. Drs. Clulow, Potvin, Robitaille, and Thompson made valuable suggestions towards improving this paper. I sincerely thank John Matthews and Tom Beck for allowing me to spend my winter field sessions at "Sinclair's pole camp" and Pearl Matthews for letting me stay in her home during a December field session. R. Routledge Sr. allowed me to take-over the trapping cabin during the study at Saddle Lake and provided lumber for track box construction. Bill Matthews generously donated his time providing me with information from his trapline. Dr. G. M. Courtin provided valuable information concerning winter animal activity, and above all else, provided inspiration through his enthusiasm in plant and animal ecology. Foreign exchange students Guillaume Lacombe and Virginie Rimbert provided enormous assistance during the initial field session despite the language barrier. I thank my fellow marten colleagues, Eric Cobb and Karl Aubry, for sharing their knowledge with me in discussions and the occasional debate. Above all else, I thank Therese Brown and John Delaney for providing me with lodging at Pine Lake Camp during the summer and autumn field sessions at Boodis Lake. Their tremendous enthusiasm surrounding my work, and assistance on occasion, was greatly appreciated.

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1.0 INTRODUCTION

1.1 Background

The American marten, *Martes americana* (Turton 1806), is a member of the Order Carnivora, Family Mustelidae. It is the only North American member of the subgenus *Martes* (Pinel 1792) which comprises four other species of Palaearctic distribution, the stone marten, *M. foina*, pine marten, *M. martes*, sable, *M. zibellina*, and Japanese marten, *M. melampus* (Nowak 1999).

American martens (referred hereafter as martens) were virtually extirpated from southern portions of their original range by the early 1900's through fire, deforestation, and over-trapping (Bergerud 1969, Thompson 1991, Buskirk 1992, Gibilisco 1994, Strickland 1994). Today martens are found over much of their original range where suitable habitat exists in mature mixed and coniferous forests across Canada, Alaska, and portions of the contiguous United States along the Rocky Mountain, Cascade, and Sierra Nevada Ranges and in northern portions of the Midwest and Northeast (Strickland et al. 1982, Clark et al. 1987, Strickland and Douglas 1987). Martens are found in central and northern portions of Ontario (Strickland and Douglas 1987), encompassing both the Great Lakes-St. Lawrence (GL-SL) and Boreal Forest Regions (Rowe 1972). They appear to select habitats with greater structural complexity (i.e., vertical and horizontal structure, Chapin et al. 1997, 1998) allowing them to elude predators (Bissonette and Brockhuizen 1995) and access prey (Sherburne and Bissonette 1994, Thompson and Curran 1995, Coffin et al. 1997) and suitable denning and resting sites (Buskirk et al. 1989, Raphael and Jones 1997, Ruggiero et al. 1998).

The breeding season in most regions lies within the months of July and August (Clark et al. 1987, Strickland and Douglas 1987) followed by an approximate 7-month period of delayed implantation and nearly 1 month of active pregnancy (Sandell 1990). Parturition occurs from mid-March to late-April (Strickland and Douglas 1987). The major dispersal period of mostly juvenile martens occurs during early to late autumn (Hawley and Newby 1957, Archibald and Jessup 1984).

Sexual dimorphism typifies martens, like most mustelids, with males weighing 50% more than females (Kurta 1995). This size discrepancy is reflected in differences in home range size; with male ranges nearly double those of females (Buskirk and McDonald 1989). Home range size estimates for martens vary greatly over their North American range (Buskirk and McDonald 1989) from averages for females and males as low as 1.0 and 3.4 km^2 (Thompson and Colgan 1987) to those exceeding 6 and 18 km^2 (O'Doherty et al. 1997), respectively. Martens display intra-sexual territoriality; exclusive within-sex home ranges with overlapping between-sex home ranges (Hawley and Newby 1957, Archibald and Jessup 1984, Katnik et al. 1994, Phillips et al. 1998).

1.2 Marten Management

The marten has been an important furbearer in Canada since the mid-1700's because of its high pelt value (Obbard et al. 1987, Shieff and Baker 1987, Strickland and Douglas 1987). In most areas where suitable habitat exists, marten populations and subsequent harvests have been increasing through the mid-1980's (Obbard et al. 1987). Major concerns arise in the management of this species because of its vulnerability to over-harvesting (Strickland et al. 1982, Strickland and Douglas 1987, Strickland 1994) and large-scale logging-induced changes to habitat (Thompson 1991, Buskirk 1992).

Although vulnerable to over-harvesting (Strickland 1994), martens are considered to have a relatively moderate ability to recover from negative population changes through dispersal and moderate reproductive output (Banci and Proulx 1999). This ability to recover may diminish, and susceptibility to over-harvesting may increase, when prey levels are low (Thompson and Colgan 1994) and road access associated with logging activity is increased (Soukkala 1983, Thompson 1994). Marten harvests in Ontario are closely managed through a trapline and quota system, shifting concern to the effect of logging activities on marten populations. This concern has lead to several logging-impact studies (Snyder and Bissonette 1987, Thompson and Colgan 1994, Potvin and Breton 1997, Chapin et al. 1998) and the marten's classification as an indicator for sustainable logging practices in forests with structural attributes characteristic of senescent stands (Bull et al. 1992, Buskirk 1992, Sturtevant et al. 1996, McLaren et al. 1998).

The current management strategy in Ontario is designed to minimize the effects of logging activities on marten populations and to closely regulate trapper's harvests. The harvest of martens in Ontario is managed through a registration system where quotas are assigned to individual traplines and adjustments to the timing and length of trapping seasons are made over administrative districts comprising many traplines (Strickland et al. 1982, Strickland 1989). Decisions concerning quotas, however, are assessed post-harvest, denying managers from taking measures to reduce quotas until the following year. A validated survey technique could be used to index marten population levels prior to current-year harvests and track population trends in habitats where martens are considered to be an indicator species (e.g., mature upland conifer and mixedwood habitat in the GL-SL Forest Region of Ontario, McLaren et al. 1998). Such a technique would also be useful in monitoring population levels in areas with active conservation strategies (e.g., Newfoundland, Thompson 1991) or in areas which have undergone a host of silvicultural treatments (e.g., Potvin and Breton 1997).

1.3 Survey Techniques

Surveys have been implemented over a wide range of habitats for a variety of terrestrial mammal species in attempts to detect their presence (Halfpenny et al. 1995, Kucera et al. 1995, Zielinski 1995), obtain an index of abundance (Diefenbach et al. 1994), or monitor trends in population levels (Kendall et al. 1992, Beier and Cunningham 1996).

Techniques specifically targeting martens have included using livetraps to capture and mark individual animals, counting the frequency of tracks left on track plates or along transects in the snow, identifying hair samples collected using hair collection devices (i.e., hair snares), recording photographic images using remotely activated cameras, and collecting harvest records from fur trappers (Raphael 1994, and references therein). While track transects and live-trapping have been used to obtain indices of marten abundance (Thompson and Colgan 1987, Thompson et al. 1989, Paragi et al. 1996b, Hargis and Bissonette 1997), track plates, hair snares, and cameras have been used only to assess marten occurrence (Spencer 1981, Barrett 1983, Bull et al. 1992, Zielinski et al. 1997, Foresman and Pearson 1998). Live-trapping may be the best index to monitor marten population trends but the high associated costs preclude its use in long-term monitoring programs over large areas (Raphael 1994). Although track transects were correlated with marten live-trapping success (Thompson et al. 1989), large variance in track counts may occur even among replicated surveys (Pulliainen 1981, Thompson et al. 1989). Fur-harvest records (e.g., harvest unit effort) from individual traplines is thought to provide an index of population trends among certain fur-bearers (Erickson 1982, Strickland 1994, but see Smith et al. 1984), but the statistical power of this method is undetermined. For harvest data to be used to extrapolate trends on scales beyond the trapline level, differences in trap distribution and density, length of time traps are actively set, time interval in which traps are checked, and environmental conditions must be addressed (Caughley 1978:17-18, Erickson 1982, Strickland et al. 1982, Strickland 1994).

Track plates, cameras, and hair snares have been used to assess marten distribution (Spencer 1981, Barrett 1983, Bull et al. 1992, Kucera et al. 1995, Zielinski 1995), but none have been validated with population estimates. The higher costs associated with the use of cameras (Brooks 1996) relative to other survey techniques (Bull et al. 1992) may restrict their use in long-term monitoring programs on a large scale. Low detection rates for martens obtained using hair snares (Spencer 1981; Jones et al. 1991, as cited in Raphael 1994) may limit their use as a potential population index (but see Foran et al. 1997). The track plate technique has provided higher detection rates depending on track plate box design (Foresman and Pearson 1998) and survey duration (Raphael 1994, and references therein). Track plate surveys have the potential to be used year-round, there is no risk of animal mortality, and they are relatively inexpensive to conduct (Bull et al. 1992, Zielinski and Kucera 1995). Many problems concerning seasonal differences in an animal's behaviour associated with sex, age, overall abundance, and differences in the availability of prey may affect bait/scent station-type surveys (Moore and Kennedy 1985, Diefenbach et al. 1994). A further problem, station habituation, may arise if surveys are replicated over a short period of time (Moore and Kennedy 1985, Diefenbach et al. 1994). The large difference in home range size between males and females (Buskirk and McDonald 1989) presents a potential discrepancy in detection rates, the rate at which either sex encounters individual stations (Buskirk and Lindstedt 1989). If track plate impressions could be used to identify martens by sex, detection rates could be assessed relative to different survey designs (Buskirk and Lindstedt 1989). If individual martens could be identified from their tracks, track plates have the potential to be used in demographic studies. Smallwood and Fitzhugh (1993) had reasonable success in identifying individual cougars (*Felis concolor*) from tracks along dirt roads while Zalewski (1999) reported poor success in identifying individual pine martens from tracks in the snow.

1.4 Objectives

The objectives of this study were to (1) determine the relationship between track plate surveys and varying marten abundance determined through mark-recapture techniques, (2) evaluate the statistical power of track plate surveys to detect annual changes in abundance, and (3) determine if track plate impressions could be used to identify individual martens or at least discriminate between males and females.

2.0 STUDY AREA

Data were obtained at Boodis Lake near Loring, Ontario, between July 1998 and September 1999. A second site at Saddle Lake near Searchmont, Ontario, was added in the second year (Jun–Nov 1999) of the study. Both sites contain mature, contiguous forest characteristic of the GL-SL Forest Region, a transition between deciduous and boreal forest (Rowe 1972). No commercial logging activity has occurred within the last 30 years on either site where historic harvests (>30 yrs) were solely selective.

The above sites were selected based on the ability to access an area of 10–11 km^2 where martens were harvested annually. This allowed sampling in the presence of high and low population levels (i.e., pre- and post-harvest). The ~10.5 km^2 area represents the sampling unit designation for the basis of track plate, camera, and snow tracking surveys for the detection of martens, fishers (*M. pennanti*), and other forest carnivores (Zielinski et al. 1995). Selecting the size of a sampling unit depends on a number of factors, including cost and logistical constraints (e.g., can one survey be conducted in a reasonable amount of time) and the population structure (i.e., density and distribution) of the target species (Thompson et al. 1998:46-9). Martens exhibit intra-sexual territoriality (Hawley and Newby 1957, Archibald and Jessup 1984), inherently creating low densities that may be further reduced by annual fur harvests. Low animal densities restrict the use of most population models due to the poor precision of estimates (Otis et al. 1978, Pollock et al. 1990, Boulanger and Krebs 1994). Thus, low densities will limit the ability of potential survey techniques in obtaining precise indices of animal abundance, in part because of an increase in the number of zero survey readings (Thompson et al. 1998:46). Nonetheless, 6–23 martens may be present in the vicinity of a sampling unit when considering densities ranging from 0.54/km^2 in clearcuts to 2.22/km^2 in uncut forest have been observed in habitat similar to that found at Boodis and Saddle Lakes (Soutiere 1979).

Boodis Lake is located in McConkey Township northwest of Loring, Ontario (45°59′N, 80°03′W). The area varies in elevation from 210–240 m and is dominated by upland stands of sugar maple (*Acer saccharum*), with eastern hemlock (*Tsuga canadensis*), yellow birch (*Betula alleghaniensis*), red maple (*A. rubrum*), black ash (*Fraxinus nigra*), and basswood (*Tilia americana*). The remaining uplands are dominated by stands of eastern hemlock with eastern white cedar (*Thuja occidentalis*), eastern white pine (*Pinus strobus*), sugar maple, and red maple. Low-lying areas, dominated by stands of cedar, white spruce (*Picea glauca*), and yellow birch, occupy only a small portion of the study area. The understory layer in sugar maple stands is dominated by sugar maple with eastern hemlock, beaked hazel (*Corylus cornuta*), basswood, red maple, yellow birch, and balsam fir (*Abies balsamea*). Hemlock stands are dominated by balsam fir, eastern hemlock, red maple, yellow birch, sugar maple, beaked hazel and fly honeysuckle (*Lonicera canadensis*). Mean daily temperatures during the study ranged from average lows of 14.5, 5.7, and -9.1°C during summer (Jun–Aug), autumn (Sep–Dec), and winter (Jan–Mar), respectively, to highs of 25.8, 13.8 and 0.7°C.

Saddle Lake is located in Lamming Township northeast of Searchmont, Ontario (46°57′N, 83°48′W). The area varies in elevation from 450–555 m. A large portion of the area is upland dominated by stands of sugar maple with yellow birch, balsam fir, red maple and paper birch (*B. papyrifera*). Stands of cedar, yellow birch, and balsam fir occupy low-lying areas. The understory layer in upland sites is comprised primarily of sugar maple, yellow birch, red maple, balsam fir, beaked hazel, and fly honeysuckle. The understory in lowland sites is more developed with the same species composition found on upland sites with a significant presence of mountain maple (*A. spicatum*), speckled alder (*Alnus rugosa*), and cedar. Canada yew (*Taxus canadensis*) is found throughout the study area. Daily temperatures ranged from average lows of 11.0 and 4.5°C to highs of 20.6 and 14.9°C during summer and autumn, respectively.

3.0 METHODS

In order to validate a survey technique as a population index, it must be compared to simultaneous measures of population size (Caughley 1978:14-16, Hatcher and Shaw 1981, Minser 1984, Smith et al. 1984, Eberhardt and Simmons 1987). This can be accomplished on multiple sites to measure spatial variability (e.g., Drennan et al. 1998, Mallick et al. 1998) or over multiple occasions on one site to measure temporal variability (e.g., Nottingham et al. 1989, Diefenbach et al. 1994, Smith et al. 1994). Due to logistical constraints, the latter protocol was selected.

3.1 Live-trapping

3.1.1 Field Layout and Animal Handling

Permanent trap sites (33–37) were established 1–420 m from trappers' trails and seasonal forest access roads at a spacing of 500 m in a grid pattern. Traps (Hav-a-hart 18 × 18 × 60 cm) were placed on the ground and covered with large woody debris, conifer boughs, and a sheet of heavy gauge black plastic to protect animals from inclement weather. Recycled fiber material (80% acrylic) placed in thin plastic bags was used as bedding when minimum temperatures fell below 5°C. Traps were baited with raspberry jam and checked daily for 6–10 consecutive days during each live-trapping session. No pre-baiting of live-traps was conducted. Since 88% (22 of 25) of individual marten first captures occurred during the first 6 days of the initial five live-trapping sessions which were ≥8 days in length, further sessions were conducted over as few as 6 days.

Martens were immobilized with ≤15 ml of anaesthetic ether (Mallinckrodt Baker, Paris, Kentucky) in a 20.3-litre wooden box with a Plexiglas window (Taylor and Abrey 1982, Davis 1983; L. U. Animal Care Committee Protocol No. 970009). Although ether is highly flammable and is a respiratory irritant, it can be administered with little fear of overdosing in the absence of sophisticated equipment (Bennett et al. 1994). Two other inhalants commonly used on mustelids, halothane (Herman et al. 1982, Lariviere and Messier 1996) and isoflurane (Potvin and Breton 1997, Kreeger et al. 1998), are safe to handle but require vaporizers to minimize overdosing (McColl and Boonstra 1999). Martens were sedated within (± SD) 299 ± 55 s, inactive for 87 ± 59 s, and released after 343 ± 123 s when movement was co-ordinated (*n* = 18). One marten of each sex could not be induced into an analgesic state following <380 s of exposure. When this occurred, a holding cone (Bull et al. 1996) was used to facilitate handling in lieu of applying a second application of anaesthetic.

All animals upon first capture were sexed by palpating for a baculum, weighed, and uniquely marked with 1–3 triangular ear notches from three possible positions per ear. Animals were released at the point of capture. Recaptured animals were identified by their unique ear notch and released. Animals were aged as juvenile or adult (>1 year old) based on reproductive status and body size at the time of capture if possible. Age was determined for individuals caught by registered trappers during autumn fur-harvest sessions using temporal muscle closure (Poole et al. 1994) and canine radiographs (Nagorsen et al. 1988).

3.1.2 Marten Abundance

The minimum number of martens known to be alive (MNA) during a live-trapping session (Krebs 1966), referred herein as marten abundance, was used in place of population estimates because the number of individuals present (i.e., population size) and subsequent captures were too low (Otis et al. 1978, White et al. 1982, Pollock et al. 1990, Boulanger and Krebs 1994). An index of marten density was calculated as MNA divided by the total area within each live-trapping grid with the addition of a 500-m area from the outermost live-traps (Thompson 1994).

Residency status was calculated as the total length of time each marten was present in either study area; resident (present for ≥3 mos), temporary resident (present during two live-trapping sessions and <3 mos), and transient (present during one live-trapping session; Hawley and Newby 1957, Archibald and Jessup 1984). An activity index was computed (the total number of different capture sites for an individual within a live-trapping session) to assess male and female marten activity within a sampling unit.

3.2 Track Plate Survey Protocol

Although the main emphasis of this study was to use track plates to survey marten populations, hair snares and snow transects were used to supplement track plate surveys and are described below. Precipitation (± 1 mm) and maximum and minimum daily temperatures (± 0.1°C) were recorded on site during all surveys.

Zielinski (1995) recommended using a box (inside dimensions: 25.4-cm high × 25.4-cm wide × 81.3-cm long) that encloses the track plate when martens and fishers are targeted (but see Foresman and Pearson 1998) as opposed to a plate that is exposed to the environment. A much smaller box was used in an attempt to minimize the amount of material used and to allow it to be easily placed in a tree to discourage non-target visitations (Barrett 1983, Martin 1987). However, the box needed to be large enough to accommodate the larger fisher, which is sympatric with martens throughout much of its range in Ontario (Douglas and Strickland 1987, Strickland and Douglas 1987). The resulting 60-cm long box was made from 1.9-cm (¾ in) softwood lumber and was 11.4-cm wide × 15.2-cm high inside. Hardware cloth was fastened to the back of each box to force animals to enter from the front. Boxes were attached to 7.6-cm angle brackets fastened to trees (dbh ≥18 cm) at 1.5 m aboveground. Aluminum track plates were 50-cm long, 10.2-cm wide, and 0.1-cm thick (0.063 gauge). They were coated with either soot (Barrett 1983, Zielinski 1995) or a mixture of marking chalk and isopropyl alcohol (Orloff et al. 1993). A 23-cm wide by 28-cm long piece of shelving paper was wrapped lengthwise around each plate with sticky side up (Fowler and Golighty 1991, as cited in Zielinski 1995). The paper was aligned to allow 10 cm of open space behind the plate for the bait (chicken drum).

Track stations (35–41) were established at 400-m intervals in a grid pattern along routes used for live-trapping. Stations were 2–87 m from routes and ≥50 m from the nearest trap site. No effort was made to place stations in locations where visitations were more likely to occur (i.e., favourable habitat, Zielinski et al. 1995). Spacing of 400 m was chosen to increase the number of stations per marten home range (notably females) in an attempt to increase the probability of detection (Raphael 1994). Stations were activated immediately prior to or following a live-trapping session (Table 1), checked and refreshed if necessary after the first day (i.e, 24 h), and removed along with any remaining bait following the second day. A short survey period was chosen to minimize station habituation and survey saturation.

A strip of double-sided adhesive tape (2.5-cm wide by 9-cm long) was placed at the entrance of each track plate box to obtain hair samples to facilitate the identification of mammal species that entered a box (Suckling 1978, Goldingay and Whelan 1997). Adhesive tape was used during eight survey periods, five during summer and three during autumn. It was not used during winter due to its lack of adherence in sub-zero temperatures. Cut sections from glue traps (Foran et al. 1997) were used only sparingly due to difficulty in handling the material.

Snow transect surveys were conducted at Boodis Lake to supplement winter track plate surveys when conditions allowed (Thompson et al. 1989). Surveys were comprised of three 3.5-km long parallel transects (seven 500-m segments per transect) ≥600 m apart. Marten tracks were tallied along each transect 24–36 h after a fresh snowfall (see Beauvais and Buskirk 1999*a* for discussion on survey timing). Tracks were often followed off a transect to clearly distinguish male martens from female fishers. Snow depth and snow hardness was measured at four stations along each transect. Snow hardness was measured (four samples per station) as the sinking depth of a 150-g wax-filled pop can dropped from a height of 50 cm (modified after Murray and Boutin 1991). An index of track density was calculated by counting the number of transect segments with marten tracks (Beier and Cunningham 1996).

3.3 Track Discrimination

Martens were released through a 91.4-cm long track plate box during live-trapping sessions to obtain track impressions from known individuals. An obstruction was placed at the end of the box to keep the animals from running through upon release, thus simulating track impressions obtained during track plate surveys (Zielinski and Truex 1995). Eleven track measurements were selected (Fig. 1) to determine if one or more of them could be used to discriminate martens by sex or as individuals. The measurements were selected to generate the largest values to decrease recording error relative to within-individual variation (Smallwood and Fitzhugh 1993) and were associated with foot pads most clearly visible on a consistent basis (i.e., digits 1–4 and interdigital pads 3 and 4; see Fig. 1).

Tracks collected were pooled per individual if they were from a period of ≤14 days to reduce variability associated with temporal differences in foot size. As an example, averages of 6 of 11 measurements taken from a juvenile male on 17 August were significantly larger by 10 September ($3.90 \leq t_4 \geq 2.22$, $P < 0.05$). The average (±SD) increase in all 11 measurements was 15.4 ± 5.5% (range = 10.1–25.7%). Tracks allowing ≥6 measurements (Fig. 1) were considered usable and were classified by individual and sex. Forefoot impressions could not be differentiated from those made by hind feet because martens walked entirely through the track box. Nevertheless, considerable overlap of gross track dimensions between marten fore- and hind-foot impressions negated the need separate them (Taylor and Raphael 1988). Left and right feet were distinguished based on the placement of the fifth toe (D-5) and the orientation of D-1 to D-4 (Fig. 1). Like other mustelids, such as the fisher and river otter (*Lutra canadensis*), the anterior portion of D-1 is posterior to that of D-4 (Rezendes 1992).

Measurements were used in further analyses if they were found on ≥75% of the tracks and had within-individual track measurement variation ≤10%. Individuals represented by as few as 2 tracks were used to increase sample size. Measurements were also considered if within-individual variation was less than between-individual variation. Measurement variation was estimated using coefficients of variation (CV). Within-individual variation represents the average of individual CV's. Between-individual variation was calculated using the average of individual measurement means. Measurement variation attributed to differences between sexes and among individuals was also assessed using a nested analysis of variance (ANOVA) design (Zar 1996:307-12). Multicollinearity was assessed from pooled within-groups correlations. Among highly correlated variables, the variable with the largest difference between means was used in further analyses. Normality of measurements was assessed using Shapiro-Wilk's W test.

3.3.1 Identifying Martens by Sex

A stepwise discriminant analysis was performed (Wilk's lambda, *P* to enter = 0.05) to determine if a model could be developed using ≥1 measurement (Fig. 1) to identify martens as either male or female (e.g., Zalewski 1999). The homogeneity of variance and covariance matrices was tested using Box's M test. Classification success was assessed using the squared Mahalanobis distance based on the derived canonical function. Due to a limited sample size, leave-one-out cross-validation (jackknife technique) was used to assess model performance. Analyses were conducted using SPSS for Windows (Version 8.0).

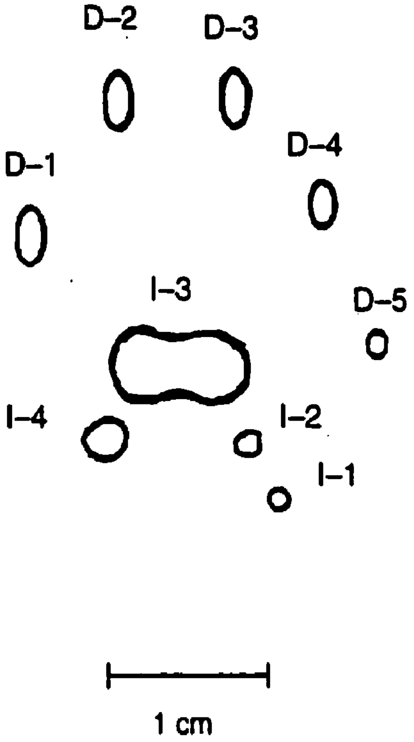
3.3.2 Identifying Individual Martens

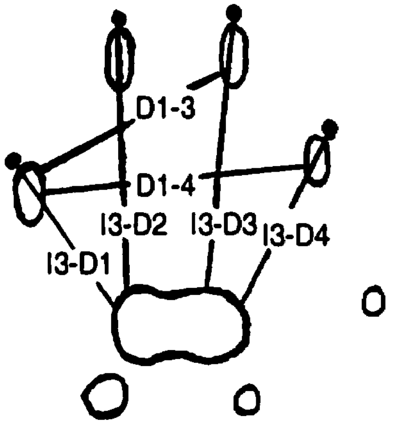
A multiple-group discriminant analysis was performed to determine if a set of measurements could be used to identify individual martens (e.g., Smallwood and Fitzhugh 1993). Similar procedures were used as above.

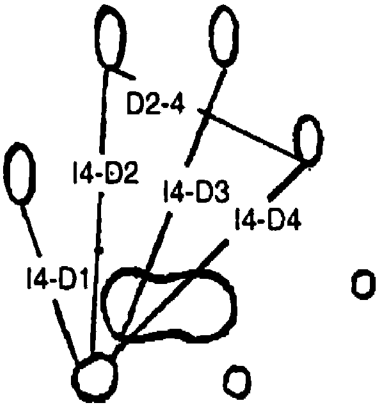
3.3.3 Comparing Fisher and Marten Tracks

As female fisher track size may overlap with that of a male marten (Zielinski and Truex 1995), measurements were taken from fisher tracks obtained during live-trapping sessions and compared to those from male martens. The efficacy of a discriminant model to separate adult male martens from adult female fishers (Zielinski and Truex 1995)

Fig. 1. Track measurements used in consideration to identify marten: nearest distance between first and fourth digits (D1-4); nearest distance between first and third digits (D1-3); distance between base of digits two and four (D2-4); nearest distance from third interdigital pad (I-3) to furthest distance beyond first (I3-D1), second (I3-D2), third (I3-D3), and fourth (I3-D4) digits; nearest distance between I-4 and first (I4-D1), second (I4-D2), third (I4-D3), and fourth (I4-D4) digits. A left foot is represented.


D–2
D–3
D–1
D–4
I–3
D–5
I–4
I–2
I–1
1 cm


D1-3
D1-4
I3-D2
I3-D3
I3-D4
I3-D1


D2-4
I4-D2
I4-D3
I4-D4
I4-D1

was evaluated. The model is described by the equation "4.595(width I-3) + 3.146(length I-3) + 0.906(width I-4) - 80.285," with values >0 being fisher and <0 marten.

3.4 Track Plate Index vs. Marten Abundance

A track plate index (TPI) was calculated as the proportion of active track stations with marten tracks after one (TPI-1) and two days (TPI-2). Active station-nights are the sum total of all nights with active track stations less 0.5 for inactive stations (e.g., knocked down by a bear) and non-target visits if bait was removed (Beauvais and Buskirk 1999*b*). If a track station was hit on both days, it was considered hit only once in the calculation of TPI-2 (Allen et al. 1996). This would best simulate a TPI-2 survey where stations are checked only after the second day.

Linear regression was used to evaluate the relationship between marten abundance (independent variable) and either index (TPI-1 and -2). Normality of the indices was assessed using Shapiro-Wilk's W test. If necessary, the proportional track data were normalized using the arcsine transformation (Zar 1996:282-3). Multiple regression (stepwise) was used to determine if independent variables accounted for significant variation in models of abundance against either index. The independent variables were actual values (continuous) or coded as dummy variables (nominal) and included the number of males and females present, total precipitation, temperature (min and max), TPI survey timing (pre and post), site, and season (summer–autumn and winter). The predictive ability of a model generated with either TPI-1 or TPI-2 was evaluated using inverse prediction (Greenwood 1996, Ryan 1997:31-4) where actual TPI values were used in the equation for the respective model to estimate abundance and calculate 90% confidence intervals. Predictive ability was assessed on the number of actual abundance levels that fell within the confidence intervals. Analyses were conducted using JMP Version 3.0 for Windows (SAS Institute Inc., Cary, NC).

Power analyses were conducted using TRENDS (Gerrodette 1987, Gerrodette 1993a, b) to determine the number of replicate track plate surveys required to detect changes in marten abundance on a sampling unit. Replicate surveys are defined as those conducted on the same site while the marten population is considered closed. Power is the probability of correctly concluding that a given population change has occurred or, in other words, the probability of not making a Type II error ($1 - \beta$). The Type I error rate (α) is the probability of erroneously concluding a population change has occurred. Results were compared using $\alpha = 0.05$ and 0.20 (Gerrodette 1993b). A power level of 80% ($\beta = 0.20$) was used as the cutoff for determining the number of replicate surveys required (Diefenbach et al. 1994, Beier and Cunningham 1996, Hatfield et al. 1996, Zielinski and Stauffer 1996).

The value for population variance (i.e., CV) used in TRENDS was estimated from the regression of TPI against abundance using the residual mean square error as the variance (Kleinbaum et al. 1988:186) and the estimated slope as the mean (Diefenbach et al. 1994). CV's were adjusted based on the assumption that they decline in proportion to the number of replicate surveys conducted per year (Gerrodette 1987). This assumption, however, may underestimate sample size predictions when compared to other power analysis programs (e.g., MONITOR, personal observation). Other parameters selected in TRENDS included the linear model of rate of change and the *t*-distribution with one-tailed tests (Gerrodette 1987, Gerrodette 1993a). Although a one-tailed test has no power to detect differences in the opposite direction, smaller sample size estimates are obtained versus testing two-tailed alternatives (Gerrodette 1987). Survey power was assessed in relation to annual declines of 20, 30, and 40% in abundance (median abundance observed during study) over three and four sampling periods.

4.0 RESULTS

4.1 Marten Abundance

Marten abundance ranged from 2–8 individuals (0.52–3.92/100 trap-nights, TN) over 11 live-trapping sessions at Boodis Lake from July 1998–September 1999 (Table 1). Low abundance during winter and summer, relative to autumn when four-fold increases were observed (Table 1), can be attributed to annual quota-based fur-harvests. Of the 24 individual martens (13 M, 11 F) captured and marked, 67% (8 M, 8 F) were recaptured at least once and 50% (8 M, 4 F) on ≥3 occasions (Table 2). Frequency of individual captures ranged from 1–17 (median = 4) for males and 1–6 (median = 2) for females. Ten males (77%) and 10 females (91%) were present during ≤2 of the 11 live-trapping sessions (Table 2). Three males were residents (23.1%) and one had temporary resident status (7.7%, Appendix I). Three females had resident status (27.3%) while three others had temporary resident status (27.3%). Resident females were distributed throughout the study area but covered far less area than males (Fig. 2A). Mean (± SD) activity indices for male ($n = 13$ individuals) and female ($n = 11$) martens were 2.3 ± 1.4 ($n = 25$) and 1.3 ± 0.6 ($n = 18$), respectively ($t_{41} = 3.05$, $P < 0.005$).

Marten abundance ranged from 3–6 individuals (1.27–3.03/100 TN) over four live-trapping sessions at Saddle Lake from June–October 1999 (Table 1). Overall, 9 martens (4 M, 5 F) were captured 31 times with 78% of them recaptured at least once (Table 2). Six (2 M, 4 F) were present during ≤2 live-trapping sessions with 1 male present during all four (Table 2). Frequency of captures were similar to those recorded at Boodis Lake, ranging from 1–13 (median = 3.5) for males and 1–3 (median = 2) for females. Five of the 9 martens were residents (2 M, 3 F; Appendix I). Activity of resident females tended to be restricted to the periphery of the study area (Fig. 2B). Mean activity indices for male ($n = 4$) and female ($n = 5$) martens were 2.3 ± 1.4 ($n = 9$) and 1.0 ± 0.0 ($n = 9$), respectively ($t_{16} = 3.51$, $P < 0.005$).

Combining both sites, the mean (± SD) latency to initial capture (LIC) was 3.2 ± 1.9 days for males and 3.9 ± 1.8 days for females ($t_{60} = 1.98$, $P < 0.05$). The LIC for all martens was 3.6 ± 2.0 days during summer ($n = 20$), 3.3 ± 1.9 days during autumn ($n = 34$), and 4.3 ± 1.7 days during winter ($n = 8$). LIC was significantly higher during winter relative to summer ($t_{40} = 1.76$, $P < 0.05$). There were 24 instances where individual martens (32 M, 2 F) were caught on consecutive days (≤24 h) in different traps. The minimum 24-h straight-line distance between these capture sites averaged 1.2 ± 0.7 km.

4.2 Track Plates

Visitation rates after 1 day (TPI-1) averaged (± SD) 8.9 ± 9.8% at Boodis Lake (range = 0–25.0%, $n = 13$ surveys) and 8.1 ± 11.6% at Saddle Lake (0–29.7%, $n = 6$ surveys; Table 1). Seven of 19 TPI-1 surveys (4-Boodis Lake, 3-Saddle Lake) recorded no visitations. Visitation rates after 2 days (TPI-2) were less variable with average readings of 9.6 ± 7.7% at Boodis Lake (range 0–20.7%) and 7.9 ± 8.8% at Saddle Lake (0–23.0%).

Forty-two stations (4.2% of SN) recorded non-target visits at Boodis Lake, including 33 red squirrels (*Tamiasciurus hudsonicus*) and 9 fishers, and 24 (5.5% of SN) at Saddle Lake that were all red squirrels. Mice (likely deer mice, *Peromyscus maniculatus*) were present at many stations throughout most surveys and removed the bait in one instance. Flying squirrel (*Glaucomys sabrinus*) tracks (e.g., see Taylor and Raphael 1988) were present at three stations alongside red squirrel tracks at Boodis Lake. Fishers removed bait in all instances whereas red squirrels completely removed the bait on only ten occasions (33%) at Boodis Lake, with eight of the instances occurring during winter surveys. Four stations (0.6%) were rendered inactive by black bears (*Ursus americanus*) and two by raccoons at Boodis Lake. One station was knocked down (0.2%) at Saddle Lake by a raccoon.

Three female fishers (2 known adults) and 1 juvenile male fisher were released through track boxes following live capture at Boodis Lake. Tracks of some or all of these fishers appeared during track surveys but no adult male fisher was observed entering a box. During the February track survey, a male fisher made visits to the base of 5 stations, as determined by tracks in the snow. Neither of these visits resulted in the animal entering a box.

Of the track stations with adhesive tape applied, 54 had marten visitations with only eight (14.8%) instances of hair being retrieved. Three of these instances recovered a substantial number of hairs while the others retrieved only 1–4 hairs each. Of the 3 snow transect surveys conducted at Boodis Lake, the survey with the fewest tracks occurred during the coldest observed temperatures and followed a recent deep snowfall resulting in a large discrepancy in snow hardness (Table 3).

4.3 Track Discrimination

4.3.1 Identifying Martens by Sex

Fifty-one tracks representing 12 individuals (7 M, 5 F) were used in the following analyses (Appendix II). Six individuals were known adults (3 M, 3 F) and 2 were juvenile males, representing 82% of all tracks (34 adult [14 M, 20 F] and 7 juvenile male). Although there was much overlap between the ranges of male and female measurements (Table 4), the differences between sexes for all 11 measurements were significant ($F_{1,48} \geq 9.63$, $P \leq 0.003$). Within-individual variation (5.5%) was on average less than between-individual variation (9.6%) over the 11 measurements (Table 5). Variation for males was consistently higher than that for females for both within- (6.1 vs. 4.6%) and between-individuals (7.3 vs.

Table 1. Track plate surveys and corresponding marten abundance (A), Boodis Lake and Saddle Lake.

Date	Location	Activity	TPI-1[a] (%)	TPI-2[a] (%)	A (M, F)[b]	Effort[c]
17-18 Jul 1998[d]	Boodis	Track plates	0.0	2.7		74
19-28 Jul		Live-trap	–	–	2 (2, 0)	369
29-30 Jul[d]		Track plates	0.0	4.1		74
18-19 Aug[d]	Boodis	Track plates	2.7	4.1		74
21-28 Aug		Live-trap	–	–	2 (2, 0)	296
29-30 Aug[d]		Track plates	5.4	12.2		74
25 Sep-02 Oct	Boodis	Live-trap	–	–	8 (5, 3)	288
03-04 Oct		Track plates	24.4	18.5		82
14-21 Oct	Boodis	Live-trap	–	–	8 (3, 5)	296
22-23 Oct[d]		Track plates	25.0	20.3		82
29 Nov-06 Dec	Boodis	Live-trap	–	–	2 (2, 0)	293
07-08 Dec		Track plates	2.7	5.4		76
21-28 Jan 1999	Boodis	Live-trap	–	–	3 (1, 2)	291
30-31 Jan		Track plates	0.0	0.0		80
12-17 Feb	Boodis	Live-trap	–	–	2 (1, 1)	222
18-19 Feb		Track plates	7.6	6.3		80

Table 1. Continued.

Date	Location	Activity	TPI-1[a] (%)	TPI-2[a] (%)	A (M, F)[b]	Effort[c]
12-17 Mar	Boodis	Live-trap	–	–	3 (1, 2)	222
18-19 Mar		Track plates	13.7	20.7		78
07-14 Jun	Boodis	Live-trap	–	–	3 (1, 2)	280
15-16 Jun[d]		Track plates	11.1	8.3		72
25-26 Jun[d]	Saddle	Track plates	0.0	0.0		70
27 Jun-06 Jul		Live-trap	–	–	4 (1, 3)	316
07-08 Jul[d]		Track plates	0.0	0.0		70
21-26 Jul	Boodis	Live-trap	–	–	2 (2, 0)	210
27-28 Jul[d]		Track plates	0.0	2.7		74
13-18 Aug	Saddle	Live-trap	–	–	6 (3, 3)	198
19-20 Aug[d]		Track plates	10.8	8.1		74
05-06 Sep[d]	Saddle	Track plates	8.1	4.1		74
07 Sep-12 Sep		Live-trap	–	–	3 (2, 1)	198
13-14 Sep		Track plates	29.7	23.0		74
21-22 Sep[d]	Boodis	Track plates	23.7	19.7		76
23-28 Sep		Live-trap	–	–	8 (5, 3)	204

Table 1. Continued.

Date	Location	Activity	TPI-1[a] (%)	TPI-2[a] (%)	A (M, F)[b]	Effort[c]
13-18 Oct	Saddle	Live-trap	–	–	5 (3, 2)	178
19-20 Oct[d]		Track plates	0.0	12.2		74

[a] Track plate index, the proportion of active stations with marten tracks following 1 (TPI-1) and 2 days (TPI-2; see Section 3.4).

[b] Number of martens present during live-trapping session (male, female).

[c] Total number of trap-nights (TN) or station-nights (SN). Total live-trapping effort was 3,861 TN (Boodis Lake, 2,971 TN; Saddle Lake, 890 TN). Total track plate effort was 1,432 SN (Boodis Lake, 996 SN; Saddle Lake, 436 SN).

[d] Surveys from which discriminant function identifying martens by sex was applied.

Table 2. Residency times and live-capture frequencies of individual male and female martens, Boodis Lake and Saddle Lake.

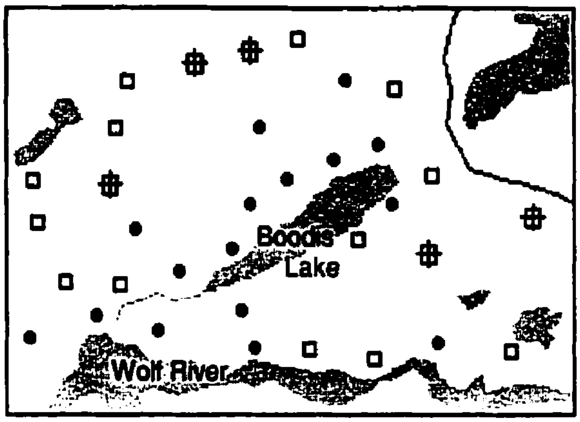
	Number of individual martens					
	Boodis Lake (13 M, 11 F)			Saddle Lake (4 M, 5 F)		
Capture frequency[a]	M	F	Cumulative percent	M	F	Cumulative percent
1	5	3	100	1	1	100
2	0	3	67	1	3	78
3	0	1	54	0	1	33
4	2	3	50	0	0	22
5	2	0	29	1	0	22
≥6	4	1	21	1	0	11
Residency[b]						
1	9	5	100	2	1	100
2	1	5	42	0	4	67
3	0	1	17	1	0	22
4	2	0	13	1	0	11
5	0	0	4	–	–	
6	1	0	4	–	–	

[a] Number of times individual martens were captured. During autumn dispersal (Sep-Nov), 63% of martens (5 of 9 M, 5 of 7 F) over both sites were captured more than once. Outside of autumn, 76% of martens (6 of 8 M, 7 of 9 F) were captured more than once.

[b] Number of live-trapping sessions (11-Boodis Lake, 4-Saddle Lake) in which individual martens were present.

Fig. 2. Capture sites of resident male (square symbols) and female (crosses) martens at (A) Boodis Lake (3 M, 3 F) and (B) Saddle Lake (2 M, 3 F). Remainder of trapping sites are represented by solid circles.

A.



B.

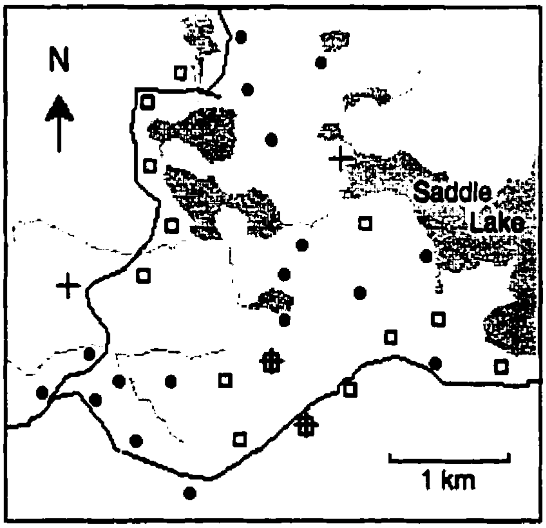


Table 3. Marten track density, daily temperature, and snow conditions during snow transect surveys, January–March 1999.

Date	Tracks	Track density[a]	Snow depth (cm)	Snow hardness[b]	Temperature (°C) min.	Temperature (°C) max.
29 Jan[c]	2	0.10	54.8 (1.4)	15.8 (0.2)	-23.0	-7.0
07 Feb	11	0.29	44.3 (1.3)	4.6 (0.1)	-14.0	-1.0
18 Feb[c]	5	0.14	43.8 (1.4)	6.7 (0.1)	-10.0	0.3
Mean	6.0	0.18				

[a] Proportion of 500-m long transect segments (*n* = 21) with tracks.

[b] Snow hardness was measured as the sinking depth (cm) of a 150-g wax-filled soft drink can dropped from 50 cm above snow level. Standard errors in brackets.

[c] Corresponds with TPI surveys conducted 30–31 January and 18–19 February, 1999.

6.3%). A nested ANOVA indicated that variation between sexes, individuals, and among all tracks accounted for an average (SD) 38.1 (17.1), 18.4 (8.0), and 30.3% (13.6%), respectively.

I3-D3 was highly correlated to I3-D2 ($r_{50} = 0.92$, $P < 0.001$) and their mean values (19.4 and 19.3 mm, respectively) were similar ($t = 0.36$, $P > 0.20$). Variable I3-D3 was eliminated because I3-D2 held more between-individual variation (Table 6) and it's distribution was less skewed (0.859 vs. 0.461) and was closer to being normally distributed ($W = 0.91$ vs. 0.95, $P < 0.001$ vs. 0.012). I3-D2 was not transformed as discriminant analyses can tolerate some skewness (Kleinbaum et al. 1988:560-2).

A significant discriminant model was derived from variables I4-D3 and I4-D1 (Wilk's lambda = 0.336, df = 2, $P < 0.001$) explaining 66.4% (Canonical R^2) of the total variance. The assumption of homogeneity of variance and covariance was satisfied (Box's M = 5.40, $P = 0.16$). The model, described by the equation "sex = 0.403(I4-D1) + 0.584(I4-D3) - 18.020," classified 94.0% of 50 cases correctly (92.3% males and 95.8% females, $F_{2,44} = 43.56$, $P < 0.001$), much greater than the expected 50.0% (Σ[prior probability]^2) based on pure chance. Group centroids were 1.35 and -1.41 for males and females, respectively. All 12 individual martens were classified by ≥75% of their tracks. Of the 3 tracks incorrectly classified, 2 were from males (adult and juvenile) and 1 was from an adult female. Cross-validation correctly classified 94.0% of the cases, 92.3% males and 95.8% females.

The chance of obtaining tracks with I4-D1 and I4-D3 present during track plate surveys was low in wet conditions, when chalk was used as the tracking substrate (vs. soot), and during winter (Jan–Mar). In surveys using soot and when <10 mm of rain fell, martens left (± SD) 3.9 ± 1.7 visible tracks per box ($n = 47$ boxes), compared to 2.9 ± 1.2 tracks per box ($n = 19$) during two surveys where >10 mm of rain fell. Overall, 3.6 ± 1.6 visible tracks were present in each of 66 boxes with marten tracks, with 37.9% of the boxes having one

Table 4. Means, ranges, and 95% confidence intervals around track measurements (mm) representing 7 male (*n* = 24 tracks) and 5 female (*n* = 23) martens.

Measurement[a]		Range	Mean[b]	SD	95% C.I.
D1-3	(M)ale	11.9 – 18.0	15.2	1.7	14.5 – 15.9
	(F)emale	10.8 – 17.6	13.9	1.5	13.3 – 14.6
D1-4	M	13.2 – 23.5	18.6	2.4	17.5 – 19.6
	F	13.9 – 21.0	17.2	1.9	16.3 – 18.0
I3-D1	M	10.0 – 15.9	12.6	1.5	12.0 – 13.2
	F	9.6 – 11.8	10.5	0.6	10.2 – 10.7
I3-D2	M	16.9 – 24 .9	20.6	1.9	19.8 – 21.4
	F	16.0 – 19.0	17.8	0.8	17.5 – 18.2
I3-D3	M	17.2 – 24.4	20.6	1.8	19.9 – 21.4
	F	16.9 – 19.9	18.2	0.7	17.9 – 18.5
I3-D4	M	13.8 – 18.0	15.3	1.3	14.8 – 15.9
	F	12.3 – 15.5	13.8	0.8	13.4 – 14.1
I4-D1	M	11.1 – 15.6	12.5	0.9	12.1 – 12.9
	F	6.7 – 12.5	10.3	1.2	9.8 – 10.9
I4-D2	M	17.8 – 26.4	23.0	1.7	22.3 – 23.7
	F	18.4 – 22.3	20.3	1.0	19.9 – 20.7

Table 4. Continued.

Measurement[a]		Range	Mean[b]	SD	95% C.I.
I4-D3	M	21.5 - 27.5	24.5	1.5	23.9 - 25.1
	F	19.5 - 23.1	21.3	1.0	20.8 - 21.7
I4-D4	M	16.4 - 26.1	21.1	1.9	20.3 - 21.9
	F	15.3 - 22.0	18.9	1.7	18.2 - 19.6
D2-4	M	11.2 - 17.3	14.3	1.7	13.5 - 15.0
	F	10.4 - 16.4	13.2	1.6	12.5 - 13.9

[a] See Fig. 1 for description of measurements.

[b] All group means different ($P \leq 0.03$ for all univariate F).

Table 5. Variation in male (*n* = 24 tracks) and female (*n* = 23) marten track measurements.

Measurement[a]	Measurement variation (%)[b]					
	Within-individual CV			Between-individual CV		
	Male	Female	Overall	Male	Female	Overall
D1-3	7.0	7.7	7.3	8.4	8.9	10.3
D1-4	7.6	5.5	6.7	9.7	8.9	11.1
I3-D1	5.5	6.0	5.7	10.3	5.1	11.0
I3-D2	5.9	2.9	4.6	7.6	3.1	8.9
I3-D3	5.7	3.1	4.6	6.8	1.6	7.3
I3-D4	5.3	4.3	4.9	7.1	5.9	8.0
I4-D1	6.0	7.0	6.4	3.0	11.2	10.4
I4-D2	6.6	2.2	4.8	5.5	1.9	7.7
I4-D3	3.7	2.6	3.3	4.1	3.2	7.8
I4-D4	6.5	4.3	5.6	7.1	8.7	9.8
D2-4	7.4	5.0	6.4	10.6	10.6	12.8
Mean	6.1	4.6	5.5	7.3	6.3	9.6

[a] See Fig. 1 for description of measurements.

[b] Within-individual CV's represent the average of individual CV's. Between-individual CV's were calculated using the average of individual measurement means.

track where variable I4-D1 and I4-D3 could be clearly measured, and 21.2% with ≥2 usable tracks. When excluding two surveys with tracks distorted by wet conditions, 80.9% of the boxes had ≥1 measurable track, as opposed to 5.3% in the wet conditions.

Using the equation to identify martens by sex, male tracks were identified in 11 of a possible 13 TPI-2 surveys (85%), while female tracks were identified in 2 of 8 possible surveys (25%). Only surveys where uniformly clear impressions were obtained were used in the analysis. Calculations were based on the occurrence of male and female martens during surveys as determined through live-trapping (Table 1).

4.3.2 Identifying Individual Marten

Six of 11 track measurements (Table 6) could identify 12 individual martens (7 M, 5 F) from ≥67% of grouped tracks (Table 7). Individual grouped track centroids showed separation of adults from juveniles (Fig. 3). When soot was used as the tracking substrate, 48.5 % of track boxes with marten tracks had ≥1 usable track (i.e., all 6 measurements present). When excluding two surveys with tracks distorted by wet conditions, 67.4% of the boxes had ≥1 usable track or 21.7% with ≥2 usable tracks.

4.3.3 Comparing Fisher and Marten Tracks

Fourteen usable tracks were available from 3 adult male martens. Twelve usable track impressions were obtained from 2 female fishers. One female of adult weight (2,275 g) and with large nipples was first caught 24 July indicating that it had likely been a breeder (Frost et al. 1999) and was >2 years old. Although the other female, first caught 20 October, was of adult weight (2,255 g), it is unclear whether it was >1 year old because females may attain adult body size by early autumn (Powell 1993). Averages of 8 of 11 measurements were not different between the 2 female fishers ($1.82 \leq t_{6\text{-}9} \geq 0.21$, $P > 0.05$). The 3 other measurements (I3-D1, I3-D2, and I4-D1) were significantly larger on the confirmed adult female ($2.73 \leq t_{8\text{-}10} \geq 2.46$, $P < 0.05$).

There was little overlap in 95% confidence intervals around the 11 measurements for marten and fisher tracks. Confidence intervals around I4-D1 and I4-D3, used to discriminate martens by sex, did not overlap between the male martens and the known adult female fisher. Only 1 of 6 measurements used to identify marten individuals (D2-4) had a confidence interval that overlapped.

Zielinski and Truex's (1995) discriminant function incorrectly classified the adult female fisher in 3 of 4 cases with values ranging from -9.4 to 0.1. The female fisher of unknown age ($n = 5$ tracks) was also incorrectly classified with function values of -28.6 to -11.7. The function correctly classified the 3 adult male martens ($n = 9$) with values ranging from -39.4 to -26.1.

4.4 TPI vs. Marten Abundance

Combined surveys (Table 1) yielded significant correlations between marten abundance and TPI-1 ($r = 0.63$, $P = 0.004$) and TPI-2 ($r = 0.55$, $P = 0.02$). Further analyses were conducted using the less variable TPI-2 which provided fewer zero readings (see Section 4.2). Marten abundance explained 20.0% of variation in arcsine-transformed TPI-2 readings ($F_{1,17} = 4.34$, $P = 0.05$, $R^2 = 0.20$) with no additional effect of site ($F_{1,16} = 1.22$, $P = 0.29$). However, the number of males present (i.e., male abundance) explained 32.3% of variation in TPI-2 ($F_{1,17} = 8.11$, $P = 0.01$) with no additional improvement to the model by adding female abundance ($F_{1,16} = 0.01$, $P = 0.92$). Further analyses were conducted using the TPI-2 adjusted for male visitations.

Distorted tracks due to season, wet conditions, or tracking substrate used (see Section 4.3.1) limited the ability to separate male and female tracks restricting sample size to 13 surveys (8-Boodis Lake, 5-Saddle Lake). At least one male was present during all 13 surveys while one or more females were present during only eight (Table 1). The surveys were conducted between June and October 1998-99 (Table 1). Male TPI-1 and TPI-2

Table 6. Contribution of track measurements to discriminant models describing individual martens (7 M, 5 F).

Measurement[a]	Function loadings[b]			
	D. F. 1	D. F. 2	D. F. 3	D. F. 4
I3-D1	0.778	0.068	0.316	-0.497
D2-4	0.276	0.571	0.431	0.592
I4-D3	0.502	-0.115	0.593	0.149
I3-D2	0.538	0.145	0.191	-0.181
I3-D4	0.489	0.075	0.084	0.387
D1-3	0.200	0.251	0.557	-0.023
Eigenvalue	7.762	3.600	2.404	0.708
Canonical R^2	0.885	0.783	0.706	0.415
% of variance	51.6	23.9	16.0	4.7
Wilks' lambda	0.003	0.023	0.105	0.359
df	66	50	36	24
P	< 0.001	< 0.001	< 0.001	0.04

[a] See Fig. 1 for measurement descriptions. $P \leq 0.001$ for all univariate F.

[b] Pooled within-groups correlations between measurements and discriminant functions. First four models presented.

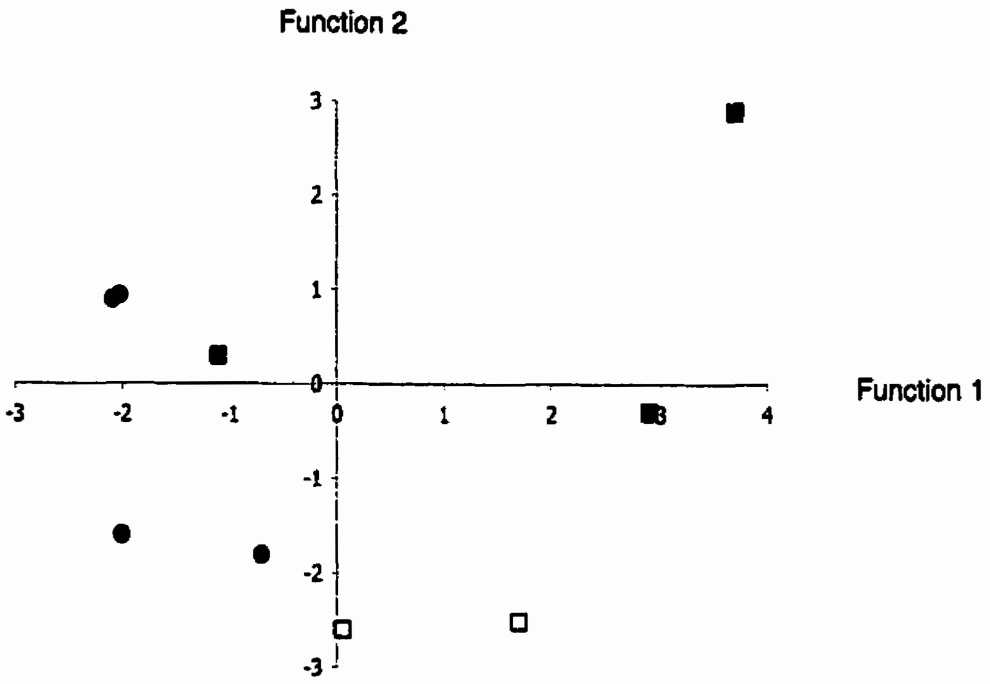
Table 7. Contribution of track measurements to the step-wise discrimination[a] of 12 martens (7 M, 5 F).

Measurement[b]	% of 51 tracks correctly classified	No. marten identified by Grouped tracks (male, female) (≥33%)	(≥67%)
I3-D1	41.2	5 (3, 2)	3 (2, 1)
Add D2-4	58.8	9 (5, 4)	5 (3, 2)
I4-D3	70.6	12 (7, 5)	7 (3, 4)
I3-D2	76.5	12 (7, 5)	8 (4, 4)
I3-D4	78.4	12 (7, 5)	9 (4, 5)
D1-3	88.2	12 (7, 5)	12 (7, 5)

[a] Each of six models generated used a different set of measurements ($P < 0.001$ for F-tests for all models).

[b] See Fig. 1 for description of measurements.

Fig. 3. The discriminant space of tracks correctly grouped to 10 martens using 6 measurements. Group centroids for male (square symbols) and female (circles) martens using the first 2 of 6 discriminant functions evaluated at individual track means are plotted. Known adults (3 M, 3 F; solid symbols) and juveniles (2 M; open) are represented. Juvenile tracks were collected 17 August.


Function 2
Function 1
3
2
1
0
-1
-2
-3
-3
-2
-1
0
1
2
3
4

visitation rates averaged (± SD) 6.5 ± 8.6% and 7.4 ± 6.5%, respectively, compared to 0.4 ± 0.8% (TPI-2) for females. A regression model incorporating TPI-2 and male abundance was developed ($F_{1,11}$ = 17.20, P = 0.002, R^2 = 0.610) with normally distributed residuals (W = 0.89, P = 0.09). Maximum temperature over 2-day survey periods (range = 3.4–27.8 °C, median = 24.0°C) had a potential effect on the model ($F_{1,10}$ = 4.12, P = 0.07, R^2 = 0.72), as it was negatively correlated with TPI-2 (r = -0.71, P = 0.006). There were no additional effects (P > 0.07) on the model from other independent variables tested (total precipitation, minimum temperature, site, and TPI timing).

Confidence intervals around the estimated number of male martens present using TPI-2 encompassed actual values in seven (53.8%) of the 13 estimates (Table 8). The predictive model for the number of males present during a survey is described by the equation "estimated male abundance (Â) = 0.612 + 0.218(adjusted TPI-2)."

CV values used in the power analyses were computed using the mean square error (18.015) and slope estimate (4.654 x no. males) from the model of TPI-2 versus male abundance (see Table 8). They ranged from 8.8–30.4%, representing 1–12 replicate TPI-2 surveys and an abundance level of 3 male martens (0.3/km^2) per sampling unit. TPI-2 surveys had low power to detect 20–40% declines (0.6–1.2 males) in abundance annually over three sampling occasions (i.e., 2 yr) with α = 0.05 (Fig. 4A). Power could be increased by increasing the probability of committing a Type I error to 0.20 (Fig. 4A) or by extending the survey period to four sampling periods (Fig. 4B).

Table 8. Estimating male abundance from 2-day track plate surveys (TPI-2) using inverse prediction.

TPI-2[a]	Location (survey no.)[b]	Abundance	Predicted abundance[c]	Relative error (%)[d]	90% Confidence intervals around Â	
					lower	upper
2.7	Boodis (1)	2	1.2	-40.0	0.3	1.7
4.1	Boodis (2)	2	1.5	-25.0	0.7	2.0
4.1	Boodis (3)	2	1.5	-25.0	0.7	2.0
12.2	Boodis (4)	2	3.3	65.0	2.8	4.3
19.0	Boodis (6)	3	4.7	56.7	3.9	6.7
8.3	Boodis (11)	1	2.4	140.0	2.0	3.0
0	Saddle (12)	1	0.6	-40.0	-0.7	1.3
0	Saddle (13)	1	0.6	-40.0	-0.7	1.3
2.7	Boodis (14)	2	1.2	-40.0	0.3	1.7
8.1	Saddle (15)	3	2.4	-20.0	1.9	2.9
4.1	Saddle (16)	2	1.5	-25.0	0.7	2.0
19.7	Boodis (18)	5	4.9	-2.0	4.0	7.0
10.8	Saddle (19)	3	3.0	0.0	2.5	3.8

[a] Proportion (%) of track plate stations with male marten tracks after 2 days.

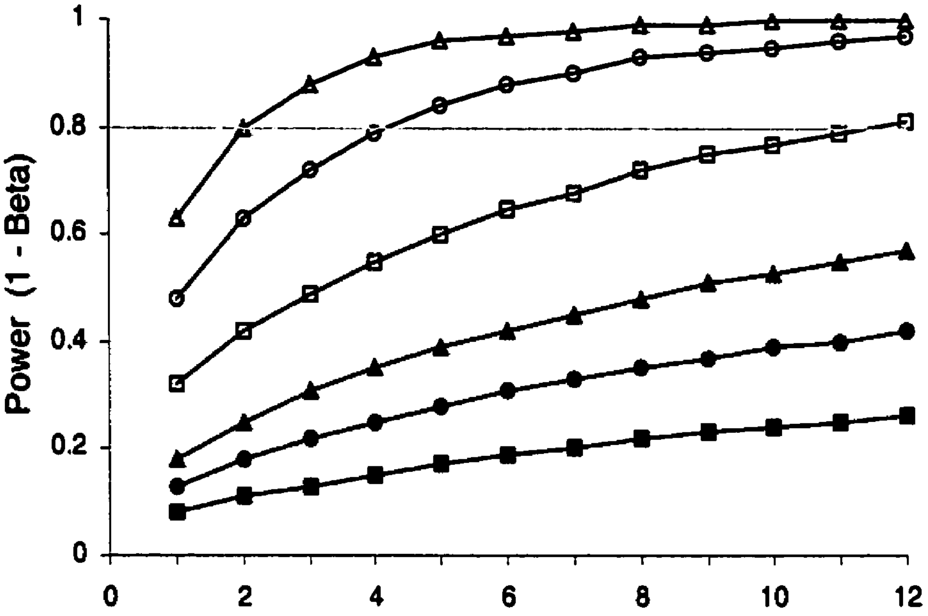
[b] Refers to order in which track plate surveys were conducted (Table 1).

[c] Estimates of male abundance (Â) using "TPI-2 = 4.654(abundance) – 3.013." The prediction equation generated by regressing Â on TPI-2 is "Â = 0.612 + 0.218(TPI-2)."

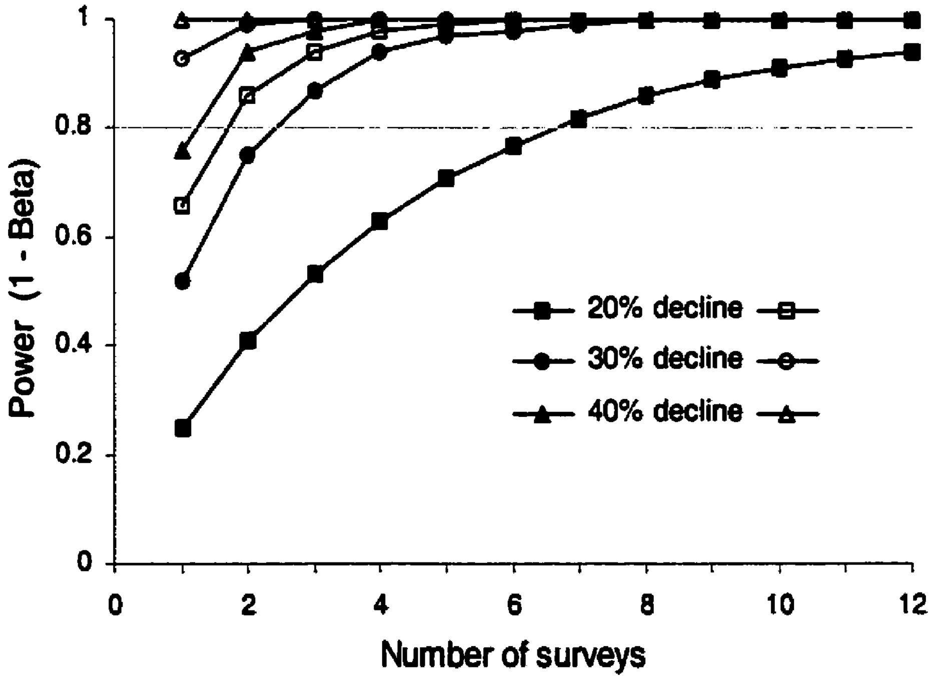
[d] Relative error = ([Â - abundance] / abundance) × 100%.

Fig. 4. Relationship between the number of replicate TPI-2 surveys and power to detect 20, 30, and 40% annual declines in male abundance over three (A) and four (B) sampling periods with 3 male martens (0.3/km^2) present on a sampling unit. Alpha values of 0.05 (solid symbols) and 0.20 (open) are represented.

A.


Power (1 - Beta)
1
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
12

B.


Power (1 - Beta)
1
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
12
Number of surveys
20% decline
30% decline
40% decline

5.0 DISCUSSION

5.1 Marten Abundance

The inquisitive nature of martens makes them vulnerable to capture (Banci and Proulx 1999) lending to perceived high visibility during live-trapping studies. A high capture probability of both sexes may depend on the placement of traps (i.e., grid vs. transect; Buskirk and Lindstedt 1989), as male home range size is typically double that of a females (Buskirk and McDonald 1989). This discrepancy in home range size may explain the male-biased capture ratio commonly reported in trapped mustelid populations (Buskirk and Lindstedt 1989). The sex ratio of captured animals during this study was 1:1 (17 M, 16 F), indicating that the intensive live-trapping effort put forth was probably sufficient in capturing all individuals present. Live-trapping sessions of ≤6 days have been used to obtain indices of marten abundance (Archibald and Jessup 1984, Thompson and Colgan 1987, Hargis and Bissonette 1997) with the assumption that most, if not all, martens during a particular survey had been caught. However, the precision of abundance levels (i.e., minimum number alive, MNA) could not be determined because capture rates were too low to use mark-recapture models (Otis et al. 1978, White et al. 1982, Pollock et al. 1990, Boulanger and Krebs 1994). Because of this, MNA is generally not recommended in place of population estimates (Thompson et al. 1998:83), although it has been used as a reference for comparison to potential mammalian population indices (Thompson et al. 1989, Smith et al. 1994, Mallick et al. 1998). There is evidence supporting a strong relationship between marten MNA and mark-recapture estimates (Flynn and Schumacher 1997).

There is nothing to suggest that the intensive live-trapping effort did not register all animals during the study as overall capture rates were relatively high (Raphael 1994, and references therein). Misidentification and behavioural changes associated with the method of marking individuals may affect capture probabilities (Thompson et al. 1998:86-7). Individuals were easily identified and did not appear to be affected by ear notching as 70%

of all martens caught were recaptured at least once, 76% (6 of 8 M, 7 of 9 F) outside of the autumn dispersal period.

The range in density indices over both sites (0.2–0.8 marten/km^2) was similar to other trapped areas (Katnik et al. 1994, Flynn and Schumacher 1997). In north-central Ontario, Thompson and Colgan (1987) reported spring and fall marten densities of 1.9 and 2.4/km^2 when prey was relatively abundant, to 0.4 and 0.8/km^2 when prey levels were much lower. The increase in marten abundance observed during both autumn periods at Boodis Lake was likely due to dispersal of juveniles from surrounding areas (Hawley and Newby 1957, Archibald and Jessup 1984) and local recruitment. This increase was not observed until November at Saddle Lake when a trapper caught 3 juvenile males within the core of the sampling unit.

5.2 Track Plates

Track surveys had similar visitation rates after the first and second days (8–10%), but were less variable (CV = 86 vs. 116%) after 2 days (TPI-2) with fewer zero readings (3 vs. 7) indicating greater precision (Thompson et al. 1998:46). Travaini et al. (1996) reported no differences in red fox visitation rates after 1 and 2 days using scent-station surveys. Martin and Fagre (1988) showed similar results for coyote (*Canis latrans*) after 1–6 survey days. It is difficult to draw comparisons with track plate surveys targeting martens (e.g., Zielinski et al. 1997, Foresman and Pearson 1998) because the number of stations used and survey length varies considerably. An average latency to first detection (LTD) at covered track stations of 3.3 days (Foresman and Pearson 1998) and 2.4 days (Zielinski et al. 1997) was documented in the western United States. Surveys had ≥4 stations spaced at 800 m and checked at 2-day intervals. Their results indicate that potentially few visitations may occur within the first 2 days of a survey. More than 84% of the 19 track surveys conducted during this study had ≥1 visitation after 2 days, supporting the premise that decreasing the distance between, and increasing the number of, stations decreases the LTD. Different track station designs may also have an effect on the LTD. Foresman and Pearson (1998) reported shorter LTD's with open versus covered track plates and suggested martens may initially avoid entering the latter design. Since martens obtain a reward of chicken bait, conducting many surveys over a short period may alter their behavior to track stations, leading to habituation. On the other hand, martens may react differently if no reward is given (i.e., olfactory attractant used), potentially decreasing the novelty of track stations (Robson and Humphrey 1985). Nonetheless, a scented lure (e.g., skunk urine) may increase visitation rates. Like most mustelids, martens are very inquisitive and may be attracted to various baits, lures, and novel objects (Kucera et al. 1995, Zielinski 1995).

Most individual martens at Boodis Lake were caught during ≤2 of the 11 live-trapping sessions with only 1 male present during 6 sessions minimizing the extent in which the same individuals were present during multiple track plate surveys. All but 1 marten at Saddle Lake were present during ≤2 of the 4 live-trapping sessions. A resident adult male marten, present during all 6 track plate surveys conducted at Saddle Lake, is suspected of making many station visits during the fifth survey. Very few stations were visited 1 month later during the final survey with the resident male maintaining placement within the live-trapping grid indicating it may not have been habituated to the baited stations. This event reflects the variability commonly associated with population indices, it either be recording tracks at scent stations (Smith et al. 1994) or counting transect-crossings (Pulliainen 1981, Thompson et al. 1989, Beier and Cunningham 1996). Most of the stations visited by this male were not visited earlier by a marten and were on the same side of trails and roads at similar depths (median = 11 m, range = 2–87 m). Since trails and roads appeared to be used to access track stations, placing stations at varying depths from trails and roads and on opposing sides may minimize multiple visits (OMNR 1990). In one other survey, it appeared that a resident adult male made multiple visits during the March survey at Boodis Lake. This animal was first observed in January replacing 2 smaller males that were present in December. Since there were no visitations during the January survey, and only 6 visitations during the February survey, there is little chance that habituation occurred. It appeared that the marten located track boxes from along established snowshoe and snowmobile trails.

Although a small sample size did not allow the effects of extrinsic factors (e.g., temperature) to be fully tested on visitation rates, some tentative inferences can be drawn from this study. There is evidence that visitation rates may have been negatively affected by high temperatures (up to 28°C) attributable to a decrease in overall activity (Zielinski et al. 1983). No visitations occurred during a January survey where the coldest temperatures were recorded (-15.2°C). Winter conditions (i.e., low temperature) have been shown to reduce daily marten activity levels (Thompson and Colgan 1994) and average home range size (O'Doherty et al. 1997) and limit activity to certain habitats (Soutiere 1979) relative to summer conditions. A factor that should be taken into account, relative prey availability, may contribute to variable home range sizes (Erlinge and Sandell 1986, Thompson and Colgan 1987) and a subsequent variability in the number of track stations encountered. Determining factors that have effects of visitation rates will allow surveys to be standardized minimizing index variation.

A small track box design appeared to minimize non-target visitations, with the exception of red squirrels, which seldom removed the bait, except during winter surveys. Although not tested, the smaller track box and arboreal placement appeared to reduce the incidence of visitations by non-target species (e.g., striped skunks, raccoons, and red foxes). While female fishers entered track boxes and have been known to use tree cavities as denning sites with entrance areas as small as 47 cm^2 (Paragi et al. 1996a, Powell et al. 1997), it is unclear whether this design is suitable for the much larger adult male fisher.

5.3 Track Discrimination

Track plate impressions made by martens were easily identified for the most part, but confusion may occur if marten range is sympatric with that of the fisher (Zielinski and Truex 1995). No other tracks should be confused with those of martens. As Zielinski (1995) reported, soot was superior to chalk in providing the clearest track impressions. Poor impressions (i.e., outline of track pads were obscure) were obtained using either substrate during heavy rainfalls when martens would enter a box with excessively wet feet. An alternative tracking substrate such as an ink solution (Mabee 1998) may provide higher quality impressions during wet conditions. Poor impressions obtained during winter surveys (Jan–Mar) may be attributed to added hair growth on the soles of the marten's feet and the use of chalk as a tracking substrate.

A function derived to separate adult male martens from adult female fishers (Zielinski and Truex 1995) proved unreliable in identifying tracks from a known adult female (>2 years old). In lieu of this, questionable tracks were compared to representative tracks obtained from female fishers and the adult male martens. The model described by the function was generated using fisher tracks from 6 captive fishers originating from Massachusetts (*M. pennanti pennanti*) among tracks from the smaller California subspecies (*M. pennanti pacifica*; Zielinski and Truex, 1995). It is apparent that a larger effort is required to collect track impressions from animals representing a range of ages from across both species' ranges. Ideally, track samples should be obtained from individuals during distinct times of the year (e.g., can juvenile female fishers be separated from adult male martens during September–October, i.e., when the fishers are 6–7 mos old). This information may allow track plate surveys to be timed according to periods during the year when tracks of all martens and fishers are most discernable. The use of adhesive tape inside track boxes to obtain hair samples, as an attempt to separate fishers from martens, proved ineffective. Constricting the entrance to a track box may force animals to rub against the adhesive tape increasing the chance that hairs will be left (e.g., Foran et al. 1997). This, however, may decrease visitations if martens and fishers are discouraged from initially entering a track box with a constricted entrance (Foresman and Pearson 1998).

Martens were identified by sex and as individuals from tracks using discriminant analyses incorporating 2 and 6 measurements, respectively. The model identifying martens by sex, described by the equation "0.403(I4-D1) + 0.584(I4-D3) - 18.020," with values >0 being male and <0 female, correctly classified 12 martens (7 M, 5 F) from ≥75% of their tracks. Six measurements correctly identified all 12 individuals from ≥67% of their tracks. Although these results are positive, further research incorporating a larger sample of tracks may identify measurements with greater discriminating power. Preliminary evidence suggests that the 6 measurements used to identify individuals have potential to differentiate juveniles from adults during late summer (i.e., mid-Aug). Identifying martens by sex or as individuals may allow track plate surveys to be used in habitat-use and demographic studies. For example, females continually identified at track stations in particular habitats may signify possible habitat affinities without the use of costly mark-recapture and radio-telemetry techniques.

Identifying individual martens at track stations requires tracks from 2 stations (i.e., group A and B, see Smallwood and Fitzugh 1993). If there is successful discrimination between the 2 groups using the 6 measurements then it can be concluded that 2 individuals were present. Smallwood and Fitzugh (1993) recommended the cutoff be ≥65% (i.e., % of grouped tracks successfully separated) for concluding 2 individuals are present when the number of tracks from both groups exceeds 5. However, the number of tracks acquired for analyses (i.e., group A and B pooled) should be at minimum four times the number of measurements used (Williams et al. 1990, Smallwood and Fitzhugh 1993). Under this requirement, ≥24 tracks should be obtained from 2 boxes (e.g., ~12 tracks per box) for individual discrimination and ≥8 tracks per box for discriminating male and female martens.

Increasing track box length (i.e., increase tracking surface) may increase the number of tracks obtained substantially beyond the 2 identifiable tracks attained on average.

5.4 TPI as a Population Index

Thorough guidelines have been drafted for the implementation and analysis of track plate surveys to index the occurrence of marten (Zielinski 1995, Zielinski and Stauffer 1996). However, prior to using an index to assess population trends, the relationship between the proposed index and population size has to be proven consistent (Roughton and Sweeny 1982, Minser 1984, Bart 1995). An ideal index should detect a consistent proportion of the target population with as little variance as possible (Greenwood 1996, Thompson et al. 1998:77-83). Heterogeneity between individuals in catchability (Caughley 1978:134-5, Pollock et al. 1990) may confound the relationship between an index and the actual population size. The two instances where many station visits were made by individual martens (see 5.2) could be removed, increasing the amount of variation in abundance explained by the TPI (e.g., Diefenbach et al. 1994). This, however, may result in natural index variation being lost, inflating the strength of the index (Diefenbach et al. 1994). Track stations may be placed further apart to minimize multiple visits but at a sacrifice to the number of stations present in an individual's home range. Since effort was made to keep martens from becoming habituated to track stations and surveys from becoming saturated (i.e., having ≥1 marten visit many stations), 2 days may be an optimal survey length. However, there was a clear discrepancy in male and female detection rates.

Male abundance explained 61% of variation in TPI-2 readings adjusted for male visitations. This was expected as male home range size is nearly double that of a female (Buskirk and McDonald 1989), making males more vulnerable to capture in a relatively short period of time (Soukkala 1983, Buskirk and Lindstedt 1989, Hodgman et al. 1994). This was supported during live-trapping sessions as males were caught more frequently, had larger activity indices, and a significantly lower LTC. Females, on the other hand, were seldom detected at track stations or caught in live-traps within 2 days. Low number of visits by females may be due, in part, to their reluctance to enter a track box in an initial visit (Foresman and Pearson 1998). This sex-biased response to live-traps was observed in a raccoon population through radio-telemetry (Gehrt and Fritzell 1996). Kelly (1977, cited in Buskirk and Lindstedt 1989) suggested male fishers were more apt to investigate and enter traps than females. Extending survey length to increase female visitations may not be an option if the survey becomes saturated with male visits (e.g., see Caughley 1978:18). This problem may be alleviated by altering the pattern of track station distribution from a grid pattern to, for example, independently-spaced transects (Buskirk and Lindstedt 1989) analogous to scent-station surveys (Roughton and Sweeny 1982, Sargeant et al. 1998).

While a positive relationship ($r = 0.78$) was found between male abundance and the TPI-2 adjusted for male visitations, the index predicted male abundance within 90% confidence intervals in just 7 of 13 estimates. Since relatively few martens, notably males, may have home ranges entirely within a sampling unit (~10.5-km^2), precision of TPI-2 surveys may be increased by increasing the size of the sampling unit. This would increase the chance that individuals would be within the boundaries of a sampling unit over the course of replicated surveys. An analysis of survey power showed that annual declines in male abundance of 30% (~1 male) can be detected with ≥4 TPI-2 surveys (35–41 stations) per sampling occasion over 3 sampling periods with $\beta = 0.20$ (i.e., power of 80%) and $\alpha = 0.20$. Increasing the level of confidence to 95% increased the number of replicate surveys required (≥12 TPI-2 surveys) and greatly reduced survey power (~40%). While the number of replicate surveys required appears reasonable, most population index surveys are conducted once annually (Konze and McLaren 1997, Sargeant et al. 1998). The number of stations required (>35) may logistically limit the use of track plate surveys on a larger scale. Zielinski (1995) recommended at least 6 stations be activated per sampling unit for a minimum 12 days. If detection is the only goal then few stations activated over 1–3 weeks is acceptable. However, there will be no resolution at the level of the sampling unit (Diefenbach 1992:65-66) over large areas (Zielinski and Stauffer 1996) with few stations.

Sample size estimates were based on 3 male martens present on a sampling unit (10–11 km^2) during summer and autumn. One to 5 males (0.1–0.5/km^2) were present during any one survey. The highest numbers were present during autumn surveys, coinciding with the major dispersal period (Hawley and Newby 1957, Archibald and Jessup 1984). Surveys were conducted in areas where martens are harvested annually on a quota basis. Katnik et al. (1994) reported a density of 0.14 resident adults (male + female) in a heavily harvested population. In unharvested populations, the number of males present within a sampling unit may be much higher, exceeding 7 resident males or 0.7/km^2 (Soutiere 1979). Movement patterns may differ in unharvested populations with a lower annual turnover of resident individuals ultimately affecting the relationship between the TPI-2 and abundance, and masking extrinsic factors that may contribute to differences in index readings (Sargeant et al. 1998). However, Katnik et al. (1994) reported martens exhibiting intra-sexual territoriality and displaying a lack of transient behavior in a heavily exploited population. Most notably, male home range boundaries were static during the breeding season and distance traveled did not vary.

Track plate surveys cannot be used to identify the population status of sampling units (i.e., high or low abundance) because of the discrepancy in male and female detection rates. Further study is required to test sampling units of variable size and shape (see Buskirk and Lindstedt 1989, Thompson et al. 1998:48) in an attempt to increase female visitations without increasing male visits further, potentially saturating surveys. Track plates do have the potential to index male abundance using multiple surveys per year. Activation of 35-41 track stations over 2 days provided reasonably precise male-adjusted index readings (CV = 86%) which were strongly related ($R^2 = 0.61$) to male abundance. Surveys should be restricted to summer and autumn periods until further information is acquired on the effects of seasonal conditions, namely winter. Surveys conducted during summer will allow the residual male component of a population to be detected. That is, the individuals present post-winter and post-harvest in exploited populations. The dispersal period of mostly juvenile individuals during early to late autumn (Hawley and Newby 1957, Archibald and Jessup 1984) may allow recruitment to be indexed.

Caution is warranted until TPI-2 surveys are conducted in other habitats (e.g., within the Boreal Forest Region) and at higher population densities (>0.8 martens/km^2) to determine if comparable relationships are found between the index and abundance. If similar relationships are found, sample size estimates (i.e., the number of sampling units) can be made (e.g., Hayek and Buzas 1997:107-8) on a large scale (e.g., regional or provincial). To date, only the occurrence (i.e., presence or absence) of a species has been used to determine the number sampling units required within a certain level of power (Beier and Cunningham 1996, Zielinski and Stauffer 1996).

5.5 Conclusions

1. Track plate surveys (35–41 stations) were less variable and more apt to have ≥1 marten detection after 2 days (TPI-2) vs. 1 day (TPI-1).
2. Discriminant models were derived allowing sex and individual identification of martens from track impressions using 2 and 6 measurements, respectively.
3. A larger track surface is required to attain an adequate number of tracks for discriminant analyses.
4. Track station placement needs to be evaluated to determine if multiple visitations can be minimized (e.g., placing stations at varying depths and opposing sides from trails).
5. Female detection rates were relatively low, limiting the use of track plate surveys to identify the population status of sampling units (~10.5 km^2).
6. Further study is required to test sampling units of variable size and shape in an attempt to increase female visitations without increasing male visitations further.
7. TPI-2 surveys, adjusted for male visits, may be used to index male abundance.
8. Annual declines of 30% in male abundance may be detected with ≥4 TPI-2 surveys per sampling period over three sampling occasions (i.e., 2 yr).
9. Relationship between TPI-2 and marten abundance needs verification at high population densities (e.g., unharvested populations with >0.8 martens/km^2).
10. Surveys are required on multiple sites in conjunction with measures of marten abundance to determine sampling unit requirements on a regional and provincial scale.

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APPENDIX I

Information on marten captured at Boodis Lake (BD) and Saddle Lake (SA)

Animal No.	Study area	Sex	Age[a]	Body weight (g)[b]	No. captures	Residency[c]	Date first captured	Status[d]
R1-L1	BD	M	A	925	17	Resident	19 Jul 98	Harvest
R2	BD	M	A	975	9	Resident	21 Jul	Harvest
L2	BD	F	J	555	2	Temp.	25 Sep	Harvest
R3	BD	M		695	1		27 Sep	
R3-NN	BD	F	A	655	3	Temp.	29 Sep	Harvest
R1	BD	F	A	635	4	Temp.	30 Sep	Harvest
R3-L3	BD	M		695	3	Temp.	30 Sep	
R1-R3	BD	M		755	1		01 Oct	
L1-L2	BD	F	A	595	6		14 Oct	Harvest
R3-L1	BD	F	A	625	1		18 Oct	Harvest
R2-R3	BD	M		735	6		30 Nov	
R1-R2	BD	M		715	4		30 Nov	
L2	BD	F		–	6	Resident	23 Jan 99	
L1	BD	F		635	2	Resident	26 Jan	
L1-L3	BD	M	A	875	14	Resident	27 Jan	
R2-L1	BD	F	A	620	3	Resident	07 Jun	
R2-L3	BD	F	A	720	1		10 Jun	
R3-L3	SA	F	A	650	3	Resident	29 Jun	Harvest

Appendix I. Continued

Animal No.	Study area	Sex	Age[a]	Body weight (g)[b]	No. captures	Residency[c]	Date first captured	Status[d]
R1-R3	SA	F	A	655	3	Resident	01 Jul 99	
L3	SA	M	A	1000	13	Resident	01 Jul	Harvest
R1-R2	SA	F		575	2	Temp	04 Jul	
R3-L2	BD	M		–	1		21 Jul	
L1-L3	SA	F		575	1		14 Aug	
R2-L2	SA	F		575	2	Resident	15 Aug	
R2-R3-L2	SA	M	J	795	1		17 Aug	Harvest
R2-L1-L2	SA	M	J	775	5	Resident	17 Aug	Harvest
R2-L2	BD	M	J	625	5		23 Sep	
R3-L1	BD	M		–	4		23 Sep	
R2-R3-L2	BD	M	A	875	1		25 Sep	
R2	BD	F	J	515	1		26 Sep	
R1-L1	BD	M	A	895	1		27 Sep	
R1-L2-L3	BD	F		535	2		27 Sep	
L3-NN	SA	M	J	(680)	2		16 Oct	Harvest

[a] Aged from carcass (autumn fur-harvest) using a combination of temporal muscle closure and canine radiographs or at the time of live capture from reproductive status and body size.

[b] Body weight at first capture. Skinned carcass weight in brackets.

[c] Resident (present for ≥3 mos) and temporary residents (present during 2 live-trapping sessions and <3 mos). Others may be considered transient.

[d] Boodis Lake was trapped in 1998 only.

APPENDIX II

Contribution of tracks from individual martens used in discriminant analyses.

Animal No.	Study area	Month collected	No. tracks[a]		Sex	Age[b]
L1-L3	BD	Sep	5[b]	4[c]	M	A
R2-L1	BD	Jun	19	15	F	A
R3-L1	BD	Sep	6	4	M	U
R2-R3-L2	BD	Sep	4	2	M	A
R3-L2	BD	Jul	3	2	M	U
L3	SA	Sep	9	5	M	A
R2-L2	SA	Aug	2	2	F	U
R3-L3	SA	Jun	2	2	F	A
R2-L1-L2	SA	Aug	4	3	M	J
R1-R2	SA	Jul	4	2	F	U
R1-R3	SA	Jul	3	2	F	A
R2-R3-L2	SA	Aug	4	4	M	J

[a] Includes only tracks pooled per individual over a collection period of ≤14 days (see Section 3.3).

[b] Usable track impressions; i.e., tracks with ≥6 measurements (see Fig. 1) obtainable.

[c] Tracks used to generate discriminant models (see Section 4.3).

[d] Adult (A, >1 year old), juvenile (J), and unknown (U). Aged at the time of live capture from reproductive status and body size or from carcass (fur-harvest) using a combination of temporal muscle closure and canine radiographs.