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FISHER AND MARTEN SURVEY TECHNIQUES ON THE TAHOE NATIONAL FOREST

by

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INTRODUCTION

The fisher (*Martes pennanti*) and the marten (*Martes americana*) are mid-size terrestrial carnivores belonging to the weasel family (Mustelidae). In California, fishers and martens have been reported in the Sierra Nevada Mountains, the northern Coastal Ranges, and the Trinity Mountains (Grinnell 1933, Grinnell et al. 1937, Schempf and White 1977). Studies on habitat use by fishers have been conducted primarily in eastern and mid-western North America (Coulter 1966, Kelly 1977, Powell 1982, Johnson 1984, Arthur et al. 1989b) where the habitat is very different from California. Few studies have been conducted on fishers and martens in California and they suggest that these species are associated with late-successional-stage forests and may require large landscapes (Buck et al. 1979, Simon 1980, Buck 1982, Spencer et al. 1983, Hargis and McCullough 1984, Martin 1987).

The population status and management of these two species have become issues of concern in western National Forests in recent years (USFWS 1991). In California, fishers and martens have been identified as Management Indicator Species (MIS) as a response to the regulations of the National Forest Management Act (section 219.19) and, National Forests must develop management programs to provide population objectives for these species. Many timber harvest plans on private lands in California must also consider these species when evaluating the impact of proposed timber harvesting. Information is lacking on the population status of martens and fishers in California which makes the development of management programs difficult (USFWS 1991). Development of standardized, accurate, and cost-effective methods of detection of these animals was identified as a high priority research goal by the Assessment Team.

Monitoring techniques used as indexes to the population must be standardized spatially and/or temporally, and the assumptions of the index must be well understood (Caughley 1977). Standardized methods to monitor fisher and marten populations are essential to assess state-wide distributions, distributions within Forests, and impacts associated with different land uses (especially cumulative impacts). Although various devices have been used successfully to detect martens and fishers (Barrett 1983, Martin 1987, Bull et al. 1992, Jones and Raphael 1993), there has been minimal focus on the objectives or assumptions of the field techniques.

True monitoring programs attempt to provide temporal and/or spatial trend information in addition to simple data on occurrence. Trend is described in the form of an index of the population. The assumptions of an index require identical technique and equal bias through time or space (Caughley 1977). Co-variables must be controlled for analyses of trends, otherwise the index may describe a trend in a wrong (and perhaps unknown) variable. Consequently, monitoring techniques must be uniformly standardized over time and/or space.

However, it is not adequate to simply develop techniques that meet the assumptions of the desired index. The investigator must also identify what changes in the index will correspond to real changes in the population. Once significant change has been identified in the index, managers must also determine what changes in the population should trigger management actions. Consequently, variation in the index measure must be an important consideration in identifying those changes in an index that will be identified as real. The degree of variation (and consequential ability to identify meaningful changes) will be influenced by sample size. For low-density and wide-ranging animals, sample size is a major consideration in the usefulness of a detection device. However, costs will also influence the implementation of monitoring programs and the costs will influence the sample size actually realized. It is important to ensure an adequate number of samples so meaningful information can be acquired. Thus, low-cost techniques will be important in meeting this goal.

In addition to using standardized detection devices that meet the assumptions of the index, it is important to understand how animals will respond to the devices, what biological influences may affect visitation by individuals, and how visitation may relate to populations. There are inherent biological influences that may affect visitation by individuals or populations and they need to be addressed to develop an effective monitoring plan.

Three spatial scales must be distinguished when surveying or monitoring populations: 1) trends observed over a statewide or large regional scale, 2) trends observed on large landscapes such as watersheds or Forest Districts that are usually associated with areas of land-management responsibility, and 3) occurrence of a target species at a specific site such as a timber sale. This report addresses the development of a survey protocol to monitor relative changes in populations on large landscapes, and to detect the occurrence of a species at a specific site. These two spatial scales would be of importance to land managers with specific landscape responsibilities. Monitoring on a statewide or large regional scale would be of interest to managers responsible for identifying cumulative impacts regarding the persistence of a particular species. This report does not address the issue of statewide or regional monitoring.

OBJECTIVES

We developed a survey design to detect and monitor marten and fisher populations. Two specific objectives were 1) to develop and test baits, devices, and survey protocol to detect and monitor populations on a large landscape scale, and 2) to examine the accuracy of detecting the occurrence of an animal at a particular site.

The first objective required development and testing of techniques to effectively detect target species. Development of an effective technique was required for population monitoring over time. An effective technique required the use of a detection device in conjunction with a bait that was able to elicit a detection of the target species. Development and testing of effective techniques required the comparison of specific devices and baits. Devices were compared for their relative ability to detect and unambiguously record the target species. Baits were compared for their ability to attract the animal to the area (measured with captive animals), and to elicit a record of the animal at a specific detection device (measured by visitation at the devices in the field). A strong and uniform bait was necessary to increase the likelihood of detection (thus reducing the cost) and meet the assumptions of an index over time.

In addition to development of an effective detection technique, the first objective also required the development of a survey procedure to monitor relative changes in fisher or marten populations on a large landscape scale (such as a particular watershed or Forest District). Population monitoring must occur on a large geographic scale because fishers and martens have large home ranges (Lindstedt et al. 1986). Development of survey protocol required examination of the survey duration, and the number and distance between the detection stations.

The second objective required the calculation of the probability of actually detecting target species. The probability of detection was determined by examining the likelihood that a marten would be detected when detection stations were placed within its home range. Track-plates and triggered-cameras were used as detection devices to calculate the probabilities.

STUDY AREA

Laboratory work was conducted at Humboldt State University, Humboldt County, California. The field study was conducted in Placer County on the Foresthill Ranger District, Tahoe National Forest, California. The Foresthill Ranger District was located in the central portion of the Sierra Nevada Mountains between the North and Middle Forks of the American River drainage. Both fishers and martens had been reported on the Foresthill Ranger District (M. Armijo, pers. comm., Foresthill Ranger District, Foresthill, CA).

The study area for development of the survey protocol was approximately 160 km^2. Locations of detection stations ranged in elevation from 720 m to 2200 m. The habitat type on the study area was characterized as Sierran Mixed Conifer (Allen 1988), Jeffrey Pine (McBride 1988), and Red Fir (Barrett 1988). The Mixed Conifer and Jeffrey Pine habitat types consisted of Douglas fir (Pseudotsuga manziesii), Ponderosa pine (Pinus ponderosa), sugar pine (Pinus lambertiana), white fir (Abies concolor), incense-cedar (Libocedrus decurrens), black oak (Quercus kelloggii), and Jeffrey pine (Pinus jeffrevi). The Red Fir habitat type consisted primarily of red fir (Abies magnifica) with intermittent white fir, incense cedar, western white pine (Pinus monticola), and lodgepole pine (Pinus contorta).

The study site for analysis of probabilities of detection was within the area for development of survey protocol to monitor fisher or marten populations. The site was selected because martens were regularly detected in this area. The area was approximately 48 km^2 and elevation ranged from 1830-2200 m. The habitat type was Red Fir.

METHODS

New technology requires specific terminology which is essential to a clear understanding of the methodology. Terms specific to baits, devices, and surveys were defined to insure precise description and consistent communication (Table 1).

BAITS, DEVICES, AND SURVEY PROTOCOL

Develonment of Baits and Devices

Baits and detection devices were compared by examining the behavioral responses of six captive fishers located at Humboldt State University, Humboldt County, California. These comparisons consisted of 20 nights of pre-trial and 50 nights of trial observations conducted from November 1990 to March 1991. The fishers (3 males, 3 females) were purchased from a dealer in Massachusetts. Four of the animals were caught in the wild and two had been captive born.

Baits. --Six baits were selected for presentation to the captive fishers (Table 2). Bait selection was based on the success in detecting furbearers in previous studies (Barrett 1983, Martin 1987, Taylor and Raphael 1988, and M. G. Raphael, pers. comm., Pacific Northwest Research Station, U. S. Forest Serv., Olympia, WA), or a potential for strong and uniform odor. Selection of a uniform and consistent odor was essential to meet the assumptions of the index.

Detection Devices. --Three detection devices (track-plate, triggered-camera, and hair-snare tube) were selected for presentation to the captive fishers. These three devices were selected based on their reported success in detecting furbearers (Nelson 1979, Barrett 1983, Martin 1987, Taylor and Raphael 1988, Jones and Raphael 1993).

Sooted-plate detection devices were originally developed to detect small mammals (Mayer 1957, Justice 1961, and Lord et al. 1970), and were later modified by Barrett (1983) to detect larger mammals including martens. We utilized a sooted aluminum track-plate positioned inside a plywood box (Figure 1, Appendix A). Modifications to Barrett's (1983) design included: the use of an open-ended plywood box to house the sooted aluminum plate (the box was easily assembled in the field without the use of nails or screws), the placement of the box on the ground rather than in trees, and the addition of white con-tact paper attached to the center third of the rectangular plate.

The triggered-camera (Figure 2) was a modification of a technique originally described by Joslin (1977) for detections of nocturnal carnivores, and later used for detecting martens in Washington (Jones and Raphael 1993). Our modifications to the design included: use of an internal flash camera that was modified to use D-cell batteries, an altered trigger mechanism that allowed removal of the camera from its stand, and weather protection that also allowed accessibility to the view finder, shutter release, and exposure reading (Appendix B).

Various types of snares have been developed to collect animal hairs including PVC piping lined with adhesive tape (Suckling 1978, Winnett and DeGabriele 1982, Scotts and Craig 1988) and coils of barbed wire to snag hairs as the animal passes to a bait (Nelson 1979, Barrett 1983). Animal hairs have distinguishing characteristics that allow identification to species (Mayer 1952, Stains 1958, Thompson et al. 1987). We used a PVC tube (Figure 3) lined with three different adhesive surfaces (Appendix C).

Comparison of Baits and Detection Devices.--Researchers working with captive fishers reported that an acclimatization period following introduction to a new environment was necessary before beginning behavioral observations (G. Proulx, pers. comm., Alberta Environmental Center, Vegreville, Alberta, Canada; T. Hoenig, pers. comm., fur farmer, Sturbridge, MA). Consequently, pre-trial observations were conducted for a six-week period following arrival of the animals at the Humboldt State University Game Pens. During this period four animals were observed in their pens (each pen had approximately 30 m^2 of floor space) to determine activity periods. The animals were observed for three 14-h periods each (1700-0700 h) and activity was examined by breaking the period into 30-min intervals which were scored either as 1 or 0 depending on whether the animal was active or not active.

During the pre-trial period the fishers were also observed in a large test pen (32 x 20 x 10 m) for a total of 17 nights. Methods of bait presentation were examined during this time and the specific behaviors of the animals in response to the detection devices (which devices an animal would approach and which would obtain a detectable record) were noted and a series of alterations were made to the devices to increase their effectiveness. A detectable record was either an identifiable track, photo, or hair sample depending on the detection device.

Formal bait and device comparison trials began on 11 December 1990 and continued to 13 March 1991. One male and one female fisher were placed in the large pen. Male and female movements were independent from one another within the pen; thus they could be examined simultaneously. Observations were conducted from a tower 2 m above the ground. Animals were placed in the large pen for eight consecutive nights; the first two nights were for acclimatization to the pen (no data were collected), and the following six nights were for bait and device comparisons. The eight-night test periods were repeated three times for each pair of animals. Observations commenced at approximately 1700 h and continued until a response from each animal was recorded (or terminated at 0700 h if no response was observed).

A different bait was presented on each of the six nights of a test period. The order of presentation was randomized. Bait and control sites within the pen were paired. Three pairs of sites were used in each trial (Figure 4). The paired locations consisted of two metal fence posts 2 m in height and approximately 6 m apart. The bait and control containers were hung from the posts 1 m above the ground. The posts were located away from the cage wall and the containers were elevated to prevent the fishers from acquiring the bait. Bait containers consisted of cotton muslin wrapped around the bait or scent; control containers consisted of a piece of muslin with no content. Control containers were visually identical to the bait containers.

Baits were tested for their ability to attract an animal to their location (approach within 1 m of the bait) and the intensity of the behavioral response to the bait or control. Intensity behaviors were divided into three categories (Figure 5). Behavior A was the most intense and conspicuous. With this behavior the animal held its nose high in the air and lifted its body up the fence post while its head often made rapid movements as the animal actively sniffed the area. Behavior B was a behavior of lesser intensity in which the animal held its head with nose in the air near the bait/control post and it was not possible to tell if the animal was sniffing the area as a response to the bait smell or responding to the visual stimulus. Behavior C was the least conspicuous behavior in which the animal held its head level to the ground near the bait/control post; again it was unclear whether the response was to visual or olfactory stimulus. In addition, the number of times an animal approached a bait or control was compared to the number of times it was available; the bait or control were considered available each time an animal passed within 2 m of the particular station.

The three detection devices were not baited and were simultaneously placed in the test pen in the evening with a pair of fishers. Devices were retrieved the following morning and examined for detections. Each pair of fishers was counted as a single sample since either animal had access to the devices. Detection devices were compared for their ability to obtain a detection relative to the number of times they were presented to the animals.

Field Testing of Baits, Devices, and Survey Protocol

Two detection devices (track-plates and triggered-cameras) and two baits (tuna cat-food and chicken) were chosen for field testing based on their effectiveness with captive fishers. The two devices were positioned within 50 m of each other in homogeneous habitat at one location (station). Bait type alternated systematically through stations (same bait for both devices at a station).

Road-based transects were established in the study area, and stations were placed 50-100 m off forest roads at approximately 1.6 km intervals (Figure 6). Distances were lineal kilometers as measured on a map rather than measured while driving along the road.

The locations of detection stations were not limited to areas of known fisher or marten presence. However, the goal of the study was to maximize the probability of detection; consequently, the stations were placed in habitat classified as suitable according to the U. S. Forest Service, Region 5, Interim Guidelines for Identification of Suitable Furbearer Habitat (Free1 1991).

On each investigator examination, the bait and detection devices were inspected. If the bait was in poor condition (desiccated or meat removed by insects or rodents), the remains were removed and replaced with fresh bait (every 2 to 4 days). In addition, track-plates were changed when tracks were visible on the track-plate or contact paper, and cameras were examined for photos and advanced if necessary.

Detection Devices. --Track-plate devices were positioned in the field so as to conceal them from human disturbance and have a natural appearance. The boxes were placed with one of the open ends against a tree trunk or log to block the back entrance and were covered with available bark, branches, leaves, pine needles, or duff (Figure 1). Where available, pieces of bark or branches were extended over the top front of the box to provide additional protection from rain or snow. In addition, boxes were positioned with the open end at a slight downward angle to prevent rain or dew from entering the box and destroying any tracks. When monitoring the stations, the track-plates were easily slid through the front entrance of the box without disturbing the camouflage.

The triggered-camera stands were placed approximately 25 cm in the ground and were tilted at approximately 30 degrees from perpendicular to achieve the best focus. The appropriate angle was achieved by sighting through the camera prior to securing the stand in the ground. Where necessary, rocks or wood shims were used to secure the stands in the ground. When monitoring the stations, the cameras were easily checked for proper sighting.

Bait. --The chicken bait consisted of a wing that was cut in half at the field station. The distal portion of the wing was attached to the bait line of the triggered-camera because the thread could be firmly tied around the wing-joint. The proximal portion of the wing was placed in the back third of the track-plate box. The cat food bait consisted of approximately 57 g of tuna cat-food. The cat food bait was either pre-wrapped at the field station in cotton muslin and secured with a rubber band for attachment to the triggered-cameras, or placed in a small empty can in the back third of the track-plate boxes.

Surveys. --Surveys were conducted in spring, early summer, and late summer. During the spring survey, 36 detection stations were examined approximately once a week for an eight week period (27 March to 21 May 1991). Attempts were made to begin surveying in early March but were discontinued due to heavy snowfall. Spring surveying required snowmobile travel and inclement weather was frequent. Thus, examining stations more frequently than once a week was not feasible. The stations were examined an average of 6.5 times during the eight week period (range 5-8 depending on accessibility).

A four week interval occurred between the spring and early summer survey. For the two summer surveys, 78 stations were examined every other day (36 of which were previously monitored in the spring). The period of time between each investigator examination of the stations was termed an examination interval. For the summer surveys each examination interval consisted of a 48-h period during which the stations were baited (or 2 survey nights). The first summer survey occurred from 22 June to 21 July 1991 (a total of 30 survey nights or 15 examination intervals). The cumulative number of stations that recorded a marten detection during the survey were plotted relative to the examination interval to determine an appropriate survey duration after which increased effort did not provide new information (minimum survey period). Two weeks after completion of the early summer survey, the bait type was systematically switched between stations and the same stations were monitored again for another eleven examination intervals (22 survey nights) from 7 to 28 August 1991. The baits were switched to reduce the confounding effect of habitat on bait selection.

PROBABILITY OF DETECTION

Capture/Marking

Live-traps (Model 205, Tomahawk Live Trap Company, Tomahawk, WI) were used to capture martens. The back of the trap was attached to a wood box (modified after Wilbert 1992; Appendix D). The box provided thermal shelter from inclement weather and security for the animal when it was in the trap. In addition, masonite board (5 mm thick) was wired to the floor of each trap to reduce injury (Wilbert 1992).

Traps were set for 25 nights between 28 October and 23 November 1991. Traps were placed approximately 50-100 m off forest roads and snowmobile trails. Traps were placed near locations where martens were detected during the summer field surveys or where fresh marten tracks were observed in the snow. Following capture of a marten, individual traps were removed from the capture site to reduce the chance of recapturing the same individual. Traps were examined every morning.

A modification of a handling-cone (S. Buskirk, pers. comm, Dept. of Zoology and Physiology, P.O. Box 3166, University of Wyoming, Laramie, WY) was used to restrain the martens for immobilization (Appendix D). Martens were immobilized using a combination of ketamine and diazepam (1 mg diazepam per 200 mg ketamine; S. Buskirk, pers. comm, Dept. of Zoology and Physiology, P.O. Box 3166, University of Wyoming, Laramie, WY). Because martens are sexually dimorphic, it was possible to determine the sex of a marten in the cone and drug doses were adjusted accordingly (Appendix E).

Martens were ear-tagged with modified Rototags (Dalton, Nasco, Ft. Atkinson, WI) that were reduced in length to 15 mm by removing the distal 20 mm of the tag. One of six colors of reflective tape (Lewis et al. 1993) (Minnesota Mining and

Manufacturing Co., Division 3M Scotch, St. Paul, MN) were affixed with Super-glue (Duro, TM Loclite Co., Cleveland, OH) onto the front and back tab of each ear tag to identify individuals with photos from the triggered-cameras.

Each animal was collared with a radio transmitter (Configuration lA, Telonics Telemetry-Electronics Consultants, Mesa, AZ). Individual collars weighed 28 g and had an operational life of approximately six months.

Body length (± 1 mm) and weight (± 5 g) were measured for each captured marten. Martens were grouped into age classifications using sagittal crest measurements as described by Marshall (1951). Although Marshall (1951) described measurements on museum specimens, it was possible to approximate measurements with immobilized animals. Male martens with sagittal crests less than 20 mm were classified as juveniles, while males with sagittal crests of larger length were classified as adults. Female martens were classified by the presence (adult) or absence (juvenile) of a sagittal crest. Tooth wear was used as a secondary consideration in age determination. It was used only as a supplemental attribute because adult dentition may occur in martens as young as three months old (Brassard and Bernard 1939).

Martens were recovered from immobilization in the wooden box which was attached to the trap. All martens were released at the capture site and had full motor capability within one hour of injection of the immobilizing drug (Appendix E).

No attempt was made to capture the entire population of martens on the study area. Trapping was terminated after capture of six individuals.

Radio-telemetry Locations

Telemetry triangulation was used to relocate individual martens within the study area. Telemetry bearings were measured beginning on 29 October 1991 and continuing until 28 February 1992. The actual beginning date for each animal varied with the time of capture (Appendix F). A receiver and hand-held Yagi antennae (Model TR-4 receiver and RA-2A antennae, Telonics Telemetry-Electronics Consultants, Mesa, AZ) were used.

Directional bearings were obtained by sighting a hand-held compass (Model 8040, Brunton, Riverton, WY) in the direction of the strongest signal. Telemetry bearings were measured from known reference locations along roads and snowmobile trails. Bearings were immediately mapped on ortho-photoquads (scale 1:24,000) until a consistent location was identified. A minimum of three bearings were measured for each estimated location. This method was adequate for determining telemetry locations when the animals were stationary. When the martens were moving it was not possible to determine accurate locations and effected bearings were deleted.

Attempts were made to triangulate locations every day for each animal, however, winter conditions occasionally prevented daily monitoring. In addition, the terrain was very steep and uneven which limited our ability to locate animals on each attempt.

The 24-h period was broken into four intervals (0000-0600 h, 0600-1200 h, 1200-1800 h, 1800-0000 h) to stratify collection of bearings at various times. It was possible to collect bearings during the 1800-0600 h interval until 14 November 1991, after which inclement winter conditions made snowmobiling at night unsafe.

Home Range Calculation

Home range areas were calculated to delineate areas for placement of detection stations. Telem, a home range computer program (K. McKelvey, pers. comm., U. S. Forest Service Pacific Southwest Research Station, 1700 Bayview Drive, Arcata, CA) and a Geographic Information System (GIS) were utilized for calculation of home range polygons for each animal. Home ranges were calculated with the adaptive kernel method (Worton 1989) and the minimum convex polygon method (MCP) (Mohr 1947). We used the adaptive kernel method because it identified areas of concentrated use within an animal's home range, and the MCP method because it provided a comparable measure of home range size to other studies that have used this method. Home range polygons were determined from telemetry locations that were digitized into the GIS.

Probability of Detection

The probabilities of detection were examined by placing detection stations within the home ranges of the martens. Home ranges overlapped and it was possible to delineate one outer boundary that contained all home ranges (a similar outer boundary was produced by both the kernel and MCP methods).

Twenty detection stations were placed within the boundary of the home ranges. The track-plate and triggered-camera devices were positioned within 20 m of each other at each station. Stations were positioned 50 to 100 m off forest roads at approximately 1 km intervals.

The unique reflective colors on ear-tagged martens allowed individual identification at the triggered-cameras; thus, the number and location of stations that had detections of individuals could be determined. Because individuals could not be identified at the track-plates, the two detection devices were placed within 20 m to increase the likelihood of the animal finding both devices.

When a triggered-camera detected a marked marten outside the estimated home range (as determined from telemetry), the home range was extended to include that point. The number of stations that had detections of an individual marten were divided by the number of stations that were within the marten's home range. The resulting fraction represented the average likelihood that a detection station would detect an individual when the station was within the animal's home range.

Detection Devices

Twenty stations were monitored for the minimum survey period. Stations were visited every other day for a total of eleven examination intervals between 23 December 1991 and 12 January 1992. The study area was snow-covered for the duration of the survey, so access was via snowmobile. The bait consisted of a chicken wing that had been cut in half.

DATA ANALYSIS

BAITS, DEVICES, AND SURVEY PROTOCOL

Development of Baits and Devices

Baits.--The ratio between an approach (response) to a bait or control and the number of times it was available to the animal was analyzed using the two-sample sign test (Zar 1984:386-387). All three behavior types (A, B, and C) were used as responses. Each bait was analyzed for each animal and compared to the control for that individual. Within each observation period (1700-0700 h), the number of times that an animal responded to a bait and control was compared to the number of times the bait or control was available; if the response/available ratio was greater for the bait than for the control, it was assigned a positive sign. A negative sign indicated that the response/available ratio was less for the bait than the control. One female was deleted from the analysis because we recorded no response to either the bait or control during the tests.

Detection Devices.--For the captive fishers, detection devices were compared with frequency of animal visitation (the number of detections at a device, divided by the number of times the device was available, multiplied by 100) as the response variable. The frequency of animal visitation was calculated for the track-plate and triggered-camera devices.

Field Testing of Baits, Devices, and Survey Protocol

Fishers were not detected during any survey period so data analysis focused on marten detections. Detections of gray fox (Urocyon cinereoargenteus) and black bear (Ursus americanus) were also analyzed because the numbers of detections were relatively high, and their populations were of concern or interest to managers.

Baits.--Responses to the two baits were compared by examining the total number of visits of target species at stations with each bait type. The stations were repeatedly counted with each visit by the target species, thus reflecting the attraction of the bait. We were not concerned about the possible learned effect of bait acquisition through time; rather, it was this aspect that we wanted to investigate so as to choose a bait that was more attractive to target animals.

The contingency table (cross-tabulation: Zar 1984:64-65) was used to analyze the seasonal effect on responses to bait to examine whether visits of a particular species could be pooled for the three survey periods. Differences between the two baits were compared for detections of martens, gray foxes, black bears, and all animals combined. A chi-square comparison was used to analyze differences in the number of visits to the two baits (Zar 1984:62-63).

Detection Devices.--Responses to detection devices were compared with two response variables: the detection ratio, and the frequency of animal visitation. The detection ratio was calculated as the number of stations with a detection of a target species divided by the total number of stations examined during the survey. The stations were counted only on the first occasion a detection occurred rather than repeatedly counted with each subsequent animal visit. Thus, the detection ratio was not seriously influenced by changing behavioral effects over the period of the survey.

Simple occurrence data obtained at a specific site provides information on the immediate status (presence) of a local population, but provides no method to detect changes in the population at a site over time. Theoretically, the detection ratio can be used to detect relative changes in populations over time. While the variable is not a product of totally independent data (the same animal may be detected at more than one station), independence is not required to meet the assumptions of the index (Caughley 1977). Rather, the requirements of the index are that the response variable be unbiased or equally dependent between surveys. Because our monitoring efforts focused on animals that use large home ranges, the index must necessarily encompass large pieces of real estate to truly sample the population in question. Thus, the detection ratio calculated from a substantial number of detection stations would be the only realistic response variable for specific large pieces of real estate.

The two devices were compared by separately calculating the detection ratio for detections of target species at the track-plate and triggered-camera devices at a station. The detectionratio was calculated for responses by martens, gray foxes, and black bears. The contingency table (cross-tabulation) was used to analyze the seasonal effect on detection devices to examine whether detections could be pooled across the three survey periods (Zar 1984:64-65). A chi-square comparison was used to analyze differences in the detection ratio between the two devices for each of the three species (Zar 1984:62-63).

The second response variable that was calculated was the frequency of animal visitation. For this variable, the number of times the device was available was calculated as the number of stations monitored during the survey multiplied by the number of examination intervals (ie. during the early summer survey, 78 stations were available for 15 examination intervals or a total of 1170 times). This differs from the detection ratio in that individual stations were repeatedly counted when visited more than once in a survey period. This measure was not statistically analyzed for differences between detection devices because of this repetitive counting of a station. We calculated frequencies of visitation for each season for martens, gray foxes, and black bears.

The devices were also compared by examining the frequency of visitation at a device when the other device at a station was and was not visited. This was compared for each season for detections of martens, gray foxes, black bears, and all animals combined (excluding detections of rodents).

Duration of Survey.--An adequate survey duration for the summer was determined for martens, gray foxes, and black bears. The cumulative number of new stations that recorded a detection of the target species was plotted with the number of examination intervals. The minimum survey period was determined as the point after which increased effort did not provide new information. A separate plot was made of detections for each device.

Number of Stations.--The effect of sample size on the response variable (detection ratio) was examined by analytically reducing the number of stations in the survey. The number of stations was reduced by half by randomly dividing the stations into two segments. The resulting detection ratios for each segment were examined. The detection ratios for half the number of station were calculated for the early summer survey period for martens, gray foxes, and black bears. Standard errors were computed for the ratios. Future work will utilize computer simulations to address this question.

Station Spacing.--The effect of station spacing on the response variable (detection ratio) was examined by analytically increasing the station spacing. Every other station across the survey extent was omitted from the analysis; resulting in two survey lines with 3.2 km spacing between stations. The detection ratio was recalculated for both possible arrangements of stations (removal of even and odd stations). Detection ratios were recalculated for the early summer survey period for martens, gray foxes, and black bears. Standard errors were computed for each ratio.

PROBABILITY OF DETECTION

The probabilities of detection were calculated at two spatial levels: home range and survey. The home range level represented the probability that a station would detect a particular individual if the station was placed within the home range of that animal. The survey level represented the probability that a station would detect a marten (marked or unmarked) when the station was placed in an area of known marten presence (within the boundary of the five home ranges).

The probability of detection at the home range level was calculated as the number of stations where an individual marten was detected (determined by identification of marked individuals at triggered-cameras) divided by the number of stations within that marten's home range. The probability of detection at the survey level was calculated as the number of stations where a marten was detected (detection of a marten at either the track-plate or triggered-camera devices at a station) divided by the total number of stations within the boundary of all the home ranges surveyed. The survey level calculation was useful to compare between similar surveys, but was not used for further analysis because it was specific to the site, season, and particular spatial arrangement of the stations in our survey.

Binomial Probability Curves

Two important factors influenced the likelihood for a station to detect an animal: the amount of time the station was monitored (duration of survey), and the spatial distribution of the stations (station density within the home range). The two factors were examined by constructing binomial curves of probability.

The binomial formula (Zar 1984:370-371) was used to calculate probabilities of detection given additional independent events (ie. first event: the probability of detecting an animal with one station in its home range; second event: the probability of detecting the animal with two stations in its home range, etc.). Additional events were calculated until a 95% probability of detection for each marten was achieved.

The calculated probabilities were plotted with the associated event (number of stations in the home range) to construct curves of probability. The plots explained the probability of detecting an individual at one or more stations given an increase in the number of stations in the individual's home range. Probability calculations were possible given three assumptions; there was a fixed probability of detection for an individual, the detection stations were spatially independent, and the home ranges did not fluctuate.

Duration of Survey. --Two methods were used to analyze the influence of the survey duration on the probability of detection. First, probabilities of detection were calculated cumulatively by examination interval for each marten and were plotted to examine changes over time. Second, plots derived from two different survey durations were examined; the 22-night survey-period (11 examination intervals) and an analytically truncated 12-night survey-period (6 examination intervals). Calculated probability plots from the two survey durations were used to determine the number of stations needed in an animal's home range to obtain a 95% probability of detection for at least one station within the survey duration. The la-night survey-period was chosen as a second duration to examine probability of detection because it has been recommended for efforts to establish occurrence in California (Zielinski 1992) that was based on preliminary field studies (Barrett 1983, Fowler and Golightly 1991, Laymon et al. 1991, Jones and Raphael 1993).

Station Density. --Two methods were used to examine the influence of station density on the probability of detection. First, the plots of calculated probabilities from the 22-night survey-period were used to determine the number of stations needed in an animal's home range to obtain a 95% probability of detection at one or more stations. The determined number of stations was used to determine theoretical station densities (number of stations divided by the average home range size). Real station densities were calculated and compared to the theoretical station densities with a Mann-Whitney Two-sample Test (Hintze 1991, BMDP Statistical Software, SOLO Base System).

Differences were analyzed for all martens collectively, and for females and males separately.

Potential confounding factors that could affect the correlation between the calculated number of stations needed to obtain a 95% probability of detection and home range size were examined. Dependence between home range size and individual probabilities were examined with simple linear regression (Hintze 1991, BMDP Statistical Software, SOLO Base System). Home range size and the actual number of stations in a home range were also regressed to examine whether the number of stations was dependent on area of home range.

The second method used to analyze the influence of station density on the probability of detection was the comparison of detection probabilities when the number of stations in an animal's home range was reduced. Every other station across the survey extent was omitted from the analysis to imitate a 2-km spacing. The probabilities of detection were recalculated for each marten for both possible arrangements of stations (removal of even and odd stations).

Detection Devices

The assumption that a marten would be detected at both devices at a particular station was tested by comparing the detection ratio of each device.

Home Range Calculation

Differences between the sizes of the two home range estimates (kernel and MCP) and between the resulting probabilities of detection were tested with a Mann-Whitney Two-Sample Test (BDMP Statistical Software, SOLO Base System). Differences between the size of male and female home ranges were also examined with the Mann-Whitney test.

RESULTS

BAITS, DEVICES, AND SURVEY PROTOCOL

Development of Baits and Devices

Baits. --Two of the six baits were more effective in obtaining a behavioral response from captive fishers. Animals responded more often to chicken (P = 0.03) and tuna cat-food bait (P = 0.03) than to their controls (Table 3). Based on our laboratory observations and the convenient availability of the baits, chicken and tuna cat food were chosen for comparison in field tests.

Detection Devices. --During pre-trial observations, hair-snare tubes were discarded as a potential detection device. The sticky surfaces (including velcro) were inconsistent in obtaining a response (acquisition of hair) in the cold and wet weather conditions encountered during trials in December, January, and February. Captive animals were observed entering the hair-snare tubes but detections did not occur. This was either due to the animal's hair being wet and not sticking to the surface, or the sticky surface being wet and losing its ability to snare hair.

The captive animals entered the track-plate box without apparent hesitation (they were also observed scent marking on the outer surface of the box and making attempts to roll the box). The animals showed no aversion to stepping on or walking on the sticky con-tact paper surface.

The triggered-cameras were initially tested with a separate flash-bar attached to the top of the camera; this set-up was discarded because the flash-bar was regularly removed and destroyed by the captive fishers, and the flash operated inconsistently. In addition, the cameras with built-in flash were more cost-effective (Appendix G).

Detections of captive animals occurred at both the track-plate and triggered-camera devices. The frequency of visitation for the track-plate devices was 75% (they were available 59 times and the animal's responded on 44 occasions). The frequency of visitation for the triggered-cameras was 56% (they were available 52 times and the animal's responded on 29 occasions).

Field Testing of Baits, Devices, and Survey Protocol

Martens were detected at the track-plate and triggered-camera devices during all survey periods. Fishers were not detected during any survey period. Fourteen species were detected during the spring survey period; 12 species at the track-plate devices and five species at the triggered-camera devices (Table 4). Seventeen species were detected during the early summer survey period; 13 at the track-plates and ten at the triggered-cameras (Table 4). Twelve species were detected during the late summer survey period; 11 at the track-plates and nine at the cameras (Table 4).

Long and short-tailed weasels (Mustela frenata and Mustela erminea) were detected only at track-plate devices, whereas, coyotes (Canis latrans) were detected only at triggered-camera devices. Ringtails (Bassariscus astutus) were detected at both devices in the spring, but were not detected during either summer survey.

Baits.--For martens, responses to the baits were independent of a seasonal effect (chi-square = 3.12, 2 df, P = 0.21), therefore detections from the three surveys were pooled. Martens visited stations with chicken significantly more often than stations with cat food bait (chi-square = 3.95, 1 df, P < 0.05) (Table 5).

For gray foxes, responses to the baits were also independent of a seasonal effect (chi-square = 3.34, 2 df, P = 0.19), thus detections from the three surveys were pooled. There was no difference in gray fox visitation between stations with chicken or cat food bait (chi-square = 0.2, 1 df, P = 0.66) (Table 5).

For black bears, responses to the baits were influenced by a seasonal effect (chi-square = 11.0, 2 df, P < 0.0l), thus detections from the three surveys were analyzed separately (Table 5). There was no difference in black bear visitation for the spring and early summer surveys between stations with chicken or cat food bait (chi-square = 0.2, 1 df, P = 0.66; chi-square = 2.6, 1 df, P = 0.11, respectively) (Table 5). However, black bears visited stations with cat food significantly more often than stations with chicken bait during the late summer survey (chi-square = 3.95, 1 df, P < 0.05) (Table 5).

Responses to baits were not independent of a seasonal effect for detections of all animals combined (chi-square = 6.91, 2 df, P = 0.03), therefore visits from each survey period were analyzed separately. For the spring survey period, there was no difference in visitation at stations with chicken or cat food bait (chi-square = 1.6, 1 df, P = 0.21). However, for the two summer survey periods, animals visited stations with chicken bait significantly more often than stations with cat food (early summer: chi-square = 34.83, 1 df, P < 0.01; late summer: chi-square = 7.05, 1 df, P < 0.01; Table 5).

Detection Devices.--For martens, gray foxes, and black bears, responses to the devices were independent of seasonal effects (martens: chi-square = 0.56, 2 df, P = 0.75; gray foxes: chi-square = 0.99, 2 df, P = 0.61; black bears: chi-square = 1.78, 2 df, P = 0.41), therefore detections from the three surveys were pooled. The track-plates were significantly more effective in eliciting a marten detection than the triggered-cameras (chi-square = 10.7, 1 df, P < 0.01; Table 6). Gray foxes and black bears were not detected at one device more frequently than the other (chi-square = 0.01, 1 df, P = 0.91; chi-square = 0.82, 1 df, P = 0.36, respectively; Table 6).

The frequency of visitation of martens was nine times greater at the track-plate stations than at the triggered-camera stations (Table 7). The frequency of marten visitation at the track-plate stations was greatest during the spring survey and least during the late summer survey, whereas the frequency at the triggered-camera stations was greatest during the early summer survey and least during the spring (Table 7). The frequency of visitation of martens at only track-plates and not at the respectively paired cameras was over 12 times greater than detections at only the triggered-cameras without their respectively paired track-plate (Table 8).

The frequency of visitation of gray foxes was approximately 1.4 times greater at the track-plate stations than at the triggered-camera stations (Table 7). The frequency of visitation of gray foxes was greatest during the spring survey period for both the track-plate and triggered-camera detection devices (Table 7). The frequency of visitation of gray foxes at the triggered-cameras was approximately the same for both summer surveys. The frequency of visitation of gray foxes at one device and not the other at a station was 1.7 times greater for the track-plates than for the triggered-cameras (Table 8).

The frequency of visitation of black bears was greatest during the late summer session for both detection devices (Table 7). The frequency of black bear visitation at the track-plates was nearly three times greater during the late summer session than during the spring session. The frequency at the triggered-camera stations was four times greater during the late summer session than during the early summer session and 20 times greater than during the spring session. The frequency of visitation of black bears at one device and not the other at a station was 2.2 times greater for the track-plates than for the triggered-cameras (Table 8).

The frequency of visitation of all animals (excluding rodent detections) at one device and not the other at a station was over two times greater for the track-plates than for the triggered-cameras (Table 8).

The costs of the two detection devices was relatively similar (Appendix H), however, the triggered-camera devices had higher maintenance costs and higher long-term costs.

Duration of Survey. --For both the track-plate and triggered-camera devices, the minimum sampling period for martens that provided consistent results was 22 days (or 11 examination intervals) (Figure 7, 8). This minimum sampling period for marten was used for the late summer survey. The minimum sampling period for gray foxes in the early summer survey was 26 days (13 examination intervals) (Figure 9, 10). The minimum sampling period for black bears was 26 days (13 examination intervals) when using the track-plates, but there was no end to new detections at the triggered-cameras (> 30 days; Figure 11,12).

Latency to First Detection.--In early summer, marten were first detected at the second examination interval for track-plates and at the fourth interval for triggered-cameras. In late summer, marten were first detected at the first examination interval for both devices.

Number of Stations. --The precision of the detection ratio was reduced for martens, gray foxes, and black bears when half the number of stations was analytically removed from the sample (Tables 9, 10 and 11). This was illustrated with marten detections during the early summer survey period. When the number of stations was reduced by half, the proportion ofstations with detections remained the same, however, the standard error increased (Table 9).

Station Spacing.--The precision of the detection ratio was also reduced for martens, gray foxes, and black bears when the spacing of stations was analytically increased to 3.2 km (Tables 9, 10 and 11). This was illustrated with marten detections during the early summer survey period. When the spacing of stations was increased, the proportion of stations with detections remained the same, however, the standard error increased (Table 9).

PROBABILITY OF DETECTION

Capture

Fifteen traps were operational for 329 trap-nights from 28 October to 23 November 1991. Six individual martens were captured on 12 occasions (Appendix I). The six martens (3 males, 3 females) were immobilized at first capture and collared with radio transmitters. Age classes of captured martens were two adults, three juveniles, and one unknown. Females weighed 712 ± 14 g (x ± SE), and males weighed 1068 ± 58 g (Appendix F).

The capture rate for martens was 3.6% which was higher than other studies on the eastern slope of the Sierra Nevada mountains on the Tahoe National Forest (Simon 1980: 2.9%; Martin 1987: 1.3%). The higher capture rate was probably a result of prior sampling with detection stations that allowed us to locate the highest density of martens on the study area. Track-plates may be used as a method to determine marten presence prior to trapping, and thus, reduce costs of equipment and personnel time to maintain trap-lines.

The addition of a plywood box on the back end of the trap was effective. There were no abrasions, broken teeth or broken nails on any of the captured animals. No injuries to the martens were incurred in the process of immobilizing and handling.

Radio-telemetry

One adult male marten (# 04) was relocated only three times after the initial capture. On the last occasion, an airplane was used to locate him 8 km from his capture location. Five other martens were located using triangulation an average of 33 ± 5 times (range 19-48). The radio signal was followed to resting locations of four martens on 23 occasions.

Home Range Calculation

Home ranges were calculated for five martens. Marten #04 was relocated only three times and it was not possible to establish a home range for this animal. Average home range estimates were 1059 ± 421 ha (kernel) and 645 ± 209 ha (MCP) (Table 12, Figure 13, 14). The difference between the sizes of the home ranges estimated by the two methods was not significant ($Z = 0.73$, $P = 0.47$).

The average female home range size was 604 ± 203 ha (kernel) and 347 ± 85 ha (MCP) (Table 12). The average home range size for males was 1741 ± 935 ha (kernel) and 1092 ± 284 ha (MCP) (Table 12). There was no statistically significant difference between female and male home range sizes for the kernel and MCP estimates ($Z = 1.15$, $P = 0.25$; $Z = 1.73$, $P = 0.08$, respectively).

Probability of Detection

The probabilities of detection were calculated for five martens. Because it was not possible to establish a home range for marten #04, the probability of detection for this animal was not determined. At the spatial level of the home range, the probability that a detection device would detect a marten when the device was placed within the marten's home range varied by individual from 1.0 to 0.4 (for both kernel and MCP home range estimates) (Table 13). The difference between the probabilities of detection for the two home range estimates was not significant ($Z = 0.31$, $P = 0.75$).

At the spatial level of the entire survey, the probability of detection was 0.95; a station had a 95% likelihood of detecting a marten when the station was placed in an area of marten presence (within the boundary of the marten home ranges).

Duration of Survey.--Detection probabilities determined from the MCP home range method were chosen for analysis of the duration of the survey because there was no significant difference between the probabilities determined by the two methods. The MCP method is less adversely affected by sample size (Harris et al. 1990), and because the number of telemetry locations was relatively low, we chose the MCP for analysis.

The cumulative probabilities of detection for each marten were plotted by examination interval (Figure 15). The cumulative probabilities exhibited a rapid increase from the first examination interval to the second, and a slower increase with subsequent intervals (Table 14). There was variation among individuals: one marten was detected at all eight stations within its home range by the seventh interval, whereas another marten continued to be detected at new stations in its home range with each additional examination interval.

Probability curves derived from the 22-night survey-period (11 examination intervals) and the analytically truncated 12-night survey-period (6 examination intervals) were plotted. When probabilities were derived from the 22-night survey-period, the five martens collectively had a 95% probability of detection at one station when six stations were placed within each home range (Figure 16). For probabilities derived from the truncated 12-night survey-period, the five martens collectively had a 95% probability of detection at one station when there were 14 stations placed in each home range (Figure 17).

Station Density.--Detection probabilities determined from the MCP home range method were chosen for analysis of station density. There was a gender difference in the station density needed to obtain a 95% probability of detection. The fivemartens analyzed collectively and the females analyzed alone had a 95% likelihood of being detected at one station when six stations were placed within each home range (Figure 16). However, the two males had a 95% likelihood of being detected at one station when three stations were placed in each of their home ranges (Figure 16).

The theoretical station density for all martens per average home range (6 stations per home range) was one per 108 ± 38 ha (Table 12). The theoretical station density for males (3 stations per home range) was one station per 364 ± 95 ha. The theoretical station density for females (6 stations per home range) was one station per 58 ± 14 ha.

The real station density for all martens analyzed collectively was one per 105 ± 15 ha (Table 12). The real station density for males was one per 136 ± 1 ha. For females, the real station density was one per 84 ± 14 ha. The real and theoretical station densities did not differ significantly for all martens analyzed collectively ($Z = 0.42$, $P = 0.7$) or for males or females ($Z = 1.5$, $P = 0.1$; $Z = 1.1$, $P = 0.3$, respectively).

The dependence between home range sizes and individual probabilities of detection was tested and there was no significant relationship ($r^2 = 0.38$, $P = 0.266$). There was, however, a significant relationship between the number of stations in a home range and home range size ($r^2 = 0.96$, $P < 0.01$).

In the analysis, every other station was deleted across the survey extent to imitate a 2 km spacing and the probabilities of detection were recalculated for each marten (Table 15). The probabilities of the two configurations did not differ significantly from the actual probabilities (alternate 1: $Z = 0.84$, $P = 0.4$; alternate 2: $Z = 0.10$, $P = 0.92$). However, one marten was not detected in one scenario and another marten was undetected when the alternate set of stations was deleted (Table 15).

Detection Devices

Martens were detected 122 times at 19 track-plate stations and 99 times at 19 triggered-camera stations (Table 16). The detection ratio for martens for each detection device during the survey was 0.95 (Table 16). Marten #04 was relocated with telemetry on only three occasions, however he was detected at three triggered-camera stations during the survey.

Marking animals with unique reflective ear-tags permitted identification of individuals at the triggered-cameras which allowed important insight into the behavior of the animals at the detection stations. Repeated visits to the stations during the survey period ranged from 34 times for one male (#06) to only two times for a female (#05) (Appendix J). The average number of visits during the survey period for males and females was 21 ± 9 and 8 ± 5, respectively. During the 48 hours of the eleventh examination interval, male #06 visited five stations, travelling a lineal distance of 6.8 km.

Unique marking also allowed examination of the number of different individuals that visited a particular station during the survey period. Visitation by more than one individual (including unmarked animals) occurred at 13 of the 20 stations; ten stations had visitation by at least two different individuals and three stations had visitation by at least three individuals (all detections of unmarked animals at one station were counted as the same animal, but may have really been more than one). Ten stations had detections of two different martens on two consecutive examination intervals).

The marked martens did not always approach the cameras from the front which made positive identification difficult on three occasions. If animals had been tagged in both ears this problem would have been reduced.

Taylor and Abrey (1982) reported that some martens may patrol and mark their foraging areas with fecal material (scat) when marten densities are high. We found scats immediately adjacent to the devices on 66 occasions (46% of the time the stations were visited). Stations that were visited by two or more different martens during the survey period had scat associated with the visit 49% of the time, while stations visited by only one marten had scat 37% of the time.

All six martens were detected at a triggered-camera device by the second examination interval (4 martens were detected on the first interval and the remaining 2 were detected on the second interval) (Appendix J). Five detection stations had detections of martens on the first examination interval. There was a rapid increase in the cumulative number of stations with detections until the fifth interval, after which the increase was gradual. Detections of martens occurred at 95% of the stations by the eighth examination interval.

There were more than six martens in the study area; an undetermined number of unmarked martens were detected on 13 occasions at nine different triggered-camera stations. Marked martens were detected 86 times at 19 different triggered-camera stations.

DISCUSSION

BAITS, DEVICES, AND SURVEY PROTOCOL

Development of Baits and Devices

The track-plate with con-tact paper and the triggered-camera were the most effective and reliable devices that were tested with captive fishers. During pre-trial observations hair-snare tubes were discarded as a potential detection device because captive animals were observed entering the hair-snare tubes but detections did not occur. Field studies have also found that track-plates were more effective than hair-snares (Barrett 1983). Hair-snares have been effective in detecting small mammals in Australia (Suckling 1978, Scott and Craig 1988); however the hair-snare detection device in these studies was designed to determine occurrence rather than monitor populations through time. The variable outcome (dependent on weather) of the hair-snare detection device that we tested would violate the assumptions of an index to monitor a population over time. In addition, if the objective is to establish occurrence, it is important to use a device that is most efficient in detecting the species. In our laboratory experiments, the inability of the hair-snares to obtain detections was either because the animal's hair was wet and did not adhere to the sticky surface, or that the sticky surface was wet and lost its ability to snare any hair. In either case these conditions could be expected to be encountered in the field in an unpredictable manner. Thus, such a device would be ineffective.

There was large observed variability in the activity both within and between the individual captive fishers. Due to this variability it was difficult to statistically examine time as a response variable to the different baits. Certain animals, particularly the females, appeared less likely to approach the baits and detection devices. Sexual bias in capture rates has been reported in trapping studies of fishers and martens in California. Although not statistically significant, Buck (1982) captured twice as many male as female fishers (14 males, 7 females). Simon (1980) and Martin (1987) also found sexual bias in capture rates of martens (14 males, 4 females; 7 males, 4 females, respectively). This bias might also occur for detection devices in the field.

One size track-plate box was tested in the laboratory and field. The box size was adequate for captive fishers (they did not appear to hesitate to enter the box); however a larger box may be more effective for larger animals such as the Sierra Nevada red fox (*Vulpes vulpes necator*). Larger boxes (30 x 30 x 80 cm) were subsequently used to detect fishers on the Hoopa Indian Reservation (Fowler et al. 1992).

Field Testing of Baits, Devices, and Survey Protocol

While detection devices such as the track-plate and triggered-camera were effective methods to detect animals, there are inherent problems which influence their efficiency. These factors require understanding prior to development of monitoring plans in order to effectively examine populations either through time or at a point in time. In addition to the biological factors that may affect monitoring, there are also several potential sampling errors. It is important to utilize a technique that will reduce these effects to the extent possible.

In the test of detection devices, we made no attempt to distinguish individuals of a species from the tracks or photographs. Therefore we were uncertain whether more than one individual of the same species visited a station, or whether one individual visited more than one station. Unless animals in a population are tagged, this relationship between visitation and density is uncertain. For indexing, this problem caused us to use the detection ratio as the response variable rather than the actual number of individual detections. Although this was essential to minimize recounting the same individual (and bias the index), the ratio may also be less sensitive to population changes at a specific site.

Habitat conditions may also affect differences in visitation rates even though densities of animals may be equal. Linhart and Knowlton (1975) reported that coyote movements were dictated by topography; unless this was controlled, the relative population indexes for different areas may be less comparable than annual trend data from the same area.

Attraction of the bait and the sampling radius around a detection station may change through time and could possibly affect visitation. The specific role of bait in obtaining a detection requires further study.

Due to the confounding factors that affect monitoring with detection devices, and because martens and fishers are relatively low-density species in California, it is important to maintain a large and intensive sampling effort. Sampling that is adequate to detect changes in a detection ratio is essential for these techniques to be useful to land managers. The confounding factors that affect individual stations will probably not be systematic. The detection ratio will be most robust to these factors in a large sample. Therefore, a large number of stations across the landscape is essential to reduce variability, increase precision, and provide consistent results that reflect the population. The relatively low-cost of track-plates or triggered-cameras is an important attribute allowing the maintenance of a large number of samples across the landscape. Without a large number of samples, it may be difficult to effectively index or monitor the population of interest.

The triggered-camera may be most useful in situations where animals have distinguishing marks (eg. ear tags). However, in the absence of such marks the cameras were not more effective than the track-plates for distinguishing individuals. Thus, for monitoring or indexing, the decision of which device to use should be based primarily on cost, an adequate sample size (which is related to cost), efficiency, and reliability of the resulting detection ratio. We recommend the use of track-plates for population surveys of martens, and probably fishers. Track-plate detection stations provide an effective method to monitor populations of several forest species. Track-plates were effective in detecting martens on the Tahoe National Forest and were effective in detecting fishers in northwestern California (subsequent study on the Hoopa Indian Reservation; Fowler et al. 1992).

In other studies, track-plates have been effective both in comprehensive surveys (Raphael and Barrett 1981), and specifically for furbearer detections (Barrett 1983, Martin 1987, Bull et al. 1992). In addition to detections of forest carnivores we found that our track-plate configuration was effective for monitoring populations of several squirrel and rodent species. Raphael et al. (1986) found that their track-plate design was effective for monitoring flying squirrel populations. Flying squirrels were also frequently detected with our track-plate box design. The incidental information gained from track-plate surveys can be useful for understanding communities that may be associated with fishers or martens.

Track-plates were more reliable and effective than the triggered-cameras. More detections occurred at track-plate stations and there was greater success of detections that could be identified to species. In addition, the greatest number of species were detected with track-plates. Track-plates have the potential to accumulate detections over time (multiple visits or multiple species, even in the absence of bait), whereas triggered-cameras require the animal to pull the bait and result in only one possible detection. The track-plate box may also provide an attraction to an animal that is in addition to, or a substitute for, the bait. Often animals entered the box and left tracks but did not remove the bait. It was not possible to determine whether an animal approached the camera but did not remove the bait.

The per-unit costs of track-plates and triggered-cameras were similar (Appendix H); however the monitoring effort (time required to check the device and change bait) for the track-plates was less. For occurrence monitoring, the greater detection ratio of the track-plates could result in reduced field effort (and personnel time). In addition, assuming similar variance between devices, the greater detection ratio for track-plates would improve our ability to identify real changes in the index and subsequently trigger a management response.

Most importantly, the track-plates were technically very simple. A simple technique would decrease problems associated with variability in technician skill. A more complicated device that required greater technician skill could either add cost or another confounding variable to the index. Track-plates as a monitoring device met the assumptions of the index: they were consistent through time and were not susceptible to variation in technician skill. However, the ability to properly identify tracks does vary. We recommend having one knowledgeable person to verify the identity of the tracks and reduce observer variability and bias. This has been difficult in the past. Because this design uses track-positives on the con-tact paper, the tracks may be readily photo-copied or sent via FAX machine. Consequently, the tracks may be easily confirmed by the person responsible for identification.

Triggered-cameras were a useful device to monitor populations of martens and fishers (fishers were detected with triggered-cameras on the Hoopa Indian Reservation; Fowler et al. 1992). Martens were successfully detected with another triggered-camera design in Washington (Jones and Raphael 1993). Problems encountered with triggered-cameras have been predominantly technical in nature; there was greater variability in establishing and maintaining a triggered-camera station because there were more complicated components to the device (eg. triggers, flash devices, batteries, aim of the device at the mobile target). The photographs were useful to distinguish between male martens and female fishers (which at present is sometimes not possible with tracks alone). They may also be effective for research to monitor specifically marked individuals in the population. We recommend the use of cameras as a back-up device to the track-plates to provide additional information where necessary. We do not recommend the use of the triggered-cameras as the single device to monitor populations over time due to the potential violations of assumptions that can not be controlled, and their poorer performance (which has sample size consequences).

The greatest detection ratio for martens was obtained in the spring season, which was also the season with a high and late snow-cover. The higher detection ratio may have been attributable to the examination interval which was longer during this period than during the summer surveys. The spring season was a difficult time of year to survey because access was difficult and unpredictable; as the snow began to melt, both snowmobile travel and vehicle travel were unreliable and sometimes unsafe. Consequently, it was difficult to guarantee standardization for examination of track-plates or triggered-cameras during spring surveys, thus violating an assumption of the index.

There was a marked increase in the number of stations with black bear detections from the spring to late summer survey. There was a decrease in both marten and gray fox detections during the same time period. This decrease may be associated with the increase in bear activity (removing available detection stations) or may result from seasonal changes in availability of different foods for martens and gray foxes. If favored food was more available during the later summer months, we might expect a decline in marten and gray fox detections because they may be less likely to respond to a bait. Based on these observations we recommend early summer surveys. Lindzey et al. (1977) stressed the importance of monitoring at similar times each year to properly examine trends in populations over time.

PROBABILITY OF DETECTION

The use of detection devices to monitor population trends or determine occurrence requires three assumptions: 1) all individuals in an area are detectable, 2) all tracks or photos are observed and distinguishable, and 3) all individuals have equal probability of being detected across time or space. The first assumption could not be addressed because we did not (and probably could not) capture all martens in the population. We acquired insight into the second assumption by examining the number of tracks and photos that could be identified to species (see previous sections).

We examined the third assumption by marking animals in the population and monitoring their visits to detection stations. The probabilities of detection were not equal among individuals, possibly because of individual variation or gender differences. Other factors that may have contributed to variance in detection probabilities across time or space included; home range size, habitat quality, season, station geometry (spacing, arrangement, and density), and survey duration. In spite of the variation, examination of the detection probabilities is useful for understanding the assumptions of a monitoring plan. The probabilities of detection calculated from this study reflected a specific area, season, duration of survey, and station geometry. Other geographic locations or seasons may result in different probabilities of detection which would provide insight into the variance associated with the probabilities. In addition, a better understanding of the variance in detection probabilities both between individuals and between different locations will allow insight into the interpretation of negative results (absence of a species). The likelihood of detecting a target species is directly related to the ability to determine its occurrence.

Individual Variation

There may be variation in movements between individual martens which may affect the probabilities of detection. Taylor and Abrey (1982) tracked several animals simultaneously and found that individual martens moved quite differently under the same environmental conditions; their activity levels also varied during the same time period. They hypothesized that movements of martens were probably related to hunting success which may explain some of the individual variation that they observed. Simon (1980) reported that martens concentrated their use of several different areas within their home range. Martin (1987) reported that re-occupations at rest sites occurred within a few days or weeks after first occupation. These movements, the timing of movements, and the duration of time spent in a particular area would influence the likelihood of an animal to encounter detection stations. On one occasion, one animal was detected at a new station within its home range on the last, eleventh, examination interval.

Gender

Gender may also affect detection probabilities. Although males and females were captured in equal numbers (3 males, 3 females), males were more likely to be detected. Differential detection rates were consistent with harvest data which were skewed toward males (Yaeger 1950, Strickland et al. 1982), and with research where males were captured in unequal proportions to females (de Vos and Guenther 1952, Lensink et al. 1955, Hawley and Newby 1957, Weckwerth and Hawley 1962).

Home Range Size

Home range size may affect the probability of detection. Our estimation of home range size was probably affected by the duration of time that telemetry locations were collected; Buskirk and McDonald (1989) reported that the duration was an important factor contributing to variation between marten home range sizes from nine studies. They hypothesized that larger home ranges were possibly attributable to shifts in home range boundaries that were observed only over a long period of time. Taylor and Aubrey (1982) reported that martens have dynamic home ranges which may be moveable; they hypothesized that adult male martens may move from one foraging area to another during the year rather than having a fixed home range. Home range areas may also shift with season as reported by Simon (1980), Martin (1987), and Buskirk and Lindstedt (1989).

The martens in our study were tracked with radio-telemetry for a limited time period; however, the home ranges were adequate to define the area used by the animals during the interval when our stations were monitored. The biological concept of home range is important in applying probabilities of detection to situations where individual animals are not marked and home ranges are unknown. Home ranges based on one season of sampling would underestimate the total area used on a year-round basis. Consequently, the likelihood of detecting an animal would probably be less than our calculated probabilities if the stations were placed in a specific area of a home range that was little used at the time of year when monitoring was conducted.

Home range size may also vary as a result of variation in habitat quality. Buskirk and McDonald (1989) reported highly significant between-site differences in marten home range sizes from nine study areas, and hypothesized a strong relationship between home range size and site conditions.

Season

Season may also affect the probability of detection. During the winter we would expect many animals to obtain our bait as a food source, thus increasing their visitation to stations. Bull et al. (1992) hypothesized that martens were less likely to visit stations in the summer than winter because more abundant prey was available. In addition, bait may have been more available in winter because of an absence of competitors. Therefore, our probabilities of detection were probably greater than what would be observed for other seasons. Black bears visited the stations < 1% of the time during the winter survey versus 28% of the time during monitoring in August in the same area.

Station Geometry

Dimorphic capture rates which are analogous to dimorphic detection ratios must be considered when interpreting probabilities of detection and the results of surveys. It is commonly believed that differences in capture rates between the sexes of Mustelidae are related to dimorphic home range size (Hamilton 1933, Yaeger 1950, Lensink 1957). In other words, males had a greater number of traps in their home range, and thus, a higher probability of encountering traps. Buskirk and Lindstedt (1989) examined this and other factors that may have contributed to differing capture rates including an effect of trap spacing proposed by King (1975). King (1975) suggested that different capture rates were attributable to effects of trap spacing: 1) when traps were spaced at greater distances than the diameter of the smallest home range, some females were excluded from capture because their home ranges did not contain traps, and 2) at small spacing intervals males had more traps in their home ranges than females. Buskirk and Lindstedt (1989) manipulated trap spacing and found that it could cause differential capture rates if home ranges were sexually dimorphic and spacing intervals were greater than 0.71 times the mean diameter of female home ranges. Consequently, certain station spacing would favor the detection of males over females and affect the assumption of equal probability.

Buskirk and Lindstedt (1989) also examined the effect of body-size-dependent factors that contributed to sex biased capture rates by conducting computer simulations. A larger size animal travelled more quickly through its home range, and thus, increased its rate of encountering traps. However, because home range diameter increased more rapidly than rate of travel, larger animals crossed their home ranges more slowly than smaller ones. Buskirk and Lindstedt (1989) found that larger animals (males) had a higher chance of encountering traps when they were placed in a grid. However, when placed in a line, smaller animals (females) had greater rates of encountering traps because density of traps was greater in small home ranges. When we analytically increased the station spacing to 2 km (station density reduced by half), the probability of detection for two females declined to zero. Two stations were in each of the female home ranges, thus an exclusion effect did not occur. Consequently, it is necessary to maintain a consistent and close spacing of stations to reduce the likelihood of not detecting individuals.

Duration of Survey

The duration of the survey influenced the probability of detection. When the survey period was analytically shortened to six examination intervals, a 95% probability of detection at one station required more stations within the animal's home range. A reduction in the survey duration required an increase in the number of stations in a home range to achieve the same level of detection accuracy. Consequently, if a survey objective was to maximize the likelihood of detecting individuals in a population, it would be necessary to survey for an adequate duration or compensate with an increased station density.

Conclusion

The assumption of equal probability of detection across individuals could not be met; however, examination of individual behavior at the detection devices allowed an understanding of factors that were affecting the probability of detection. Many factors that influence the probabilities of detection can be controlled such as season, station geometry including spacing, layout, and density, and survey duration. These should be consistent between studies if the objective is to monitor trends. Even if studies are consistent from year to year, it is necessary to consider and adjust for unequal detection probabilities that are influenced by factors such as gender or individual variability. Adjusting for such factors requires conservative interpretation of detection probabilities to increase the likelihood of detecting all individuals.

Our estimates of marten detection probabilities were collected during the winter season when the weather conditions may have been favorable to high rates of detection. In addition, habitat may have favored easy accessibility or perhaps a poor prey base which would contribute to high detection ratios. Consequently, these results are probably liberal estimates and can not be used to infer minimum sample interval in areas of different habitat, season or marten density.

RECOMMENDATIONS

We recommend that surveys be conducted at similar times each year. While winter surveying may result in the greatest number of visits by target species (due to reduced problems with bears or removal of bait by other animals), weather conditions and resulting behavior patterns vary from year to year. If used for trend analysis, variation in weather would violate the assumptions of the index. Weather variation could also alter between year probabilities of detection. Martens visited stations less frequently in summer than winter or spring (Bull et al. 1992); greater effort would be required to achieve the same level of accuracy in summer. Spring or fall surveys can be more consistent between years while providing the greatest number of visits of the target animal.

Spacing of stations should be consistent between studies. Longer distances reduced the probability of detecting animals, thus a greater survey effort would be required. Consequently, we recommend that stations be spaced at 1 km intervals in a linear configuration to insure the likelihood of detecting females.

If the objective of surveying is to determine occurrence of a marten in a small area such as a timber harvest unit, it is particularly important to understand and adjust for the variation in detection probabilities between gender. The likelihood of detection for the least detectable individuals (females) should be used to calculate minimum survey effort. We recommend a 22-night (11 examination intervals) survey period if the objective of the survey is to be reasonably certain that any individual marten that is present at the site is in fact detected. Shorter durations must be compensated by greater station densities; however, the relationship between station-density and certainty of detection would require apriori knowledge of the home range (which is not generally available). Use of the technique for other species may also require adjustment of the survey duration.

Further investigation into the potential for trend analysis at the scale of the Forest District is still needed. Specifically, variation in detection ratios, sample size (number of stations), and statistical power in detecting changes in the response variable will need to be addressed. Finally, we did not investigate the regional or statewide scale of monitoring. Extrapolation of our findings to other species or scales should be done so with great caution until further data become available.

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Table 1. Terminology for evaluation and use of devices to survey and monitor marten and fisher populations.

Term	Definition
Detection Device	A specific technique or physical device such as a track-plate or triggered-camera used to survey species by recording their visitation to the device (previously described in progress reports as "detection technique").
Detection	A positive record of the presence of an animal resulting from a detection device (track-impression or photo).
Track-plate	A detection device that utilizes a metal surface with an applied layer of soot (and/or other temporary adhering medium) to detect an animal. The soot is removed from the surface or lifted onto the adhering medium by the animal's foot resulting in a track-impression.
Track	The imprint of an animal's foot on the track-plate surface (either a negative track resulting from the soot or other medium being removed from the metal plate, or a positive track resulting from a sooty foot leaving an imprint on the con-tact paper).
Triggered-camera	A detection device that utilizes a baited camera to detect an animal. The resulting detection is a photo.
Station	A specific site within a forest stand where detection device(s) are placed.
Investigator Examination	The systematic inspection and re-baiting of the detection device(s) at a station (detections are chronicled during each investigator examination).
Examination Interval	The interval between investigator examinations (eg. in our work stations were examined every other day for a total of 11 exam&ion intervals) (previously described in progress reports as "sample-trial").
Survey	The effort expended to survey or monitor target animals.
Survey Period	The duration of the survey effort (ie. the sum of the examination intervals in real time) (previously described in progress reports as "sample period").
Survey Night	The 24 hour period during which one detection device is baited.
Survey Extent	The area surveyed during the survey period.
Survey Intensity	An index of the effort expended for a survey: calculated as the total of the examination intervals divided by the number of nights in the survey period, multiplied by the number of stations examined.
Latency to First Detection	The number of days to the first detection of a target species.
Minimum Survey Period	The time period after which an increase in investigator effort provides no significant increase in the detection ratio (eg. in our -work, established by plotting the cumulative new stations with a detection against the examination intervals in a survey) (previously described in progress reports as "minimum sample-period")
Frequency of Animal Visitation	A measure of repeated detections; calculated as the total number of detections of target species at the stations divided by the total number of times the station was available, multiplied by 100. The number of times the station was available was calculated as the number of stations monitored during the survey multiplied by the number of examination intervals. The frequency is reported for the survey to compare visitation between subsequent surveys or adjacent surveys (previously described in progress reports as "frequency of occurrence"). This measure is similar to the relative index value as reported by Lindsey et al. 1976.
Detection Ratio	A binomial measure of detections; calculated as the number of stations with a detection of a target species divided by the total number of stations examined during the survey. The detection ratio is reported for the survey to compare visitation between subsequent surveys or adjacent surveys (previously described in progress reports as "detection rate").
Probability of Detection	The likelihood of detecting target species; calculated using marked animals and detections at stations that are placed within known home range areas.

Table 2. Six baits used in laboratory tests with captive fishers at the Humboldt State University Game Pens (November 1990-March 1991).

Bait	Source/Availability
Pseudocorpse Scent Formulation II (chemical based canine training scent)	Sigma Chemical Company Saint Louis, MO (800)325-3010
Fatty Acid Scent (FAS) (chemical based scent for surveying coyote populations)	U.S.D.A. Pocatello Supply Pocatello, ID (208) 236-6920
Fisher Urine (freeze-dried)	obtained from captive fishers, Humboldt State University Game Pens
9-Lives Tuna Cat-food	grocery store Heinz Pet Products Co. Newport, KY
Smucker's Strawberry Jam	grocery store J.M. Smucker Co., Orville, OH
Chicken Wings	meat market/grocery store

Table 3. Number of times captive fishers responded to baits and controls divided by the number of times the bait and control were available[a], Humboldt State University Game Pens, Humboldt County, California, November 1990- March 1991.

	Animal				
Bait	1	2	3	4	5
Chicken	42/87 +	2/3 +	16/28 +	2/15 +	3/8 +[b]
Control	0/34	0/1	1/26	0/13	1/7
Tuna Cat-food	17/33 +	2/2 +	10/26 +	6/23 +	7/18 +[b]
Control	14/34	0/0	0/16	0/12	1/5
Strawberry Jam	9/37 +	2/6 -	2/61 -	5/8 +	3/8 +
Control	1/12	3/5	3/55	0/8	0/7
FAS	3/34 +	0/1	3/25 +	0/9	0/7
Control	3/39	0/2	0/18	0/6	0/7
Pseudocorpse	5/38 -	0/1	2/49 -	0/6	6/15 +
Control	6/30	0/0	3/48	0/3	1/7
Fisher Urine	13/46 +	0/0	0/8 -	0/5 -	1/3 +
Control	4/15	0/0	1/11	1/7	0/5

[a] The sign test was used;. a + sign indicates that the animal responded with greater probability to the bait than to the control, and a - sign indicated the animal responded with greater probability to the control.
[b] Significant difference between the bait and the control (P = 0.03).

Table 4. Species identified at paired triggered-camera and track-plate stations-monitored during three seasons on the Foresthill Ranger District, Tahoe National Forest, California.

Species	Season					
	Spring		Early Summer		Late Summer	
	Track-plate	Camera	Track-plate	Camera	Track-plate	Camera
Marten	X	X	X	X	X	X
Gray Fox	X	X	X	X	X	X
Black Bear	X	X	X	X	X	X
Ringtail	X	X				
Long-tailed Weasel	X				X	
Short-tailed Weasel			X		X	
Spotted Skunk			X	X	X	X
Striped Skunk	X					
Raccoon			X		X	
Coyote				X		
Mule Deer		X		X		X
Rabbit				X		
Goshawk				X		
Opossum			X		X	
Woodrat	X		X		X	X
Gray squirrel	X					
Calif. Ground Squirrel	X		X	X	X	X
Douglas Squirrel	X		X		X	
Flying Squirrel	X		X	X	X	X
Golden-mantled Ground Sq.	X		X	X	X	
Chipmunk spp.	X		X		X	

Table 5. Number of visits of target species at stations with chicken versus cat food bait. Detections are from the Foresthill Ranger District, Tahoe National Forest, California.

Species	Bait	Season			Total
		Spring	Early Summer	Late Summer	
Martens	Chicken	12	26	12	50[a]
	Tuna	13	11	8	32
Gray Foxes	Chicken	37	98	68	203
	Tuna	49	116	55	220
Black Bears	Chicken	2	96	170	367
	Tuna	3	75	243	320
All Animals	Chicken	228	869	909	2006[b]
	Tuna	203	724	762	1689

[a] Significant difference between the baits ($P < 0.02$).
[b] Significant difference between the baits ($P < 0.05$).

Table 6. Detection ratios[a] of martens, gray foxes, and black bears (the number of stations that detected an animal in parentheses) during three seasons in 1991 on the Foresthill Ranger District, Tahoe National Forest, California.

		Season		
Species	Device	Spring	Early Summer	Late Summer
Martens	Track-plate	0.22 (8)	0.10 (8)	0.08 (6)
	Triggered-camera	0.03 (1)	0.03 (2)	0.03 (2)
Gray Foxes	Track-plate	0.42 (15)	0.22 (17)	0.13 (10)
	Triggered-camera	0.31 (11)	0.22 (17)	0.17 (13)
Black Bears	Track-plate	0.06 (2)	0.59 (46)	0.80 (62)
	Triggered-camera	0.08 (3)	0.41 (32)	0.78 (61)

[a] Detection ratio was the proportion of stations with a detection of a particular species (number of stations that detected an animal divided by the total number of stations monitored during the survey).

Table 7. Number of stations, number of times the stations were visited, and frequency of visitation[a] of martens, gray foxes, and black bears at track-plate and triggered-camera stations during three seasons. Detections are from the Foresthill Ranger District, Tahoe National Forest, California.

Species	Device	Season	Stations	Visits	Frequency
Martens	Track-plate	Spring	8	24	10.3
		Early Summer	8	30	2.6
		Late Summer	6	15	1.7
	Triggered-camera	Spring	1	1	0.4
		Early Summer	2	7	0.6
		Late Summer	2	5	0.6
Gray Foxes	Track-plate	Spring	15	55	23.5
		Early Summer	17	129	11.0
		Late Summer	10	50	5.8
	Triggered-camera	Spring	11	31	13.2
		Early Summer	17	85	7.3
		Late Summer	13	71	8.3
Black Bears	Track-plate	Spring	2	2	0.9
		Early Summer	46	113	9.7
		Late Summer	62	239	27.9
	Triggered-camera	Spring	3	3	1.3
		Early Summer	32	57	4.9
		Late Summer	61	174	20.3

[a] Frequency of animal visitation was the number of times the stations were visited in a season divided by the number of times they were available (one estimate of availability was calculated for each season and equaled the number of stations that were monitored multiplied by the number of examination intervals; spring = 234, early summer = 1170, late summer = 858).

Table 8. Number of detections of martens, gray foxes, black bears and all animals (excluding rodent detections) at one device at a station and not the other. Detections are from the Foresthill Ranger District, Tahoe National Forest, California.

Species	Device	Season: Spring	Season: Early Summer	Season: Late Summer	Total
Martens	Track-plates	23	28	10	61
	Triggered-cameras	0	5	0	5
Gray Foxes	Track-plates	30	79	9	118
	Triggered-cameras	6	35	30	71
Black Bears	Track-plates	2	84	134	220
	Triggered-cameras	3	29	69	101
All Animals	Track-plates	61	162	134	357
	Triggered-cameras	10	77	84	171

Table 9. Detection ratio and standard error associated with changes in the station spacing and number of stations monitored during a survey. Detections are of martens on the Foresthill Ranger District, Tahoe National Forest, California.

Season	Station Arrangement	Number of Stations	Proportion w/Detections (Detection Ratio)	Standard Error
Early Summer	all stations	78	0.103	0.034
	every other station (1)[a]	39	0.103	0.049
	every other station (2)	39	0.103	0.049
	line A[b]	39	0.103	0.049
	line B	39	0.103	0.049

[a] Every other station was deleted from the analysis (resulting in 2 different station arrangements with a 3 km spacing between stations).
[b] The study area was divided into two random segments with 39 stations in each line.

Table 10. Detection ratio and standard error associated with changes in the station spacing and number of stations monitored during a survey. Detections are of gray foxes on the Foresthill Ranger District, Tahoe National Forest, California.

Season	Station Arrangement	Number of Stations	Proportion w/Detections (Detection Ratio)	Standard Error
Early Summer	all stations	78	0.269	0.050
	every other station (1)[a]	39	0.205	0.065
	every other station (2)	39	0.333	0.075
	line A[b]	39	0.284	0.072
	line B	39	0.256	0.07

[a] Every other station was deleted from the analysis (resulting in 2 different station arrangements with a 3 km spacing between stations).
[b] The study area was divided into two random segments with 39 stations in each line.

Table 11. Detection ratio and standard error associated with changes in the station spacing and number of stations monitored during a survey. Detections are of black bears on the Foresthill Ranger District, Tahoe National Forest, California.

Season	Station Arrangement	Number of Stations	Proportion w/Detections (Detection Ratio)	Standard Error
Early Summer	all stations	78	0.628	0.055
	every other station (1)[a]	39	0.666	0.076
	every other station (2)	39	0.59	0.079
	line A[b]	39	0.641	0.077
	line B	39	0.615	0.078

[a] Every other station was deleted from the analysis (resulting in 2 different station arrangements with a 3 km spacing between stations).
[b] The study area was divided into two random segments with 39 stations in each line.

Table 12. Theoretical and real station densities (hectares of home range per station, determined from MCP estimates) for martens, Fore&hill Ranger District, Tahoe National Forest, California, 23 December 1991 to 12 January 1992.

	Average Home Range Size (ha) x ± SE	Average Theoretical Density[a] (ha) x ± SE	Average Actual Density (ha) x ± SE
Kales and Females	645 ± 209	108 ± 35	105 ± 15
Males	1092 ± 204	364 ± 95	136 ± 1
Females	347 ± 85	58 ± 14	84 ± 14

[a] Average calculated station densities for males and females combined and for females alone are based on six stations per home range. Station densities for males alone are based on three stations per home range. The number of stations per home range is derived from the number of stations required to obtain a 95% probability of detection at one or more stations in the home range.

Table 13. Probabilities of detection for martens (home ranges estimated with the adaptive kernel and minimum convex polygon methods), Foresthill Ranger District, Tahoe National Forest, California, 23 December 1991 to 12 January 1992.

	Adaptive Kernel Method			Minimum Convex Polygon Method		
Marten ID	Stations in Rome Range	Stations Detected	Probability of Detection	Stations in Rome Range	Stations Detected	Probability of Detection
01	8	8	1.0	8	8	1.0
02	4	2	0.50	4	2	0.50
03	4	3	0.75	4	3	0.75
05	5	2	0.40	5	2	0.40
06	13	9	0.69	11	9	0.82

Table 14. Cumulative probabilities of detection for individual martens (home ranges estimated with the minimum convex polygon method), Foresthill Ranger District, Tahoe National Forest, California, 23 December 1991 to 12 January 1992.

Examination Interval	Marten ID				
	01	02	03	05	06
1	0.13	0.25	0	0	0.09
2	0.38	0.25	0.5	0.2	0.46
3	0.63	0.25	0.5	0.2	0.46
4	0.63	0.25	0.5	0.2	0.46
5	0.75	0.25	0.5	0.2	0.55
6	0.88	0.25	0.75[a]	0.2	0.55
7	1.0[a]	0.5[a]	0.75	0.2	0.64
8	1.0	0.5	0.75	0.2	0.64
9	1.0	0.5	0.75	0.2	0.73
10	1.0	0.5	0.75	0.4[a]	0.73
11	1.0	0.5	0.75	0.4	0.82[a]

[a] The examination interval when a marten attained its greatest probability of detection.

Table 15. Probabilities of detection (estimated with the MCP method) calculated with every other station deleted (2 different station arrangements resultingin a 2 km spacing between stations), Foresthill Ranger District, Tahoe National Forest, California, 23 December 1991 to 12 January 1992.

Station Arrangement	Marten ID				
	01	02	03	05	06
A	1.0	1.0	1.0	0	0.8
B	1.0	0	0.5	0.66	0.83
all stations	1.0	0.5	0.75	0.4	0.82

Table 16. Number of stations that were visited by martens, number of times the stations were visited, and the detection ratio[a] at track-plate and triggered-camera stations Foresthill Ranger District, Tahoe National Forest, California, 23 December 1991 to 12 January 1992.

Detection Device	Stations Visited	Detection Ratio	Number of Visits
Track-plates	19	0.95	122
Triggered-cameras (all martens)	19	0.95	99
Triggered-cameras (marked martens)	19	0.95	86

[a] Detection ratio was the number of stations where a marten was detected divided by the total number of stations monitored during the survey.

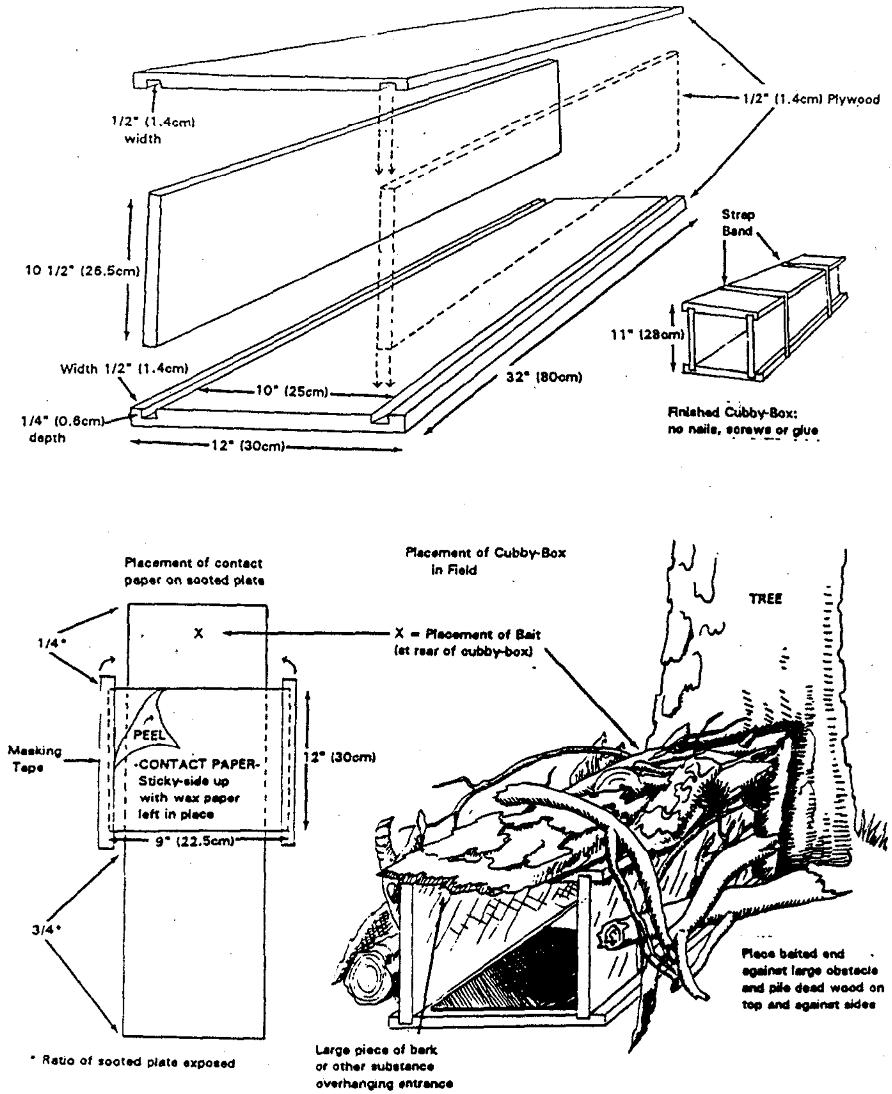


Fig.1. Details of the track-plate device used with captive fishers (Humboldt State University Game Pens), and for field testing on the Foresthill Ranger District, Tahoe National Forest, California.

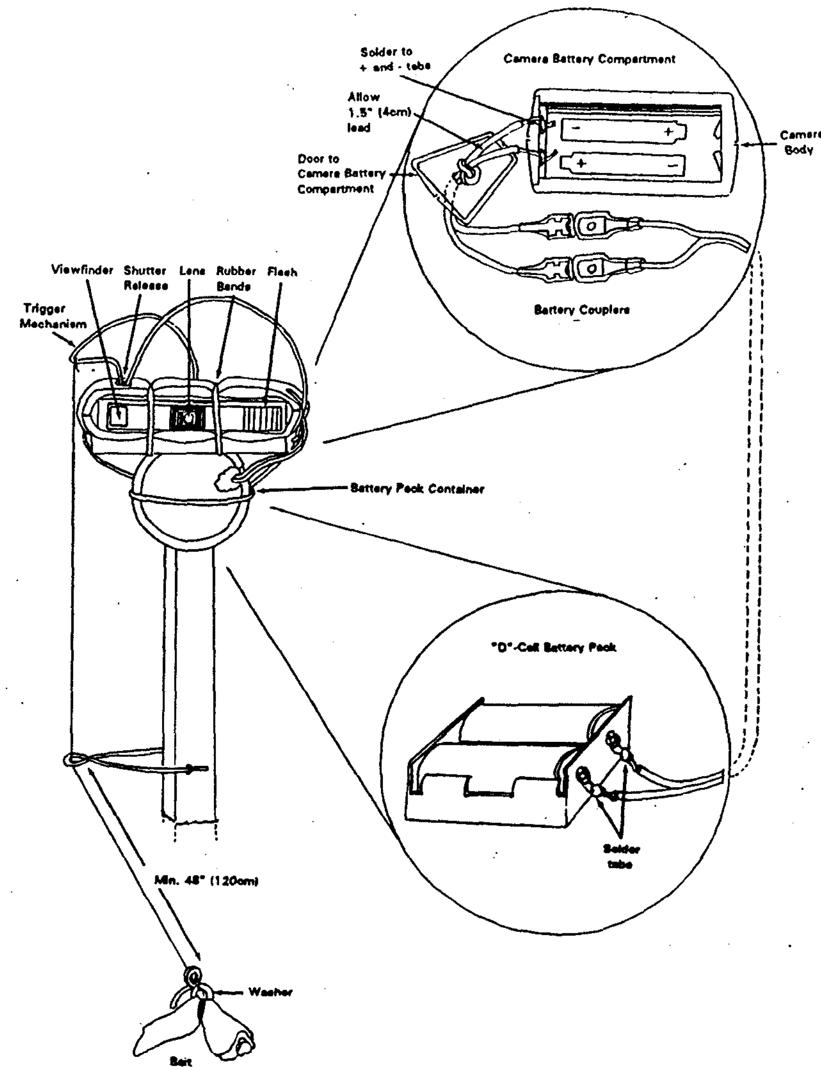


Fig.2. Details of the triggered-camera device used with captive fishers (Humboldt State University Game Pens), and for field testing on the Foresthill Ranger District, Tahoe National Forest, California.

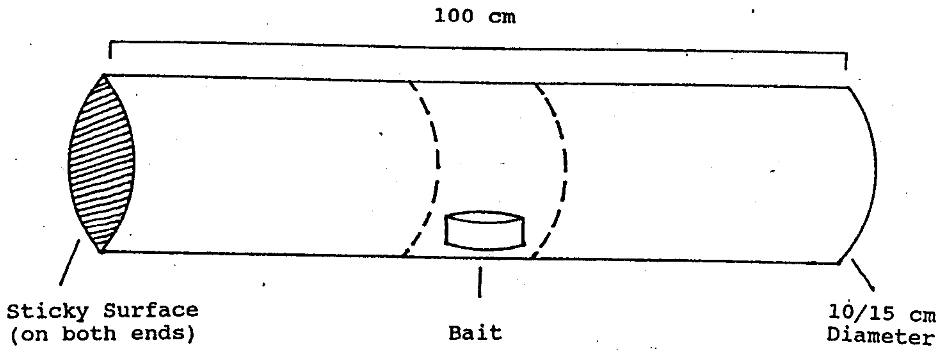


Fig.3. Details of the hair-snare device used with captive fishers (Humboldt State University Game Pens).

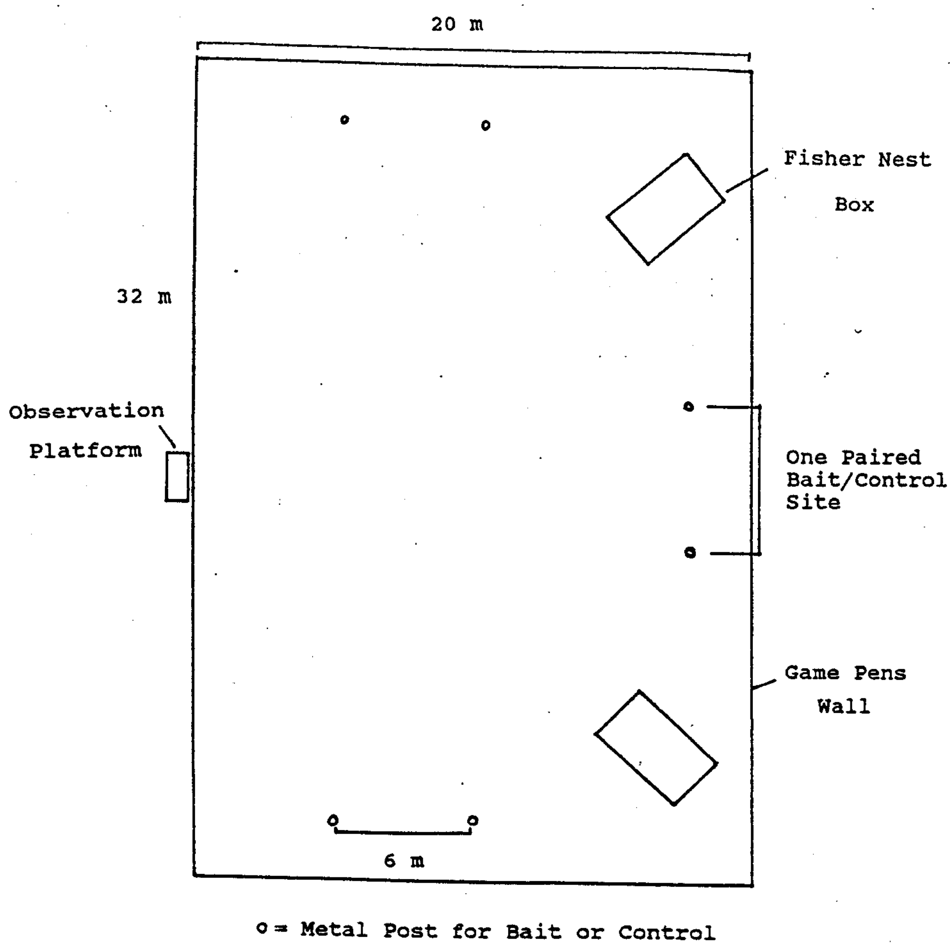


Fig.4. Location of paired bait and control sites for a bait response study of six captive fishers at the Humboldt State University Game Pens, November 1990 to March 1991.

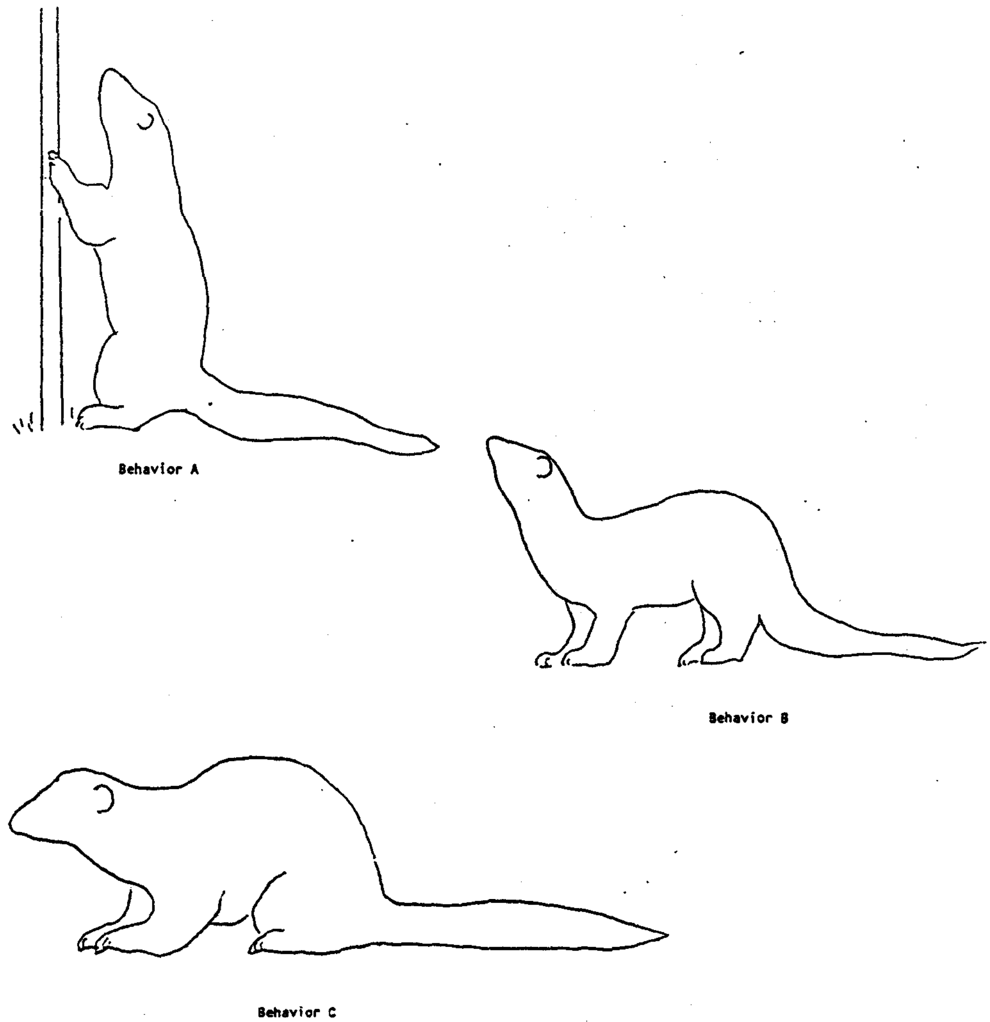


Fig.5. Three behaviors exhibited by captive fishers in response to different baits presented on a metal post one meter above the ground in the test-pen at the Humboldt State University Game Pens.

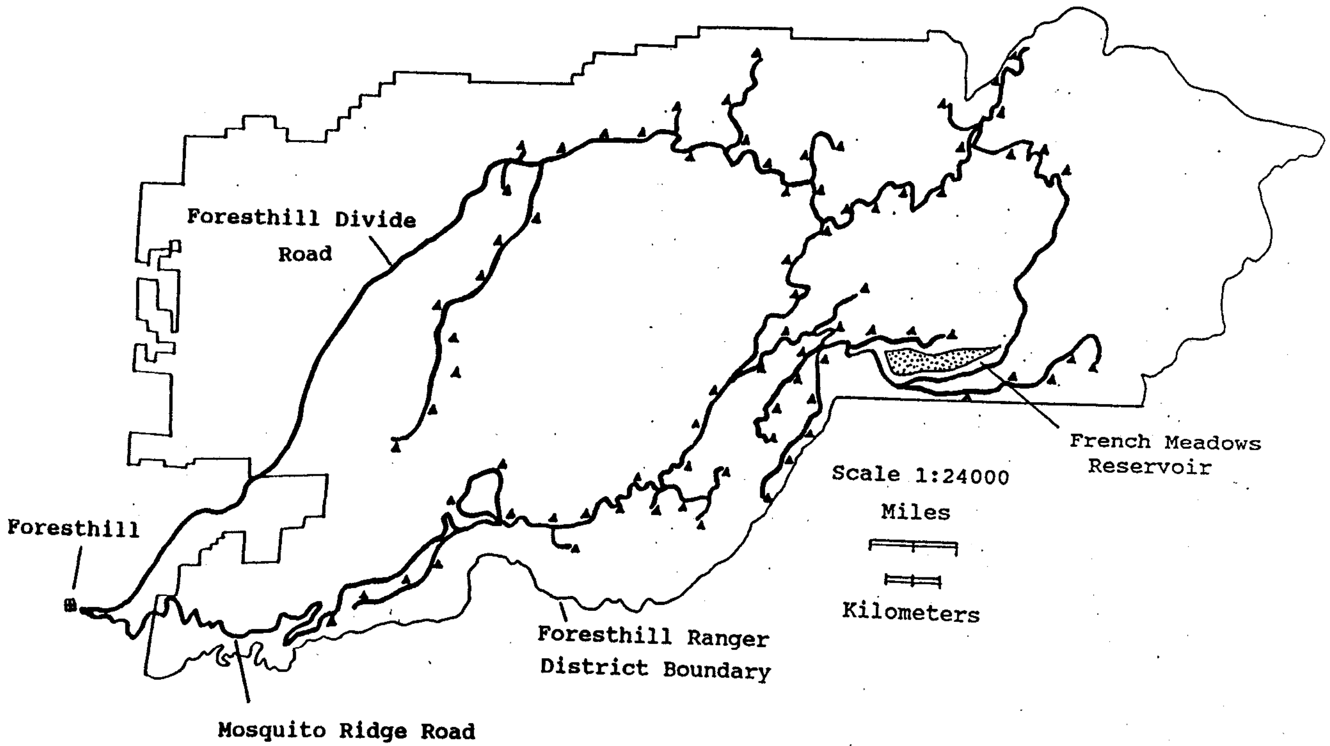


Fig.6. Distribution of detection stations to survey animals on the Foresthill Ranger District, Tahoe National Forest, California.

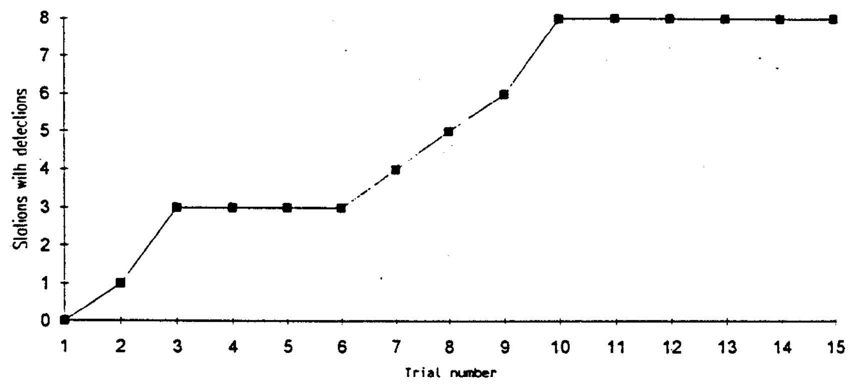


Fig.7. Minimum survey period for martens calculated from detections at track-plate stations during the early summer survey (22 June- 21 July 1991) on the Foresthill Ranger District, Tahoe National Forest, California.

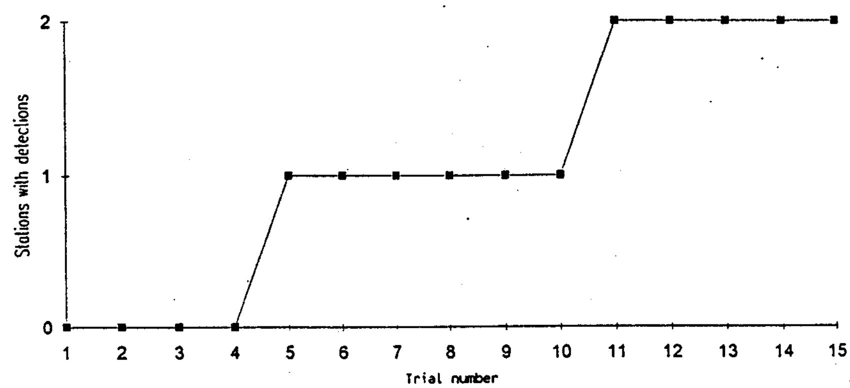


Fig.8. Minimum survey period for martens calculated from detections at triggered-camera stations during the early summer survey (22 June- 21 July 1991) on the Foresthill Ranger District, Tahoe National Forest, California.

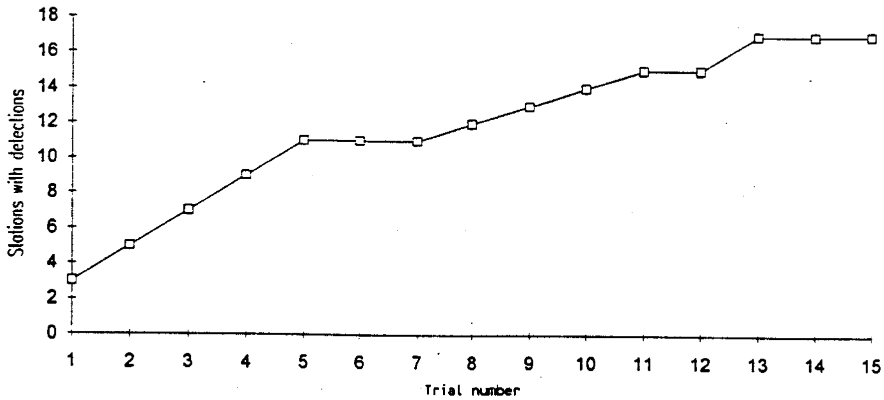


Fig.9. Minimum survey period for gray foxes calculated from detections at track-plate stations during the early summer survey (22 June- 21 July 1991) on the Foresthill Ranger District, Tahoe National Forest, California.

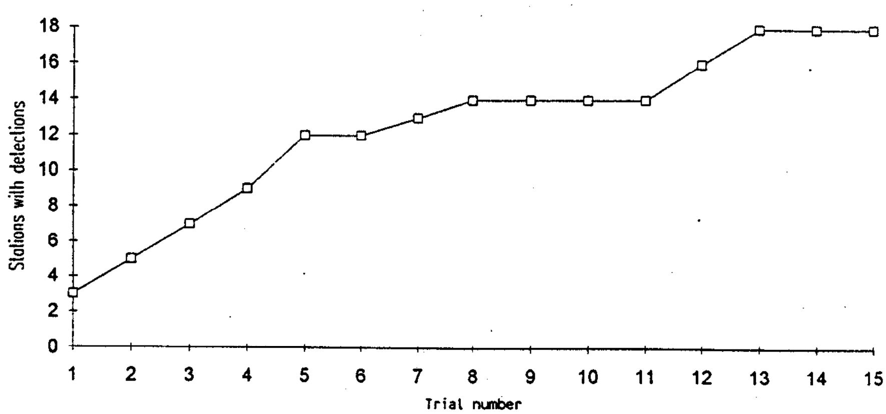


Fig.10. Minimum survey period for gray foxes calculated from detections at triggered-camera stations during the early summer survey (22 June- 21 July 1991) on the Foresthill Ranger District, Tahoe National Forest, California.

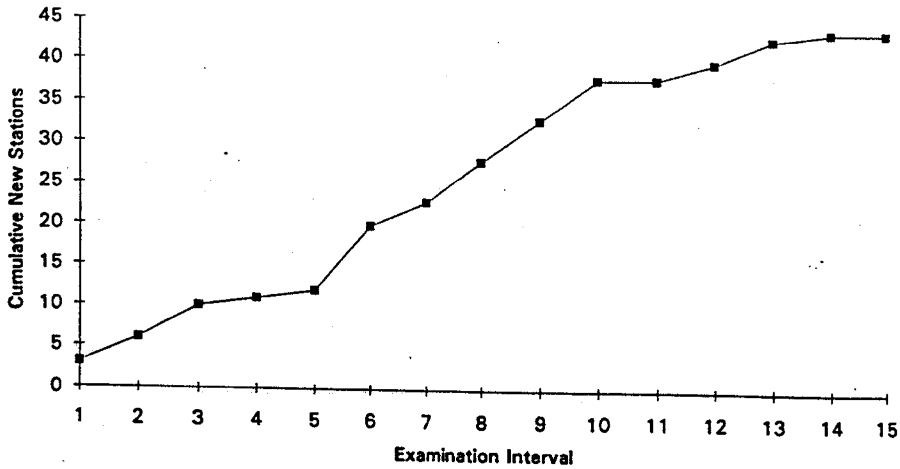


Fig.11. Minimum survey period for black bears calculated from detections at track-plate stations during the early summer survey (22 June- 21 July 1991) on the Foresthill Ranger District, Tahoe National Forest, California.

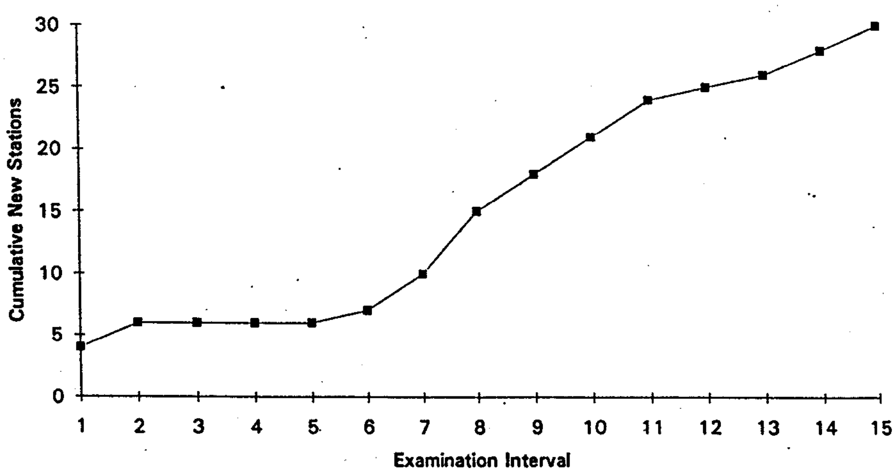


Fig.12. Minimum survey period for black bears calculated from detections at triggered-camera stations during the early summer survey (22 June- 21 July 1991) on the Foresthill Ranger District, Tahoe National Forest, California.

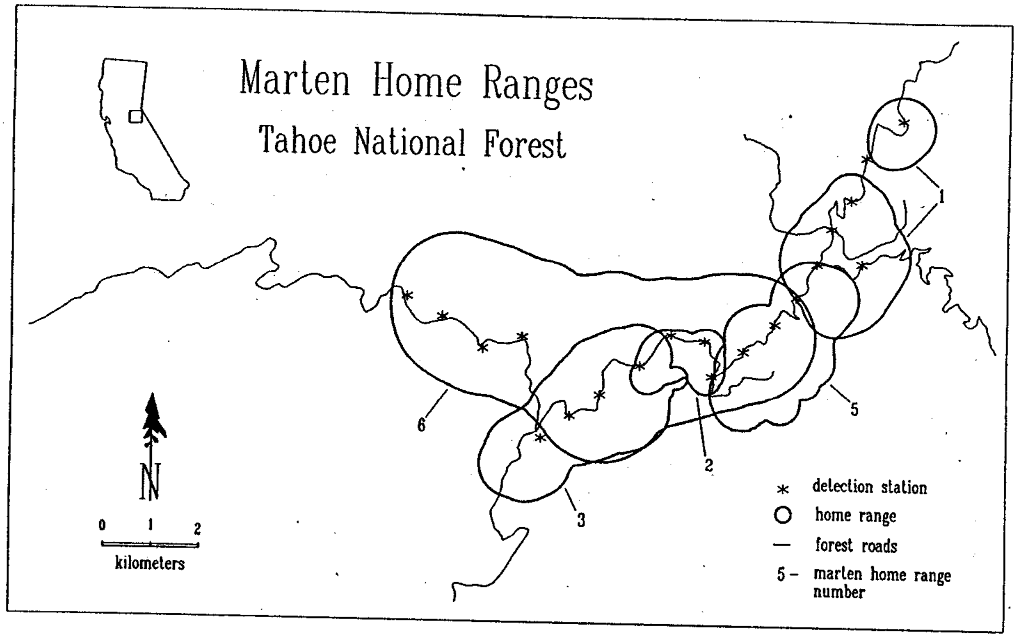


Fig.13. Marten home ranges (estimated with the adaptive kernel method), Foresthill Ranger District, Tahoe National Forest, California, October 1991 to February 1992.

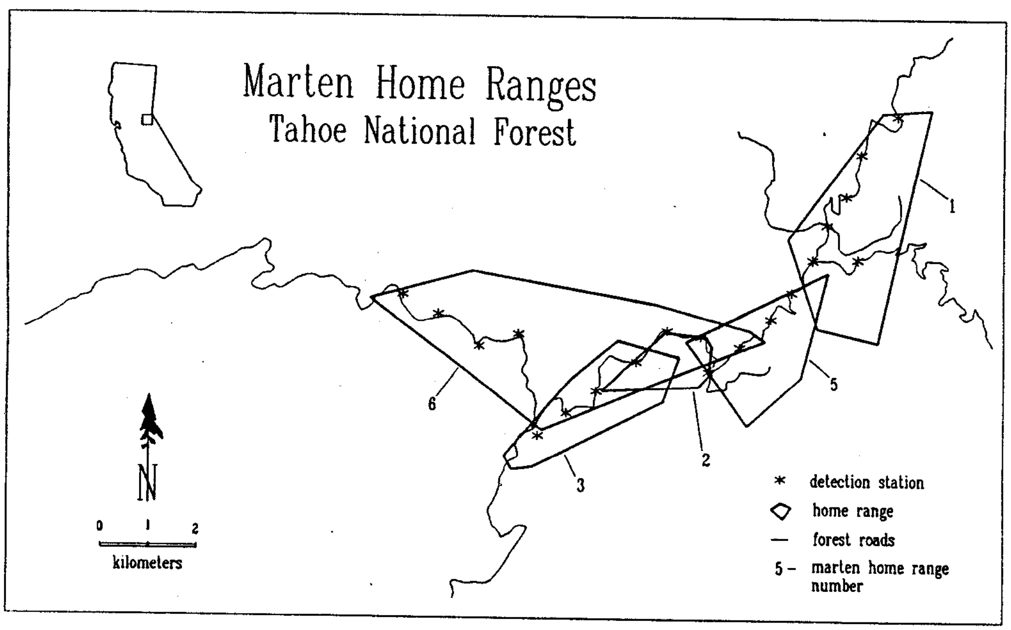


Fig.14. Marten home ranges (estimated with the minimum convex polygon method), Foresthill Ranger District, Tahoe National Forest, California, October 1991 to February 1992.

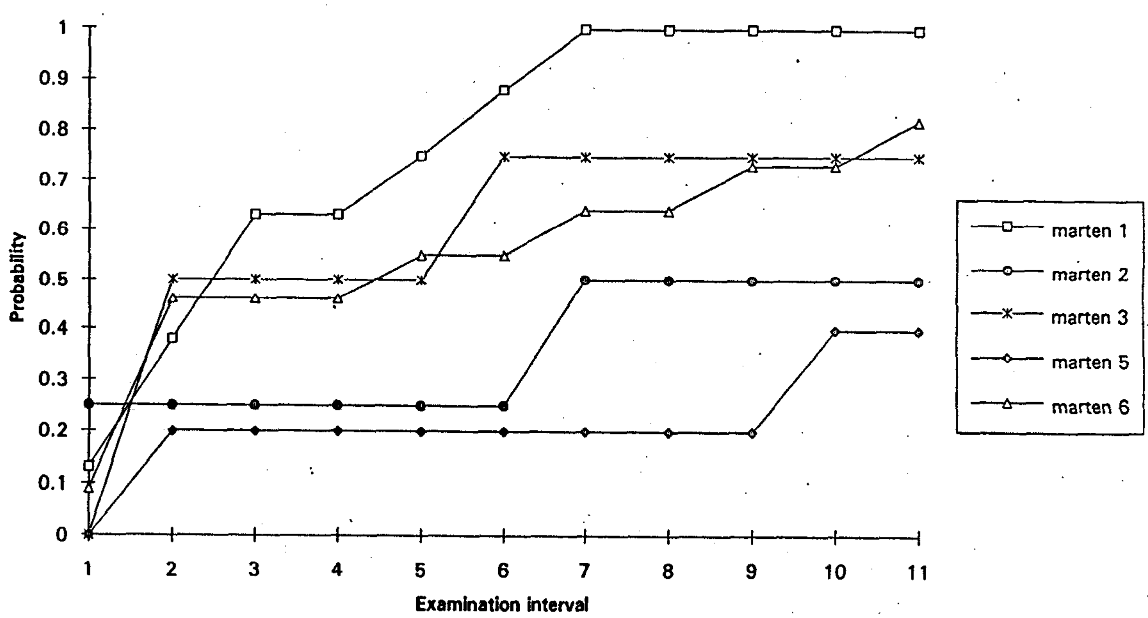


Fig.15. Marten detection probabilities calculated cumulatively by examination interval, Foresthill Ranger District, Tahoe National Forest, California, 23 December 1991 to 12 January 1992.

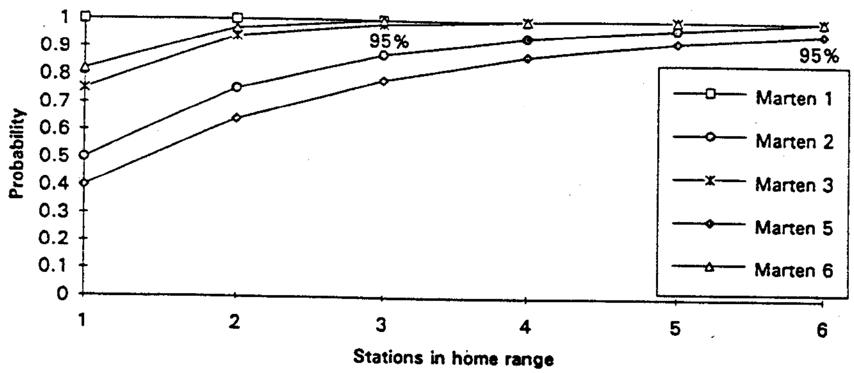


Fig.16. Probabilities of detection at one or more stations with an increase in the number of stations in a marten's home range. Initial probabilities were calculated from the 22-night survey-period (11 examination intervals), Foresthill Ranger District, Tahoe National Forest, California, 23 December 1991 to 12 January 1992.

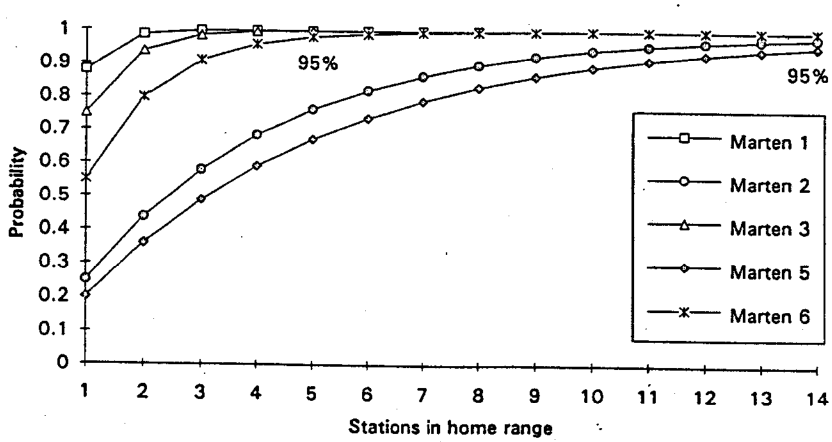


Fig.17. Probabilities of detection at one or more stations with an increase in the number of stations in a marten's home range. Initial probabilities were calculated from an analytically truncated 12-night survey-period (6 examination intervals), Foresthill Ranger District, Tahoe National Forest, California, 23-31 December 1991.

Appendix A. Description of the track-plate device used with captive fishers (Humboldt State University Game Pens), and for field testing on the Foresthill Ranger District, Tahoe National Forest, California.

Track-plates were constructed with 0.063 gauge aluminum sheeting (20 x 75 cm) The track-plates were sooted with an acetylene gas flame from a welding torch (Uniweld Products, 2850 Ravenswood Rd., Ft. Lauderdale, FL). Black soot was emitted from the torch when the oxygen valve was blocked with tape: A uniform and solid layer of black soot was easily obtained by holding the track-plate above the torch.

The track-plate was placed in an open-ended plywood box to protect it from adverse weather. The box was constructed with 1.3 cm thick low-grade plywood and had an inside dimension of 20 x 20 x 80 cm. The design of the box was simplified so assembly was possible in a field situation; this was necessary for monitoring in areas accessible only on foot or by snowmobile. The top and bottom pieces of the box (25 x 80 cm) were dado-edged (two groves 1.6 cm from each side, 1.6 cm wide, and 0.8 cm deep were cut along the length of the top and bottom pieces). The side pieces (20 x 80 cm) were easily slipped into the dado grove, hammered into place, and secured with rope near the two ends of the box. We later utilized a freight strapping-tool to secure the sides with plastic banding. The boxes were also increased in size for subsequent studies (inside dimension 30 x 30 x 80 cm)'.

White con-tact paper (Rubbermaid Inc., Con-tact Decorative Coverings, P.O. Box 6000, Wooster, OH) (cut to 11.5 x 30 cm) was attached to the center of the track-plate (sticky surface upward) to assess' the effectiveness of the paper in obtaining a distinguishable print. A distinguishable print was obtained when a fisher would step first on the sooted plate and then on the con-tact paper leaving a sooted print. The con-tact paper was more effective in obtaining an identifiable print than the sooted plate alone. It was also more effective than the traditional tape "lifting" or transfer process (tape or clear con-tact paper pressed on the track and the imprint on the tape lifted and pressed onto a piece of paper, preserving a negative of the print) (Fowler and Golightly in prep.). Prints on the con-tact paper have an advantage in that the actual print (a track positive) can be removed from the plate and stored as a permanent record for later identification.

Appendix B. Description of the triggered-camera device used with captive fishers (Humboldt State University Game Pens), and for field testing on the Foresthill Ranger District, Tahoe National Forest, California.

We utilized a pocket instamatic camera (Concord Camera Corporation, Model 110EF, 35 Mileed Way Avenel, NJ) with a built-in electronic flash. The cameras were initially tested with a separate flash-bar attached to the top of the camera; this system was rejected because the observed removal and destruction of the unit by the captive fishers. The flash-bar was also inconsistent and thus not appropriate for use with the index. In-addition, we found that the camera with built-in flash was more cost-effective (Appendix G).

The trigger mechanism was constructed with clothes-hanger wire that was formed into the appropriate shape by bending It around nails set in a wooden template. The trigger was designed to be effective in adverse weather conditions such as snow and wind, as well as allow convenient access to the camera (the camera was easily removed from the stand and trigger during non-monitor periods).

The camera stand was constructed with 5 x 5 x 120 cm redwood posts that were cut at a 45 degree angle on one end to facilitate placement in the ground. A platform for the camera was constructed with a piece of Douglas fir (15 x 6.5 x 1.5 cm) that was secured on top of the post with screws. The trigger was firmly attached to the stand with fence nails.

A protective cover for the camera was constructed from a polyethylene foam camping pad (cut to 21 x 23 cm). The foam was folded in half lengthwise and wrapped with duct tape so it would remain folded like an envelope. With the camera placed inside, holes were cut into the foam cover at the location of the shutter release, view-finder, and exposure counter so these areas of the camera would be accessible and visible through the cover. A plastic cover was constructed with a sandwich-size Ziploc bag (Ziploc bags, Dowbrands Inc., P.O. Box 68511, Indianapolis, IN) that was cut lengthwise in thirds; the middle piece was discarded and one of the end pieces was placed around the camera like an envelope exposing only the front of the camera. The camera was then placed in the foam cover and attached to the platform with two rubber bands. The cameras were also secured with bailing wire to prevent their removal by animals.

The cameras were modified to use two D-cell batteries. This was accomplished by soldering 18-gauge stereo wire (cut to 50 cm in length) from the positive and negative battery tab in the camera to a two-cell battery holder (Philmore, D-cell Battery holder No. BH121, Rockford, IL). The battery holders were placed inside 8 oz. plastic freezer containers to protect them from moisture. A hole for the wire was drilled in the containers, and they were attached with bailing wire to the camera stand. The flash ready-lights on the cameras were removed to decrease any excess power drain on the batteries. The life expectancy of the D-cell batteries was adequate to power the flash for a full survey period (22 days) and reduced the cost of frequent replacement of AAA batteries.

The bait-line for the triggered-cameras consisted of 20 lb. test fishing line. The fishing line was first tied to the trigger with a fishing knot and then down the length of the stand to the base where it went through a wire guide (a 25 cm piece of clothes-hanger wire that was bent in half with a loop in the middle and nailed to base of the stand). The line then extended approximately 138 cm out from the base of the stand and was threaded through another wire guide that was secured in the ground. The line terminated after the wire guide where it was tied to a metal washer. The metal washer was larger in diameter than the loop in the wire guide and thus functioned to keep the line in place even after bait removal. The bait was attached to the washer with polyester thread that was looped through the washer and then knotted around the bait. The animal would pull the bait releasing the shutter and break the thread rather than the fishing line.

Appendix C. Description of the hair-snare device used with captive fishers (Humboldt State University Game Pens).

Two different size PVC tubes (IO and 15 cm in diameter and both 100 cm in length) were used to collect hairs. Sticky substances were attached to the interior of both ends of the PVC tubes Several different sticky surfaces were used: double-sided carpet tape (Scotch 3M, Rug and Carpet tape; Box 33053, St. Paul, MN), fly paper (Pic Corp., Fly Catcher, 23 S. Essex Ave, Orange, NJ), and sticky-back vel-cro (Velcro USA Inc., 406 Brown Ave, Manchester, NH).

Appendix D. Description of the trapping and handling procedures for martens captured on the Foresthill Ranger District, Tahoe National Forest, California.

Trapping

Traps were placed in or alongside hollow logs, or against stumps and snags. Traps were covered with bark and forest debris to conceal and protect the captured animal. The traps were baited with chicken dipped in strawberry jam. A variety of strong scent-baits including heated tuna oil, anise and maple flavoring, honey, and peanut butter were placed on logs or sticks in the area around the trap.

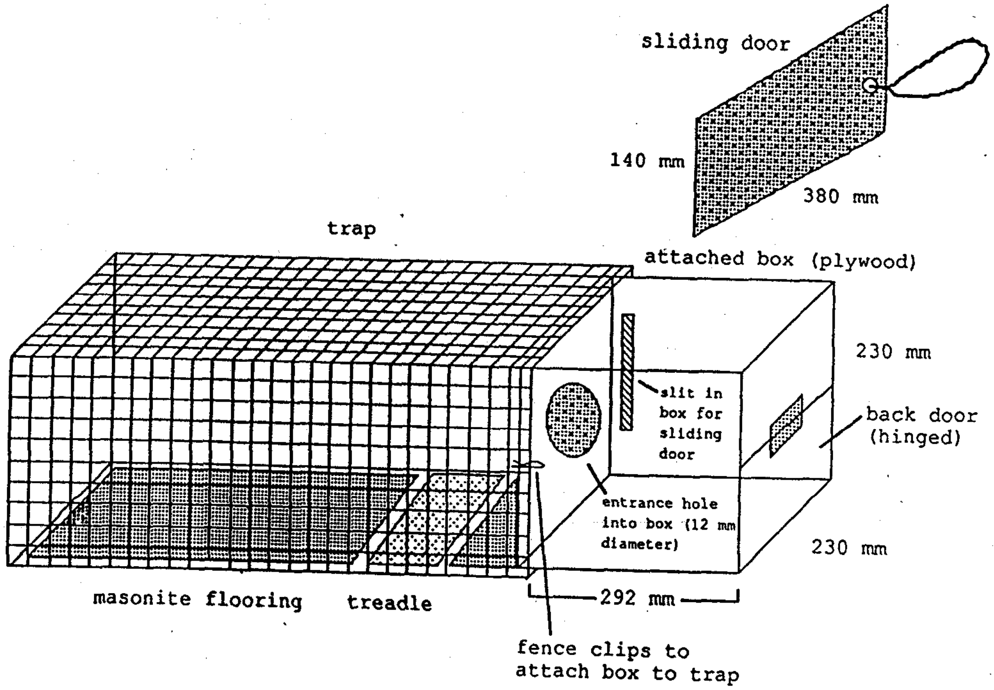
Handling

When traps were approached, captured martens usually remained in, or returned to the attached plywood box. Martens were restricted to the box by sliding a masonite door through the slot in the front of the box.

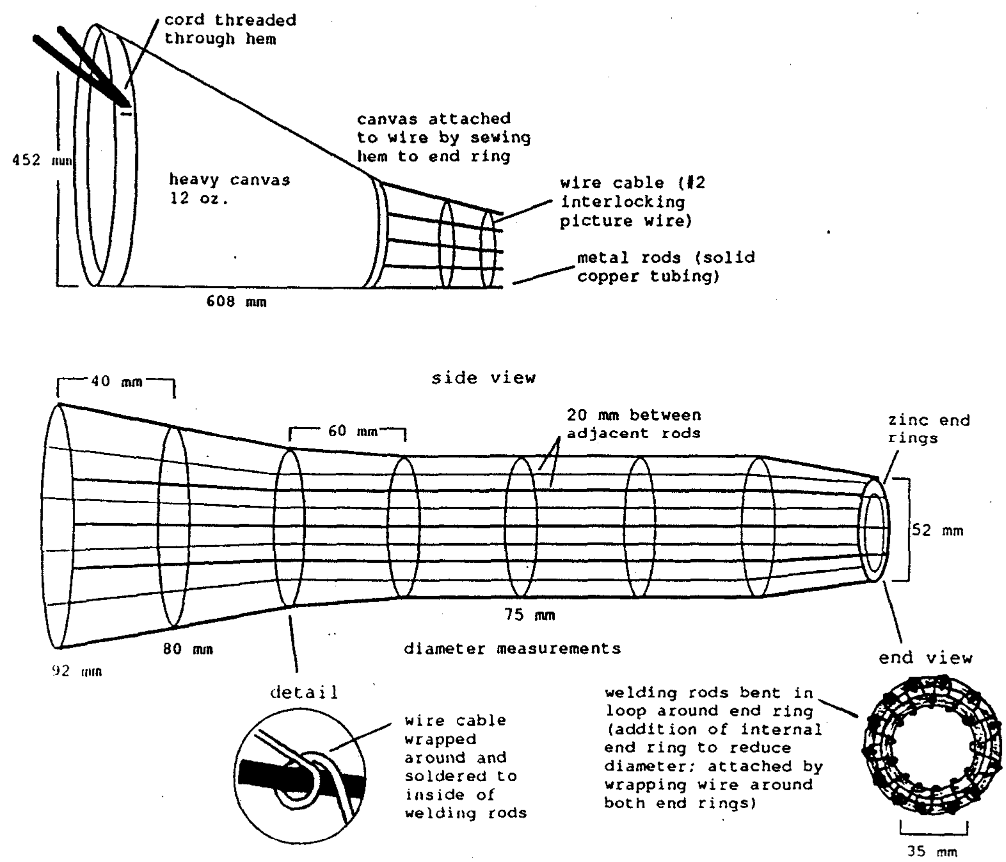
The canvas portion of the handling-cone was placed around the back of the box and fastened with a cord. The back door of the box was opened by removing the nail that fastened it closed, and pulling up on a cord attached to the back door latch. The martens entered the cone in an attempt to escape, but were restrained by the conical shape of the bent metal rods and were unable to reverse direction. The martens were immovable in the cone which facilitated injection of the immobilizing drug in a rapid and precise manner.

Following immobilization, animals were removed from the cone by gently shaking it upside-down. Radio transmitters were fitted to individual martens (approximately one finger could fit under the collar when it was fastened).

Release of the martens was simplified by leaving the trap connected to the box. Martens were returned to the box at the first signs of recovery (head-lift), and allowed to enter the trap when they began to scratch at the box. The martens were examined in the trap for full motor capability prior to release.



Appendix D. cont. Details of the trap and attached box used to capture martens on the Foresthill Ranger District, Tahoe National Forest, California.



Appendix D. cont. Details of the handling-cone used to restrain and immobilize martens on the Foresthill Ranger District, Tahoe National Forest, California.

Appendix E. Summary of drug dose (ketamine and diazepam; 200 mg:l mg), induction time[a], and time to head lift and full recovery[b] for martens captured and immobilized on the Foresthill Ranger District, Tahoe National Forest, California.

Marten ID	Sex	Drug Dose (mg/100g) lst/2nd/3rd Injection[c].	Induction Time[a] (min)	Time to Head-lift	Time to Recovery
01	M	0.019/0.010	1.0/0.5	3.5	60
02	F	0.019/0.004/0.014	36.0/2.0	14.0	43
03	F	0.024/0.014	12.0/5.5	4.5	30
04	M	0.021	2.0	17.0	52
05	F	0.026	1.5	7.0	48
06	M	0.023	1.5	l8.0	44

Drug dose[d] for male martens #04 and #06 (x ± SE):
0.022 ± 0.001 mg per 100 g

Drug dose for female #05:
0.026 mg per 100 g

[a] Induction is the time period between injection and complete immobilization of the animal. Where more than one injection was necessary for complete immobilization, the induction time is given for both the time between the first injection and complete immobilization, and the last injection and complete immobilization.
[b] Time to head-lift is the time period between complete immobilization and head movements by the animal. Full recovery is the period between immobilization and release from the trap. The animals were released only after full motor ability was regained.
[c] Additional drug doses were necessary either when martens were not fully immobilized with primary doses, or when processing of the animal was not complete when the animal began to recover.
[d] Drug doses were calculated for animals that received a single dose.

Appendix F. Capture statistics for martens trapped on the Foresthill Ranger District, Tahoe National Forest, California.

					Physical Measurements mm		
Marten ID	Sex	Capture date	Age	Weight g	Total Length	Tail Length	Neck Circum.
01	M	10-29-91	Juv	970	665	185	126
02	F	10-31-91	Juv	695	526	165	120
03	F	10-31-91	Adult	740	529	175	118
04	M	11-15-91	Adult	1170	641	188	126
05	F	11-15-91	Juv	700	581	188	103
06	M	11-23-91	Unk	1065	655	215	136
Males and females (x ± SE):				890 ± 84	600 ± 26	186 ± 7	122 ± 5
Males:				1068 ± 58[a]	654 ± 7[a]	196 ± 10	129 ± 3[a]
Females:				712 ± 14[a]	545 ± l8[a]	176 ± 7	114 ± 5[a]

[a] A Mann-Whitney Two-Sample test was used to examine differences between measurements of male and female martens. The difference was significant for weight, total length and neck circumference ($Z = 1.96$, $P < 0.05$).

Appendix G. Cost comparison (excluding film and development) for two styles of triggered-cameras to monitor forest carnivores during a 22-day sampling period. Both cameras are manufactured by Concord and differ in their internal verses external flash capabilities.

	Concord 110EF Built-in Flash ($)	Concord 118 Flash-bar ($)
Camera cost incl. tax:	6.38	4.04
Battery (based on two D-cell batteries that are replaced -during each 22-day sample period):	0.55	
Battery conversion:		
D-cell battery pack:	1.48	
Wire couplers:	0.04	
wire:	0.09	
Flash-bar (assume one flash per day for 22 days = one flash from animal and one test-flash per visit; 22 @ 0.24):		5.28
Total cost per camera:	8.54	9.32
Cost for each additional sampling period:	0.55	5.28

Appendix H. Costs for monitoring forest carnivores using sooted track-plates and triggered-cameras on the Foresthill Ranger District, Tahoe National Forest, California (March-August 1991). Costs are expressed as cost per station for a 22-day sample period.

	Season		
	Spring ($)	Early Summer ($)	Late Summer ($)
Track-plates:	12.05	12.05	12.05
Triggered-cameras:	18.09[a]	12.09	12.09
Personnel cost ($6.50/hour):	213.89	38.01	38.01
Travel- vehicles ($0.26/mile):	55.18	16.20	16.20
Travel- snowmobiles ($0.26/mile):	13.63		
Total monitoring cost per station:	312.84	78.35	78.35

[a] Higher costs for triggered-cameras in spring reflects repeated cost of AAA batteries prior to camera conversion to D-cell battery packs.

Appendix H. cont. Equipment and bait costs per station for sooted track-plates; reflecting costs for a 22-day sampling period (stations monitored every other day). These costs are based on 2262 sample trials conducted during three seasons on the Foresthill Ranger District, Tahoe National Forest, California (March-August 1991).

Description	cost ($)
Aluminum plates (2 per station), acetylene torch[a], and wood for boxes[b]:	9.34
Con-tact paper and acetylene gas:	1.79
Bait:	
Tuna cat-food bait (l/3 can every other day)	1.38
Chicken (l/2 wing every other day)	0.53
Total cost for first sample period:	
with cat food bait:	12.51
with chicken bait:	11.66
Cost for each additional 22-day sample period:	
with cat food bait:	3.17
with chicken bait:	2.32

[a] Acetylene torch costs are based on the total cost of the torch divided by the 78 stations that were monitored.
[b] Based on $8.00 cost of plywood sheets (4 by 8 ft).

Appendix H. cont. costs per station for triggered-cameras (Concord 110EF with built-in flash). The cost reflects a 22-day sampling period (stations monitored every other day). These costs were based on 2262 sample trials conducted during three seasons on the Foresthill Ranger District, Tahoe National Forest, California (March-August 1991).

Description	cost ($)
Modified camera, camera stand, and foam covering:	7.76
Batteries (D-cell), battery packs, film, and development:	6.33
Bait	
Tuna cat-food bait (1/3 can per check):	1.38
Chicken:	.53
Total	
with tuna cat-food bait:	15.47
with chicken bait:	14.62
Cost for each additional 22-day sample period	
with tuna cat-food bait:	7.71
with chicken bait:	6.86

Appendix I. Trapping effort and capture results from 28 October to 23 November 1991 on the Foresthill Ranger District, Tahoe National Forest, California.

Description	Number	Rate
Total trap-nights	329	
Traps which were closed	85	
Captures of martens	12	
Marten recaptures (individuals)	3	
Total marten capture rate[a]		3.6%
Other captures:		
Douglas squirrel	14	
Spotted skunk	2	
Golden-mantled ground squirrel	1	
Chipmunk spp.	1	

[a] Capture rate is the number of captures divided by the number of trap-nights, multiplied by 100.

Appendix J. Number of detections[a] of individual martens at the triggered-camera stations, totalled by examination interval and by marten, and the frequency of visitation for each marten.

Marten ID	Examination interval											Total	Frequency of visitation
	1	2	3	4	5	6	7	8	9	10	11		
01	1	2	4	4	4	4	4	1	1	0	1	26	0.12
02	1	0	1	0	0	0	1	0	1	0	0	4	0.02
03	0	2	2	2	1	3	2	2	1	1	1	17	0.08
04	1	0	0	0	0	0	0	0	1	1	0	3	0.01
05	0	1	0	0	0	0	0	0	0	1	0	2	0.01
06	1	5	4	2	3	3	4	3	2	2	5	34	0.15

[a] The numbers are the total stations where the animal was detected during an examination interval.