



ABUNDANCE AND ECOLOGY OF MARTENS (*MARTES AMERICANA*) IN
INTERIOR ALASKA

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ABUNDANCE AND ECOLOGY OF MARTENS (*MARTES AMERICANA*) IN
INTERIOR ALASKA

A
THESIS

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ABSTRACT

I studied marten (*Martes americana*) abundance and ecology in the Yukon-Charley Rivers National Preserve during 1991-1993. Using a multiple sample, mark-recapture estimator, I estimated marten densities to be 0.69, 0.41, and 0.45 martens/km² during each August for 1991-1993, respectively. Density estimates were derived with the boundary-strip method to address the edge effect inherent in live-trapping studies. During the study, marten density declined 43% between 1991 and 1992 and remained low during 1993. I hypothesize that a decline in primary prey (i.e., microtine rodents) and increased environmental stress (i.e., cold temperatures and snow cover) contributed significantly to the decline in marten abundance. Using carcasses provided by trappers, I documented that female martens had lower ovulation rates and overall fecundity during winter 1991-92, and as a result of low recruitment during summer 1992, the number of martens harvested by trappers decreased 85% during the 1992-93 trapping season.

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INTRODUCTION

In 1991, the U. S. National Park Service began a study of marten ecology and population dynamics related to trapping in Yukon-Charley Rivers National Preserve in eastern, Interior Alaska. A major objective of the study was to determine marten abundance and the effects of intensive trapping on local populations. The following thesis is composed of 2 manuscripts. Chapter 1, "Estimating marten density by combining mark-recapture techniques with radiotelemetry" is prepared for submission to the Journal of Wildlife Management and presents a quantitative estimator to measure marten abundance during live-trapping studies. Chapter 2, "Effects of food abundance and weather on marten density and trapping success in Interior Alaska" is prepared for submission to the Journal of Canadian Zoology and evaluates changes in population abundance during the study relative to decreased food abundance, inclement weather, and trapping. I independently drafted both manuscripts, but they are co-authored by Layne G. Adams and Frederick C. Dean, who provided constructive and encouraging comments to me during the writing and revision process.

CHAPTER 1

ESTIMATING MARTEN DENSITY BY COMBINING MARK-RECAPTURE TECHNIQUES WITH RADIOTELEMETRY¹

Abstract: Comparisons of marten (*Martes americana*) population densities among studies of livetrapping have been difficult because of an absence of statistically valid estimates of abundance as well as inadequate explanations of the conversion of abundance estimates to density. To demonstrate the necessary application of those methods, we estimated abundance of martens for 5 consecutive days during each August in 1991-93 in Interior Alaska, USA, with a multiple sample, mark-recapture estimator (IEJHE) that allowed for immigration and emigration of martens from the study area (Neal et al. 1993). We converted abundance estimates to density by dividing the estimates by an estimate of the effective area trapped (i.e., "the study area"). Using program NOREMARK (White 1996), total martens using the study area were 29 (0.69 martens/km²), 19 (0.41 martens/km²), and 25 (0.58 martens/km²) during each year for 1991-93. Mean daily population estimates were 19.0 (0.45 martens/km²), 11.9 (0.26 martens/km²), and 12.2 (0.28 martens/km²) for 1991-93, respectively. We recommend that biologists employing livetrapping and radiotelemetry to study population ecology of martens use a mark-recapture estimator that produces statistically valid estimates with a

¹ Shults, B. S., L. G. Adams, and F. C. Dean. Estimating marten density by combining mark-recapture techniques with radiotelemetry. In prep. Journal of Wildlife Management.

good measure of precision. In addition, we suggest that the method used to determine the effective area trapped be presented when abundance is converted to density.

Key words: abundance estimation, Alaska, density, edge effect, live-trapping, mark-recapture, marten, *Martes americana*, NOREMARK, radiotelemetry

Changes in marten (*Martes americana*) abundance due to natural (e.g., weather and food availability) or human effects (e.g., trapping and forest practices), are best understood with quantifiable estimates of abundance that are comparable among studies. Marten abundance or density often has been inferred from models of habitat suitability, data on harvest (e.g., trapper questionnaires or trapper success), data from livetrapping (e.g., capture rates, enumeration of individuals), and detection surveys (snow tracking, sooted track-plates, hair snares, or cameras) (Raphael 1994). Buskirk and Ruggiero (1994) stated that multiple estimates of marten populations should be made so that accuracy and precision of those indices could be evaluated.

Most intensive studies of livetrapping used enumeration (i.e., the minimum number of individuals captured or MNC) as the basis for estimates of abundance (Buskirk and Ruggiero 1994) or capture rate (new captures/100 trapnights) as an index to abundance (Raphael 1994). Although intensive livetrapping allows for the identification of individual martens within the population, enumeration of the population is complicated

by variable capture probabilities (Otis et al. 1978), the edge effect (White et al. 1982), and movement.

Mark-recapture methods and radiotelemetry have been criticized as too costly and labor-intensive for estimation of marten abundance over large areas (Strickland and Douglas 1987); yet, Buskirk and Ruggiero (1994) summarized 24 studies that used marking or radiotelemetry to meet study objectives. Given the large number of live-trapping studies, direct measures of abundance from marked martens in conjunction with a quantitative estimation technique, such as mark-recapture, surprisingly are lacking in the literature, especially when mark-recapture estimators have been reviewed and applied to other taxa (Otis et al. 1978, White et al. 1982, Pollock et al. 1990). To my knowledge, only 1 study of martens employing live-trapping and radiotelemetry provided estimates of marten abundance derived from probabilistic estimators; however, validity of the model assumptions has not yet been tested (Flynn and Schumacher 1997). Nonetheless, radiotelemetry in conjunction with mark-recapture methods has been used to estimate population abundance of bears (*Ursus arctos* and *U. americanus*) (Miller et al. 1997), mule deer (*Odocoileus hemionus*) (Bartmann et al. 1987, Kufeld et al. 1987), skunks (*Mephitis mephitis*) (Greenwood et al. 1985), mountain sheep (*Ovis canadensis*) (Neal et al. 1993), river otters (*Lontra canadensis*) (Testa et al. 1994) and coyotes (*Canis latrans*) (Hein and Andelt 1995).

Assumptions of the basic Lincoln-Petersen mark-recapture model are: (1) the population is geographically and demographically closed; (2) all animals have a constant

and equal probability of capture; (3) each sample is a simple random sample (i.e., each of the possible samples has an equal chance of being chosen); (4) animals do not lose their marks between samples; and (5) all marks are reported correctly (Otis et al. 1978, White et al. 1982, Pollock et al. 1990). Assumptions that are most difficult to assess are geographic closure and constant and equal probability of capture. Violating these assumptions may result in biased and imprecise estimates (Otis et al. 1978).

Radiomarking, however, has led to innovative techniques and estimators to compensate for violation of the assumption of geographic closure, permitting calculations of a precise and accurate measure of abundance (Eberhardt 1990, Neal et al. 1993).

Measures of relative abundance based on capture rates may not be accurate indices of population changes because rates of capture are sensitive to environmental factors and the inherent variability among individuals in catchability (Otis et al. 1978). Otis et al. (1978) and White et al. (1982) discussed in detail 3 sources of variation that affect catchability of an individual animal. First, individuals may have capture probabilities that vary over time (i.e., temporal variation) most commonly caused by environmental conditions, especially weather. Second, individual catchability is attributed to factors inherent to the individual (i.e., heterogeneity), which may be related to age, sex, reproductive status, social status, rate of movement, or trapping effort within the home range (White et al. 1982). Third, an individual may have 1 initial probability of capture prior to the first capture and a different subsequent capture probability because of

a behavioral response to being trapped the first time (i.e., trap-happy or trap-shy) (White et al. 1982).

Quantitative comparisons of marten abundance among live-trapping studies are difficult to interpret because abundance is commonly converted to density without empirical support to delimit the area being sampled by the live traps. The "edge effect" (Dice 1938) is present because animals outside the trapping area may be attracted to the traps, and some home ranges only may encompass a portion of the trapping area, thereby affecting the probability of encountering traps (White et al. 1982, Eberhardt 1990). Consequently, martens located beyond the boundary of the sampling area are not available for live-trapping during the sampling session, thereby violating the assumptions of geographic closure and equal catchability.

Several methods have been proposed to address the edge effect. Dice (1938) proposed adding a boundary strip, equal to the radius of an average home range, to the area of the trapping grid to define the study area. More recent efforts to address the edge effect include nested grids (White et al. 1982), assessment lines (White et al. 1982), a boundary strips (Wilson and Anderson 1985), and a study area defined by the cumulative home-range areas of marked animals (Flynn and Schumacher 1997).

We used live-trapping, radiotelemetry, and mark-recapture methods to estimate marten abundance and density in Interior Alaska, during 1991-93. Each

August, following a 3-6 week live-trapping and marking session, we intensively livetrapped and radiocollared martens on the study area and simultaneously located instrumented martens to determine their locations relative to traplines. In this chapter, we: (1) estimate the abundance of martens by applying the joint hypergeometric maximum likelihood estimator that allows for immigration and emigration (IEJHE; Neal et al. 1993); (2) compare IEJHE results with other indices of marten abundance including capture rate, number of individual martens captured, and mark-recapture population estimates assuming geographic closure (JHE; Bartmann et al. 1987, White 1996); (3) test for violations of the mark-recapture assumptions of population closure and constant and equal capture probabilities; (4) evaluate effects of boundary-strip width around the live-trapping area on estimates of marten density; and (5) evaluate the utility of the IEJHE model for martens by conducting Monte Carlo simulations, while varying the proportion of marked individuals in the population, the number of trapping occasions, and the estimated capture probability.

STUDY AREA

We estimated abundance of martens in Yukon-Charley Rivers National Preserve ($65^{\circ} 10'N$, $142^{\circ} 05'W$) in Interior Alaska (Fig. 1.1). The preserve encompasses $10,360 \text{ km}^2$ within the Yukon-Tanana uplands (Wahrhaftig 1965) and is characterized by narrow steep-walled valleys dissecting an upland plateau from which creeks and rivers

drain into the Yukon River (Young 1976). Elevations within the study area range from 300 to 700 m.

The study area was moderately to severely burned by 2 wildfires approximately 24 years prior to my study. In 1967, the Dewey Creek fire burned 996 ha, and 2 years later the more widespread and severe Butte Creek fire burned 213,000 ha (Bureau of Land Management, unpublished data). Prior to those fires, the study area probably had not been burned for about 80 years (G. Ahlstrand, National Park Service, personal communication). Vegetation was a mosaic of post-fire successional stages. The tall shrub-sapling stage (Foote 1983:77) predominated with dwarf birch (*Betula glandulosa*), labrador tea (*Ledum* spp.), and berries (*Vaccinium* spp.). Well-drained slopes were characterized by regenerating stands of quaking aspen (*Populus tremuloides*). Severely burned areas throughout the study area were in a prolonged moss-herb stage (Foote 1983:76). Unburned inclusions were primarily needleleaf woodlands or forests (Viereck et al. 1992) with mixed overstories of black and white spruce (*Picea mariana* and *P. glauca*, respectively). Coarse woody debris was present throughout the study area primarily as standing, fire-killed trees and dead-fall. The study area was described in detail by Chapman (1958), Young (1976), and Gallant et al. (1995).

METHODS

Live-trapping and Marking

We livetrapped martens each year (1991-93) for 3-6 weeks (from early July to mid August) prior to the census to achieve a high proportion of marked animals (i.e., >50%)

within the study population. We used single-door, folding box traps (Model 205, 66 x 23 x 23 cm; National Live Trap, Tomahawk, Wisconsin) spaced at 250-m intervals along traplines that followed creeks and ridgetops. Traps were wired to sloping poles 1-1.5 m above the ground and baited with jam and marten lure (Stanley Hawbaker, Fort Loudon, Pennsylvania). Traps were covered with spruce boughs and moss to minimize exposure of trapped martens to inclement weather. During precensus trapping, we operated each trapline for 5 to 7 consecutive days to maximize captures of resident martens while minimizing repeated capture of individuals.

Traps were examined daily. Previously marked martens were noted and released, whereas unmarked martens were radiocollared and eartagged prior to their release. Martens were restrained with a holding cone (V. Hawley, Canadian Wildlife Service, unpublished data) and immobilized with ketamine hydrochloride (20-30 mg/kg body mass; Steventon 1979, Wright 1983). For a secondary mark, martens were eartagged at the base of both ears with serially numbered, monel tags (Style 1005, size 3, National Band and Tag, Newport, Kentucky). Males and females were fitted with 55 and 40 g radiocollars, respectively. We classified martens as juvenile (<1 yr) or adult (≥ 1 yr) based on the presence or absence of deciduous teeth, respectively (Brassard and Bernard 1939). Field procedures were approved by the Institutional Animal Care and Use Committee at the University of Alaska Fairbanks and conducted under scientific permits from the Alaska Department of Fish and Game.

Abundance Estimation

We estimated marten abundance each year for 5 consecutive days during August using live-trapping in conjunction with aerial radiotelemetry locations obtained daily.

Using program NOREMARK, we calculated abundance estimates with the immigration-emigration joint hypergeometric maximum likelihood estimator (IEJHE) (Neal et al. 1993:440) that allowed for immigration-emigration of martens from the study area. The IEJHE has the same assumptions as the simple Lincoln-Petersen estimator, but does not require geographic closure. The IEJHE provides a mean daily population estimate (\hat{N}_{IEJHE}) of martens on the study area and a population estimate of all martens using the study area (\hat{N}_{IEJHE}^*). We calculated both estimates using only those martens that had functioning radiocollars and were located by radiotelemetry >2 days during the census. We also eliminated those martens that died prior to or during the census each year ($n = 2, 1, \text{ and } 1$ for 1991-93, respectively) from all estimates. The resulting minimum number of martens captured (i.e., MNC) also was reduced by the number of mortalities each year. NOREMARK calculated confidence intervals with the profile likelihood method (White 1996). This method provided asymmetrical confidence intervals with a lower bound that always equaled or exceeded the minimum number of martens known to be alive.

We also calculated abundance estimates that assumed geographic closure using the JHE (i.e., \hat{N}_{JHE}) developed by Bartmann et al. (1987:47). For this estimate, we again eliminated mortalities, but used all martens that were captured and marked. For

comparison, we also calculated MNC and the capture rates (i.e., new captures/100 trapnights) we obtained during live-trapping. We used the statistical notation of White et al. (1982), Neal et al. (1993), and White (1996) when appropriate (Appendix A).

Density Estimation

To define the effective area trapped (A), we connected the outermost trap locations on the study area to form a polygon (i.e., minimum-area trapped, $A(t)$) and added a boundary strip (Dice 1938) with the width, w , equal to the radius of the average home range of male martens for each year of this study ($w = 1.2$ km, 1.3 km, and 1.2 km, for 1991-93, respectively, unpublished data) to yield an estimate of the parameter A (i.e., $\hat{A}(w)$). We assumed circular home ranges to determine w . The minimum-area trapped (i.e., $A(t)$) differed between 1991 and 1992-93 because we increased the length of traplines by 5 km in 1992. We used ArcView (Environmental Systems Research Institute, Redlands, California) to overlay radiotelemetry locations of martens on the polygons and determined the presence of each marten within or outside the polygons for calculating the daily estimate of martens present and their availability for sampling by live-trapping. We converted abundance to density by dividing the abundance estimates (i.e., \hat{N}_{IEJHE} , \hat{N}_{IEJHE}^* , \hat{N}_{JHE}) and MNC by the areas $A(t)$ and $\hat{A}(w)$.

To evaluate the boundary-strip method proposed by Dice (1938), we calculated densities using the IEJHE (i.e., \hat{N}_{IEJHE}) with boundary-strip widths ranging from 0 to 2,800 m each year. To eliminate annual differences in density estimates, we converted actual densities to relative densities such that densities calculated with $A(t)$ (i.e., $w = 0$ m)

for each year equaled 1.0 for that year. We also determined the distance that marten radiolocations were from the perimeter of the polygon $A(t)$. We used a 2-factor ANOVA on ranks (Zar 1984) to determine differences in distances between years and age classes (i.e., juvenile or adult) of martens.

Tests of Geographic Closure and Capture Probabilities

Radiotelemetry and Geographic Closure

We attempted to locate all radiocollared martens each day of the census prior to or during the daily examination of live traps. We assumed that obtaining telemetry locations of martens and daily live-trapping were instantaneous and independent events (Eberhardt 1990). This assumption is necessary because the timing of telemetry locations should best represent the time that recapture by live-trapping is most likely to occur.

To determine factors that best predicted the probability of a marten being within the study area, we used a logistic regression model (Hosmer and Lemeshow 2000) with the binary response variable for each case representing the presence or absence of the marten within the effective area trapped. The explanatory variables tested were sex, age, and year. For each year, we also calculated distances between daily locations of radiocollared martens and tested for differences in mean travel distance using ANOVA with sex, age, and year as factors (Zar 1984).

Capture Probabilities

We evaluated capture probabilities for heterogeneity, behavioral response (i.e. trap-shy or trap-happy), and temporal variation between occasions with program

CAPTURE (Otis et al. 1978, Rexstad and Burnham 1991) to test for the presence of each source of variation independently and concurrently. Program CAPTURE employs model selection criteria to test hypotheses regarding the presence of those 3 sources of variation and chooses an appropriate estimator. We used program CAPTURE to choose the model that “best” fit the capture data each year. Models used by program CAPTURE follow Otis et al. (1978).

To further investigate capture heterogeneity, we calculated estimates of capture probability for individual martens each year by calculating the proportion of days a marten was captured during the census given that it was located by radiotelemetry on the study area. We tested for sex, age, and year effects in a logistic regression model (Hosmer and Lemeshow 2000) with the response variable being captured or not captured on each occasion. In the model analysis, we included only those martens located within the study area by radiotelemetry and were, therefore, available for sampling by live-trapping.

Simulations

We conducted Monte Carlo simulations to evaluate the utility of the IEJHE model given the small sample sizes commonly encountered when conducting live-trapping studies of martens and to quantify the effects of pre-marking of martens on bias and precision of the estimates. We used a simulated population size of 30 martens with 70% present on the study area. We set the proportion of martens marked at 0.3, 0.5 and 0.7; specified a capture probability of 0.5, and conducted simulations specifying the number

of live-trapping occasions as 5, 7, and 10. We obtained 1,000 replications for each scenario and reported percent bias (PB), percent confidence interval length (PCIL), and 95% CI coverage (Neal et al. 1993).

RESULTS

Livetrapping and Marking

Trap effort varied among years because we expanded the trapping area and increased the density of traps after 1991 (Table 1.1; Fig. 1.1). We captured 30, 20, and 26 martens during the pre-marking and census period in 1991-93, respectively. Four martens died as a result of livetrapping and were eliminated from abundance analyses. Therefore, the minimum number of martens captured was 28, 19, and 25 martens for 1991-93, respectively (Table 1.2). Sex and age composition of captured martens varied among years ($G = 4.37$, 1 df, $P = 0.037$), probably because few juveniles were trapped in 1992.

On average, we initially captured 71% of the total martens captured each year during the precensus marking. Capture rates of new martens during precensus live-trapping varied within and among years (Fig. 1.2), ranging from 0.7 new martens/100 trapnights in 1992 to 1.8 new martens/100 trapnights in 1991. For all years, capture rate was lowest during late July and early August (Fig. 1.2).

We captured 9, 2, and 10 unmarked martens during the 1991-93 censuses, respectively (Table 1.2). In 1991 and 1993, capture rates during the census were comparable to the precensus trapping, but in 1992 new captures occurred at less than one-

half the previous rate (i.e., 0.3 martens/100 trapnights vs. 0.7 martens/100 trapnights) (Fig. 1.2). Juvenile martens averaged 59% of 21 new captures during the 3 censuses.

Population and Density Estimation

Based on mark-recapture results (Table 1.3), we estimated the marten population using the study area (i.e., \hat{N}_{IEJHE}^*) to be 29, 19, and 25 martens for 1991-93, respectively. With mortalities eliminated, these estimates closely correspond to the minimum number of martens captured each year (Table 1.4). Estimates of the average number of martens using the study area (i.e., \hat{N}_{IEJHE}) were substantially lower (Table 1.4).

Estimates of marten density assuming geographic closure (\hat{N}_{JHE}) were 27-51% higher than estimates accounting for movement in and out of the effective area trapped (Table 1.4; Fig. 1.3). Further, while the IEJHE estimates of density declined by 43% and 8% during 1991-92 and 1992-93, respectively, other density estimates and capture rates declined during 1991-92, but all increased during 1992-93 (Table 1.4). Density calculated with the MNC and $A(t)$ yielded estimates averaging 81% higher than densities calculated from IEJHE estimates and $\hat{A}(w)$ (Table 1.4; Fig. 1.3).

We determined that time and distance traveled between successive radiotelemetry locations of individuals (\bar{x} time = 24.3 hr; SE = 0.3) (Table 1.5) were not correlated ($r = 0.016$, $n = 210$, $P = 0.817$). Distances traveled by martens each day during the census ($n = 210$ marten-days) were related to age ($P = 0.001$), with juveniles traveling significantly farther ($\bar{x} = 2.2$ km; SE = 0.2 km) than adults ($\bar{x} = 1.4$ km; SE = 0.1 km), but not

influenced by sex ($P = 0.766$) or year ($P = 0.782$). Distances of marten locations from the minimum-area trapped, $A(t)$, were not significantly different among years ($P = 0.490$).

With years pooled, juveniles were located significantly farther from $A(t)$ than adults ($P < 0.001$). The median distance for all locations from $A(t)$ was 1,192 m.

On average, estimates of marten density decreased 32% when the width of the boundary strip was increased from 700 m to 2,100 m (Fig. 1.4). For comparison, mean change in estimated density was 3% and 21% for $w \leq 700$ m and $w > 2,100$ m, respectively (Fig. 1.4).

Validity of Assumptions

Population Closure

Demographic closure was satisfied by conducting the census following the birthing period and by eliminating those animals that died prior to or during each census from the estimation procedure. Geographic closure was violated; marked martens were located on the study area an average of 71% (SE = 2.0%) of the days of the census (Fig. 1.5). The probability of being on the study area was influenced by age ($G = 29.3$, 1 df, $P < 0.001$), but not sex ($G = 0.2$, 1 df, $P = 0.655$) or year ($G = 1.3$, 1 df, $P = 0.254$). Lack of geographic closure was accommodated with the IEJHE model by determining the actual number of marked martens present each day within the defined effective area trapped (i.e., $\hat{A}(w)$) and therefore available for capture.

Capture Probabilities

Tests for heterogeneity, behavioral response, and temporal variation in capture probabilities in each year indicated that allowing for heterogeneity significantly improved model fit in 1991 and 1992 ($\chi^2 = 11.9$ and 11.4 , respectively, 1 df, $P = 0.001$). In 1993, both heterogeneity and behavioral response entered the model ($\chi^2 = 10.7$, 1 df, $P = 0.001$). Capture probabilities varied by sex ($G = 14.6$, 1 df, $P < 0.001$) and year ($G = 32.9$, 1 df, $P < 0.001$), but not age ($G = 0.1$, 1 df, $P = 0.752$). Males were 3 times more likely to be captured than females (Fig. 1.6).

Simulations

As the number of trapping occasions and the proportion of martens marked increased, percent bias increased and percent confidence interval length decreased in Monte Carlo simulations with the IEJHE (Table 1.6). Confidence interval coverage averaged 96.4% for all simulations. Percent confidence-interval length decreased 62% by increasing the proportion of marked individuals, whereas there was only a corresponding 37% decrease in PCIL when the number of trapping occasions was increased. These simulations with parameters that best represent my data indicate that the IEJHE slightly underestimated the true population (\bar{x} PB = -0.57%).

DISCUSSION

Of the quantitative methods we employed to estimate marten abundance from livetrapping and radiotelemetry, the IEJHE, \hat{N}_{IEJHE} , theoretically was most appropriate. Other estimates did not account for lack of geographic closure that was inherent in

martens and, therefore, overestimated their abundance. Those overestimates were substantial. Further, estimates that assumed geographic closure, as well as indices such as capture rate, may not serve as reasonable indices of marten population trends because the biases can vary among years. Efforts to assess marten abundance or population trends have relied entirely on potentially biased estimates or indices.

Comparisons of abundance estimates among study areas or among years require that marten abundance be converted to density. Such comparisons require standard methods for determining the minimum size of the effective capture area and adding a boundary strip around $A(t)$ to account for the edge effect. Boundary-strip width will have significant effects on density estimates unless $A(t)$ is large relative to home-range size (White et al. 1982). For studies of martens, this method is a concern because $A(t)$ is likely to be small compared with the size of home ranges for martens, particularly in remote, undeveloped areas. We expected a significant edge effect because marten home ranges in this study were 32-64% of $A(t)$ (unpublished data). Estimate bias was similar to that reported by Wilson and Anderson (1985), who calculated an 82% increase of density estimates using simulations to investigate edge effect.

We chose to use a boundary-strip width of one-half of a home-range width as recommended by Dice (1938). Density estimates were most influenced by changing boundary-strip width between 700 and 1,400 m, but less so with smaller or larger widths. Intuitively, an increasing boundary-strip width will decrease density because the effectiveness of live traps to capture new martens on the periphery of the live-trapping

area will decrease. For this study, the live traps effectively sampled the marten population within one-half of a home-range width and density changed at a slower rate beyond this strip width. This result may not be the same for other studies where population age structure, spacing patterns, or movement rates are different. We recommend the traditional approach of Dice (1938) because this procedure is a simple and well-known method that has been reviewed extensively without strong negative criticism and is easy to apply to irregularly shaped live-trapping areas (Tanaka 1972, Wilson and Anderson 1985). Although this method may lack statistical rigor, specifying a boundary-strip width provides a useful criterion for standardizing methods used to determine density of martens.

Capture rates for martens commonly are reported in the literature and are used as indices of abundance (Raphael 1994). Nonetheless, we caution against using individual rates of capture as an index of abundance because population composition could bias the rate. When compared with 1991, capture rates for 1992 and 1993 were similar in magnitude to changes in density; however, the percentage change in capture rates between 1992 and 1993 was 4 times greater than the corresponding change in estimated density. Population composition in 1993 was similar for adults, but included 2 times as many juveniles. Individual rates of capture increased because of those transient juvenile martens, whereas they made no significant contribution to the resident population we estimated. We did not test for statistically significant differences in density estimates among years because the test algorithm has not been programmed (G. White, Colorado

State University, personal communication). Nevertheless, the absence of overlap in confidence intervals indicates that the population decline between 1991 and 1992-93 is biologically significant, whereas the difference between estimates in 1992 and 1993 estimates is not significant. We hypothesize that the population decline was attributable to trapping, a decline in prey abundance, and an unusual, May snowfall. First, a resident trapper removed about 74 martens on and adjacent to the study area during the winter of 1991-92. Second, a decline in the abundance of small mammals (unpublished data) during 1992 combined with a snowfall in May 1992 (~30 cm) could have affected marten recruitment and survival.

Because marten populations have a significant transient component (Weckwerth and Hawley 1962), the timing of live-trapping efforts must be chosen to meet the specific study objective. We observed that the assumption of geographic closure could not be met for this study. Age class of martens (i.e., adult vs. juvenile) was a significant factor affecting the probability that a marten was located within the effective area trapped. This result is not surprising because the estimation period coincided with the autumn dispersal of martens documented by Archibald and Jessup (1984). We observed that capture rates of previously unmarked martens were lowest between 30 July and 5 August, but captures increased through August in each year. Therefore, conducting mark-recapture estimation during late July and early August may have yielded a more accurate estimate of resident adult martens and juvenile martens born within the study area.

Equal catchability is a difficult assumption to meet for martens because capture heterogeneity related to sex was the best explanation for variation in individual capture probabilities. Neal et al. (1993) showed that heterogeneity in capture probabilities would increase bias, decrease precision, and result in poor confidence interval coverage for the IEJHE, but effects need to be evaluated relative to sample sizes, pre-marking effort prior to the estimation period, and range of capture probabilities that are likely to be obtained for studies of martens. Given the close correspondence between the minimum number of martens captured and IEJHE estimates, and the results of simulations, effects of capture heterogeneity were minimal because of extensive pre-marking of martens. Applying mark-recapture estimation to martens in future studies, however, may require calculating separate estimates by sex to eliminate capture heterogeneity (Eberhardt 1990).

We detected a behavioral response to capture during 1993 and attribute the response to the reduction in pre-marking effort (i.e., 2 weeks less in 1993), the high number of new captures during the census, and an increase in the mean capture probability that CAPTURE calculated for the model testing procedure (Otis et al. 1978). We believe that pre-marking most martens triggered a "trap-happy" behavioral response to occur prior to censuses; therefore, capture probabilities were constant during censuses. We observed no temporal variation in capture success within any year. Overall, we contend that heterogeneity related to sex is more important than either behavioral response or temporal variation. My results demonstrate that homogenous probabilities of

capture are unlikely for martens and that appropriate estimators and requisite assumptions must be evaluated with respect to estimating bias and precision.

Studies of martens employing livetrapping usually involve small population sizes (i.e., <50 animals) and, therefore, mark-recapture estimators may be problematic (White et al. 1982). Martens, however, are easy to capture, and marking a large proportion of the population prior to the population census is feasible. Monte Carlo simulations indicated that increasing the proportion of marks in the population was twice as effective in increasing precision as increasing the number of trapping occasions. However, the number of marked animals required to meet a goal of specified precision could be an important cost consideration when developing survey designs.

MANAGEMENT IMPLICATIONS

Most estimates or indices of marten abundance probably are biased because population closure did not exist. Because martens are easily captured, large proportions of study populations can be marked prior to a census effort to counteract the influences of small sample sizes that are likely to occur on any trapping area of practical size. We suggest that mark-recapture estimation is useful and applicable for marten studies that invest substantially in livetrapping and marking to determine population size. We recommend that simulations be conducted with program NOREMARK (White 1996) prior to live-trapping studies to evaluate trapping and survey effort. We demonstrated that geographic closure is not a valid assumption for martens on my study area, but that a mark-recapture estimator, such as the IEJHE (Neal et al. 1993), in conjunction with

radiotelemetry locations can adequately address the lack of closure. If sample sizes permit, sex-related heterogeneity in capture probabilities may be overcome by calculating separate estimates by sex (Eberhardt 1990). We suggest that pre-marking of martens occur prior to the actual period of estimation recognizing that cost and labor need to be considered. We also demonstrated that density derived from abundance estimates is influenced by the edge effect. We recommend that density estimates reported in the literature be accompanied by empirical or qualitative descriptions of the effective area trapped. Finally, to make useful comparisons among years or studies, procedures used to convert abundance estimates to density should be well documented and justified.

ACKNOWLEDGMENTS

This project was funded by the National Park Service Natural Resources Preservation and Protection Program with the support of A. Lovaas, Regional Chief Scientist, and D. Chase, Superintendent of Yukon-Charley Rivers National Preserve. We are indebted to Natural Resource Specialists P. Knuckles and S. Ulvi and the YUCH staff, especially K. Fox, D. Mott, L. Mott, B. Ricklefs, J. Roberts, and J. Roach for their support in developing and implementing this project. We also thank C. Adams, N. Barten, J. Burch, W. Cella, B. Dale, L. Daniel, P. Del Vecchio, N. Demma, A. Demma, H. Golden, D. Grangaard, R. McDonald, P. McLaughlin, T. McKean, S. Mills, E. Olexa, E. Rexstad, B. Route, M. Schnorr, M. Schroeder, S. Swanson, J. Syder, J. Taylor, and J. Warburton for participating in fieldwork. Pilots D. Glaser, S. Hamilton, M. Helmer, B. Lentsch, M. Lynch, D. Miller, C. Warbelow (dec.), and R. Warbelow (dec.) provided safe

aircraft support.

Charley F

Attribute

Number

Trapline

Trapped

(10); 10

Effectively

trapped

Trap of

No

No

Live-

Pr-

Co-

Trap

Pr

Co

Trap

no

Table 1.1. Trapping area characteristics and live-trapping effort for martens, Yukon-Charley Rivers National Preserve, Alaska, 1991-93.

Attribute	Year		
	1991	1992	1993
Number of traps	90	140	140
Trapline length (km)	30	35	35
Trapped area ^a ($A(t)$; km ²)	15	19	19
Effective area trapped ^b ($\hat{A}(w)$; km ²)	42	46	43
Trap density			
No. Traps/ $A(t)$	6.0	7.4	7.4
No. Traps/ $\hat{A}(w)$	2.1	3.0	3.3
Live-trapping Period			
Precensus	9 Jul-7 Aug	9 Jul-17 Aug	23 Jul-14 Aug
Census	9-13 Aug	19-23 Aug	16-20 Aug
Trapnights			
Precensus	1,260	2,270	1,629
Census	450	700	700
Total	1,710	2,970	2,329

^a $A(t)$ = Minimum-area polygon calculated by connecting the outermost trap locations.

^b $\hat{A}(w)$ = Area polygon calculated using a boundary strip equal to the radius of an average male home range.

Table 1.2. Sex and age characteristics of martens live-trapped prior to and during annual mark-recapture censuses, Yukon-Charley Rivers National Preserve, Alaska, July-August 1991-93.

Year	Period	Adult		Juvenile		Total
		Male	Female	Male	Female	
1991	Pre-marking	5	5	8	1	19
	Census	2	1	4	2	9
	Total	7	6	12	3	28
1992	Pre-marking	7	6	3	1	17
	Census	1			1	2
	Total	8	6	3	2	19
1993	Pre-marking	8	1	5	1	15
	Census	1	3	6		10
	Total	9	4	11	1	25
Total		24	16	26	6	72

Table 1.3. Daily capture statistics for martens during mark-recapture studies, Yukon-Charley Rivers National Preserve, Alaska, 1991-93.

Year	Date	Statistics ^a			
		n_i	m_i	M_i	T_i
1991	9 Aug	10	6	14	19
	10 Aug	9	8	17	23
	11 Aug	8	6	18	24
	12 Aug	13	11	17	26
	13 Aug	10	10	12	28
1992	19 Aug	6	6	13	17
	20 Aug	4	4	13	17
	21 Aug	7	6	10	17
	22 Aug	7	7	11	18
	23 Aug	5	4	10	18
1993	16 Aug	7	6	8	15
	17 Aug	11	9	9	16
	18 Aug	11	9	9	18
	19 Aug	12	10	12	20
	20 Aug	14	11	13	22

^a n_i = number of martens captured; m_i = number of marked martens captured; M_i = number of marked martens within the census area, $\hat{A}(w)$; T_i = total number of marked martens with functioning radiocollars

Table 1.4. Marten abundance and density estimates calculated using enumeration (MNC), capture rate, the JHE (Bartmann et al. 1987), and the IEJHE estimators (Neal et al. 1993), Yukon-Charley Rivers National Preserve, Alaska, August 1991-93.

	Year		
	1991	1992	1993
Abundance Estimate or Index (95% CI)			
MNC	28	19	25
Capture rate ^a	1.8	0.7	1.1
\hat{N}_{JHE} ^b	29 (28-32)	19 (19-21)	25 (25-27)
\hat{N}_{IEJHE}^* ^c	29 (28.0-34.8)	19 (19.0-21.9)	25 (25.0-28.7)
$\hat{\bar{N}}_{IEJHE}$ ^d	19.0 (17.6-21.7)	11.9 (11.8-13.3)	12.2 (12.2-13.3)
Density Estimates (martens/km²)(95% CI)			
MNC/A(t)	2.6	1.1	1.5
$\hat{N}_{JHE} / \hat{A}(w)$	0.69 (0.67-0.83)	0.41 (0.41-0.48)	0.58 (0.58-0.67)
$\hat{\bar{N}}_{IEJHE} / \hat{A}(w)$	0.45 (0.42-0.52)	0.26 (0.26-0.29)	0.28 (0.28-0.31)

^a Number of new martens captured/100 trapnights

^b JHE estimate assumes geographic closure.

^c Estimated number of martens using the study area.

^d Mean daily estimate of martens using the study area.

Table 1.5. Mean distance (km) between successive telemetry locations of radiocollared martens, Yukon-Charley Rivers National Preserve, Alaska, August 1991-93.

Age class	Year	Sex					
		Male			Female		
		\bar{x}	SE	<i>n</i>	\bar{x}	SE	<i>n</i>
Adult	1991	1.7	0.3	25	1.4	0.2	23
	1992	1.5	0.2	24	1.6	0.3	18
	1993	1.0	0.1	31			
Juvenile	1991	1.4	0.2	37	2.1	0.5	8
	1992	2.9	0.6	12	2.6	0.9	8
	1993	3.2	0.5	20	3.0	0.6	4

Table 1.6. Percent bias (PB), percent confidence interval length (PCIL), and percent of confidence interval (CI) coverage for 1,000 Monte Carlo simulations of each scenario using the immigration/emigration model in NOREMARK (Neal et al. 1993, White 1996) with expected capture probabilities of 0.50 and 70% of the population of 30 marten present within the effective area trapped. Simulation results are for the scenario when all model assumptions are met.

Simulation	PB		PCIL ^a		CI COVERAGE (%)
	\bar{x}	SE	\bar{x}	SE	
All Scenarios					
	-0.57	0.51	48.51	7.53	96.44
Proportion Marked					
0.30	0.98	0.90	73.34	10.80	95.00
0.50	-0.72	0.26	44.11	5.22	96.93
0.70	-1.98	0.19	28.08	3.13	97.40
No. of Capture Occasions					
5	0.15	1.29	60.00	17.42	96.18
7	-0.52	0.78	47.57	12.76	96.70
10	-1.35	0.54	37.95	9.58	96.47

^a PCIL = ([95% Upper - 95% lower confidence interval endpoints]/population size x 100).

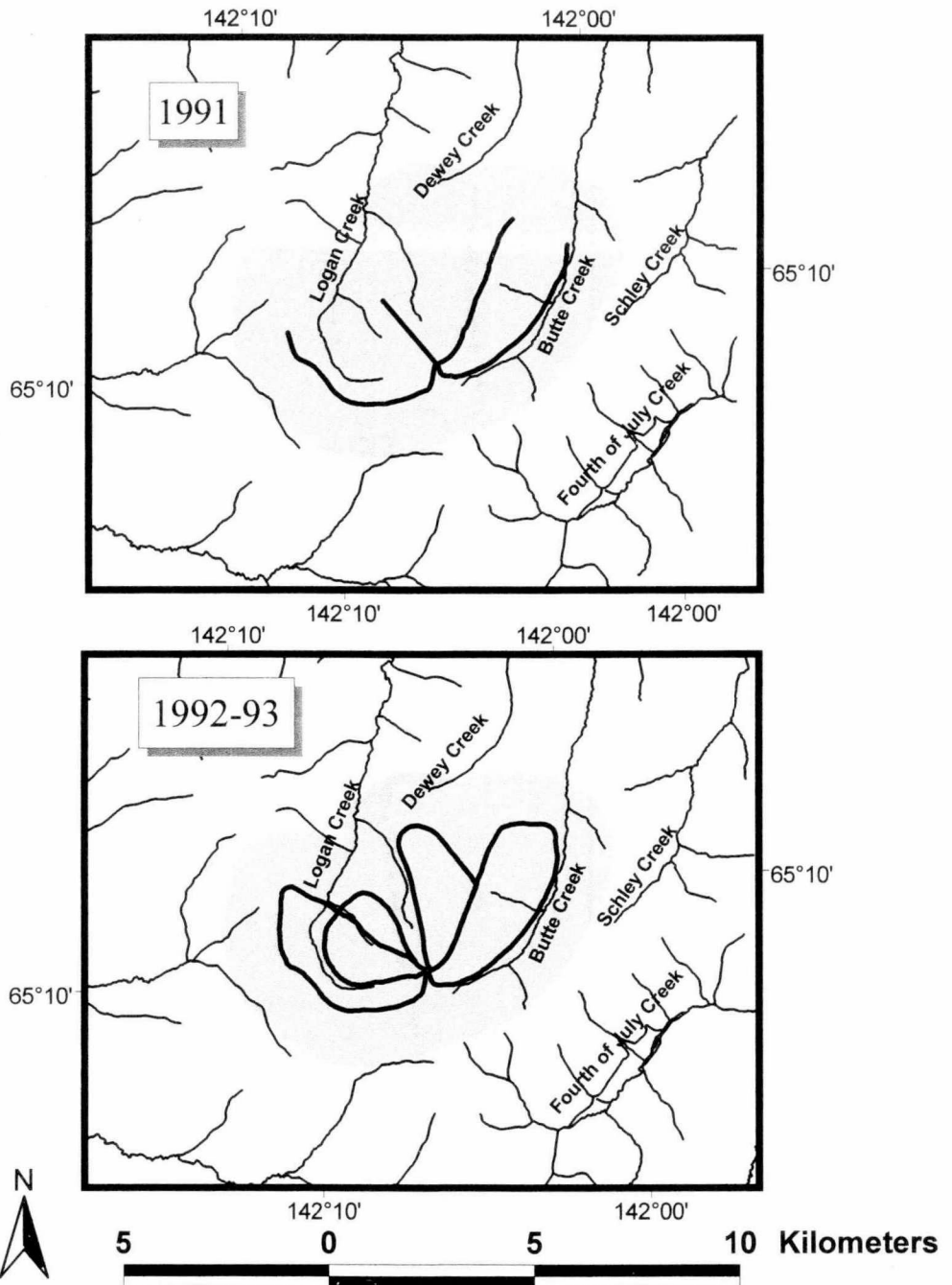


Figure 1.1. Marten study area in Yukon-Charley Rivers National Preserve, Alaska, 1991-93. The shaded polygon represents the effective area trapped. Traplines are depicted by solid lines.

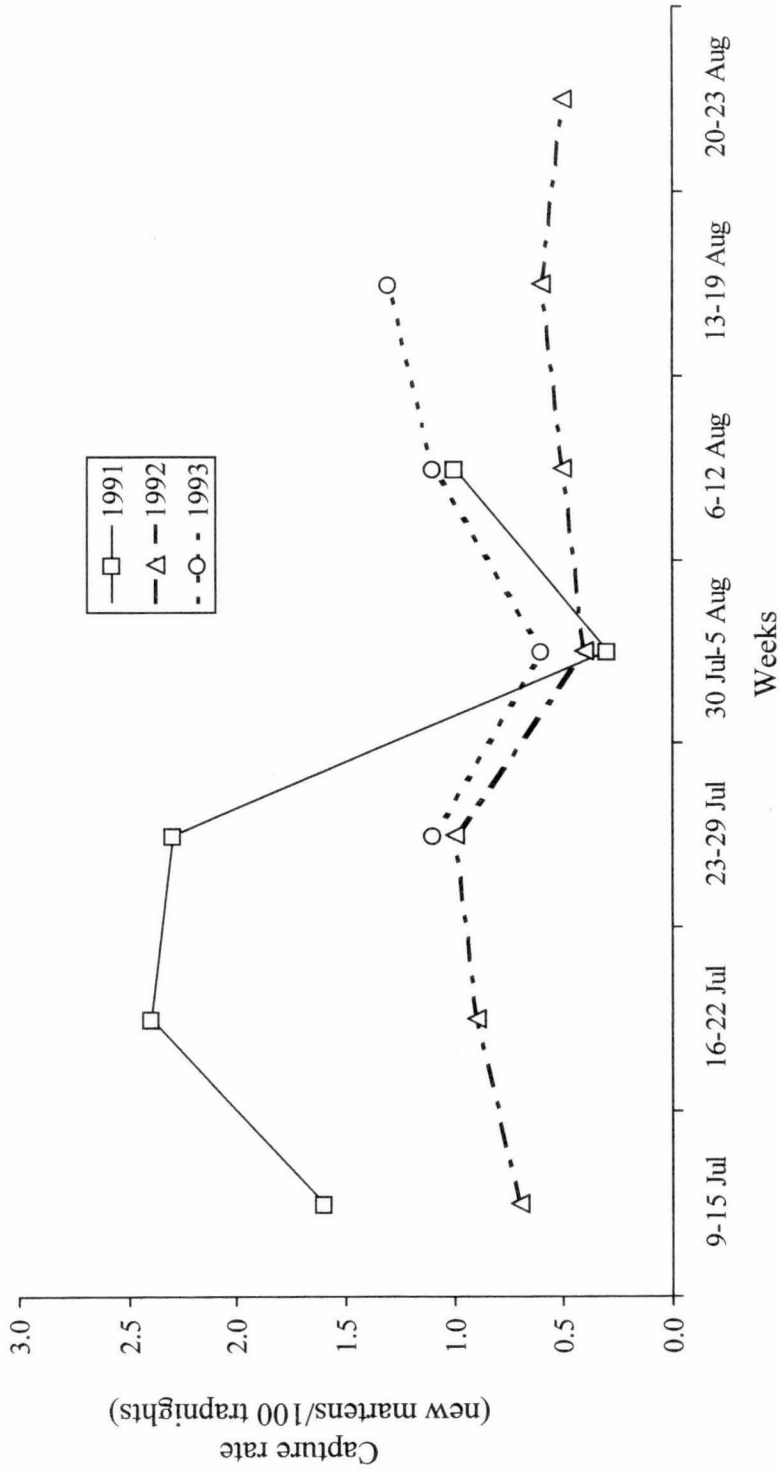


Figure 1.2. Capture rates (new martens/ 100 trapnights) for live-trapped martens, Yukon-Charley Rivers National Preserve, Alaska, 1991-93.

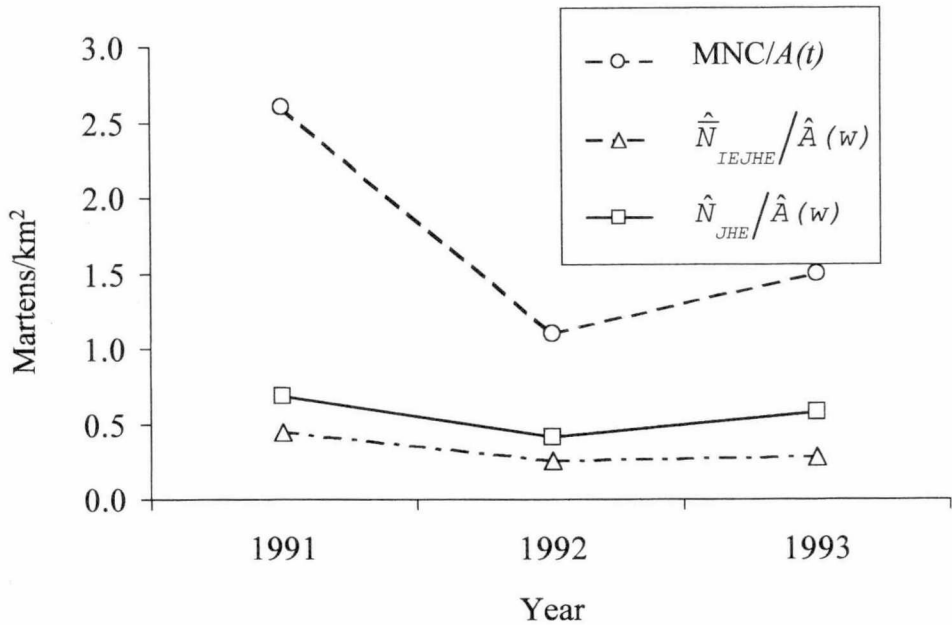


Figure 1.3. Comparisons among 3 estimates of marten density (martens/km²) calculated with the minimum number of martens captured (MNC), the IEJHE, and the JHE, Yukon-Charley Rivers National Preserve, Alaska, 1991-93.

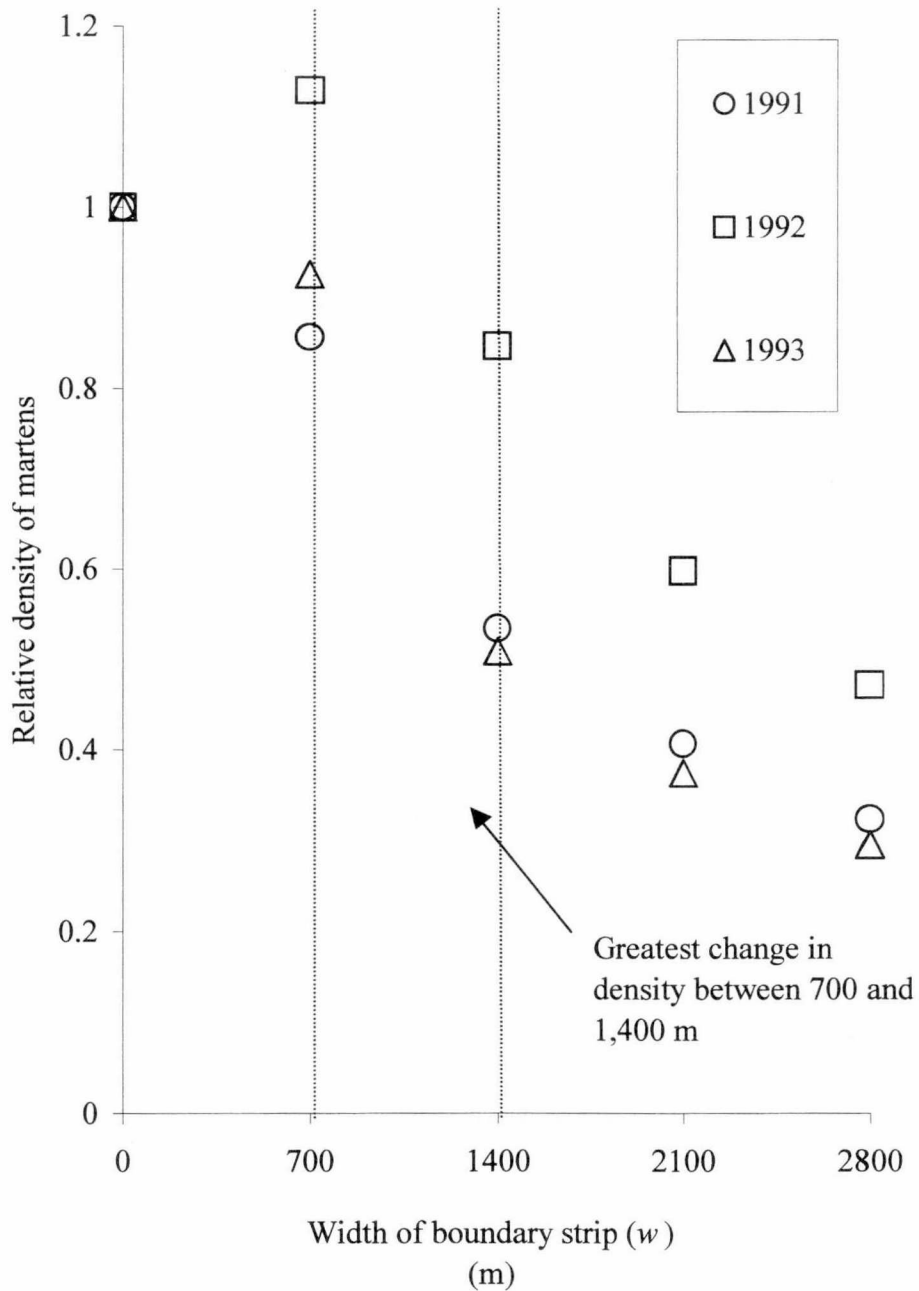


Figure 1.4. Marten density estimates as a function of the boundary-strip width. Annual density = 1.0 with $w=0$.

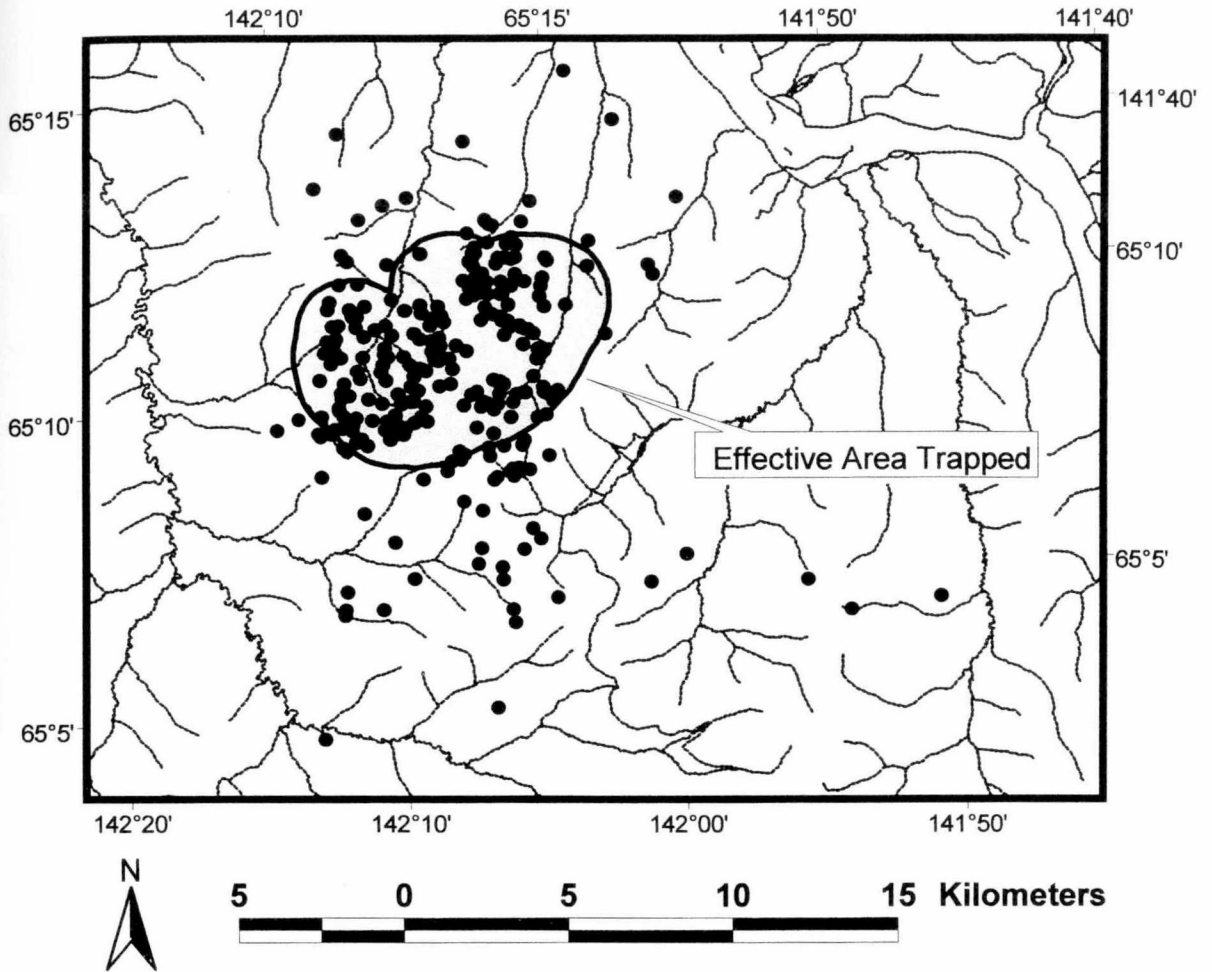


Figure 1.5. Locations of radiocollared martens during the three censuses relative to the effective area trapped, 1991-93.

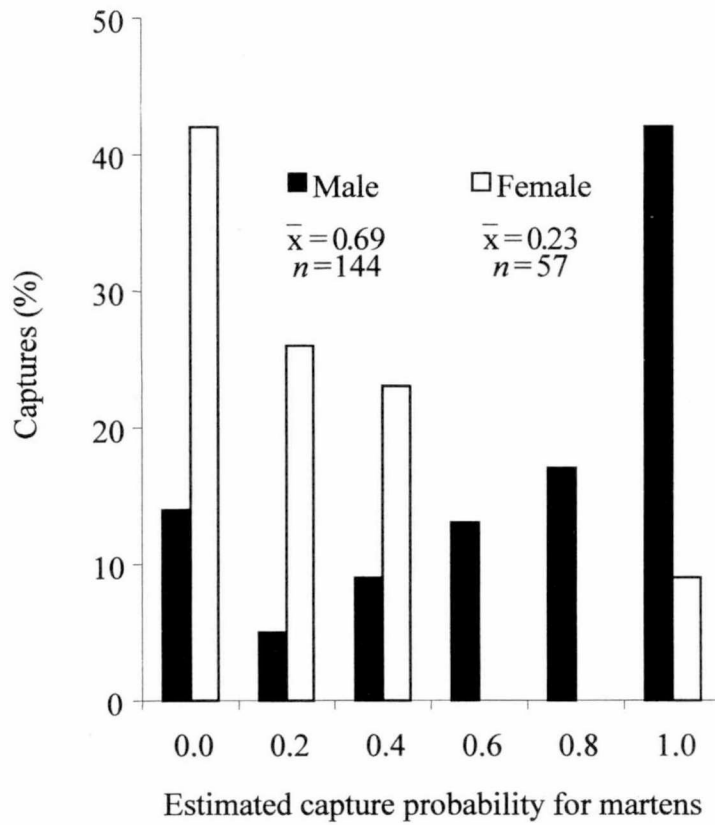


Figure 1.6. Frequency distribution of estimated capture probabilities for male and female martens, Yukon-Charley Rivers National Preserve, Alaska, 1991-93. Frequencies are weighted by the number of times during the 5 day census that the marten was located within the effective area trapped.

CHAPTER 2

EFFECTS OF FOOD ABUNDANCE AND WEATHER ON MARTEN DENSITY
AND TRAPPING SUCCESS IN INTERIOR ALASKA¹

ABSTRACT: During 1991-1993, we documented how a decrease in food abundance and unusually cold, snowy weather affected productivity, recruitment, and abundance of martens (*Martes americana*) on a 19 km² live-trapping area in eastern, Interior Alaska. We measured the relative abundance of small mammals with transects using snap-traps and pitfall traps. Relative abundance of primary prey declined during the study. Adverse weather may have also contributed to the population decline. Snowfall in the winters of 1991-92 and 1992-93 were the 3rd and 4th highest recorded since 1948. In addition, spring temperatures were 2-3^o C below normal, and record monthly snowfalls were recorded for both April and May 1992. In the summer following decreased food availability and unfavorable weather, density of martens decreased 43% between 1991 and 1992 and remained low during 1993. We documented that yearling and adult females had lower mean fecundity during winter 1991-92. Ovulation rates were lowest for yearling females. Live-trapping results documented that juvenile martens were nearly absent from the population during summer 1992. Because juveniles are a substantial proportion of harvested martens, trapping success also declined following summer 1992.

¹ Shults, B. S., L. G. Adams, and F. C. Dean. Effects of food abundance and weather on marten density and trapping success in interior Alaska. In prep. Canadian Journal of Zoology.

INTRODUCTION

Marten abundance is determined by interactions among habitat suitability, food abundance, and trapping pressure (Strickland and Douglas 1987). Weather conditions also may negatively alter population abundance as a result of direct mortality on individuals or by increasing metabolic demands for maintenance that reduce reproductive success.

Habitat selection by martens varies across geographic areas, but martens generally prefer conifer-dominated woodlands and forests (Buskirk and Powell 1994). However, their habitat selection also is linked closely to prey availability (Buskirk and MacDonald 1984). Effects of fire on habitat also appear to influence marten density as well as prey diversity and abundance (West 1982, Johnson et al. 1995). Martens are dietary opportunists (Martin 1994), but analyses of feces show that microtine rodents dominate the diet of martens in Interior Alaska (Lensink et al. 1955, Buskirk and MacDonald 1984).

Red-backed voles (*Clethrionomys rutilus*) are small (i.e., 20-50 g) and inhabit forested habitats across Interior Alaska (West 1982). Reproductive potential is high because females may produce 4 to 7 litters between May and September (West 1982). In contrast, and occurring in the diet of martens less often, yellow-cheeked voles (*Microtus xanthognathus*) are comparatively large (i.e., 45-150 g) and have a patchy distribution, especially with respect to post-fire successional stages (Wolff and Lidicker 1980). Females produce only 2 litters

averaging 8 young each year (Wolff and Lidicker 1980).

Although prey abundance is generally accepted as a regulating factor for martens, only 3 published studies (Hawley and Newby 1957, Weckwerth and Hawley 1962, Thompson and Colgan 1987) have documented or suggested a relation between marten density and prey abundance. During those studies, martens responded to reductions in prey abundance with increased dispersal, larger home ranges, increased mortality, and lower reproductive success.

Compared with larger mustelids, martens must balance their energy needs daily because of higher thermoregulatory costs associated with short fur and a high surface-to-volume ratio (Worthen and Kilgore 1981, Harlow 1994). Harlow (1994) provided a detailed discussion of the energetic tradeoffs and costs by martens given their low fat reserves (i.e., <5%) and the high thermal conductance of their fur.

Successful reproduction relies upon females allocating available energy between gestation and lactation. Most importantly, lactation has the higher energetic cost (i.e., 2 to 3 times more costly than gestation) (Robbins 1993). Harlow (1994) reported that martens must "pay" for lactation costs with body reserves other than fat or find and capture abundant and predictable foods.

Thermoregulatory stress of the female directly affects her ability to allocate energy to reproduction, especially transferring heat to the offspring either directly through contact or indirectly by heating the den (Thompson 1992).

Because martens maintain a delicate energy balance (Harlow 1994), especially during lactation, both cold temperatures (increased thermoregulatory cost) and snow cover (increased locomotor costs) may affect foraging time and ultimately the survival of adults and neonates.

We documented how marten density, population structure, and reproduction responded to small mammal abundance during a 3-year study of marten ecology. In addition, we hypothesize about the effects of colder than normal spring temperatures and an unusual early summer snowfall on reproductive success during 1992. We also discuss how these 2 factors affected trapping success.

METHODS

Study Area

The study area was described in detail by Chapman (1958) and Gallant et al. (1995). The Yukon-Charley Rivers National Preserve (65° 10' N, 142° 05' W) in Interior Alaska encompasses 10,360 km² within the Yukon-Tanana uplands (Wahrhaftig 1965).

The climate is sub-Arctic and semiarid with average annual precipitation of 30 cm and snowfall of 141 cm (National Weather Service; Eagle, Alaska). Seasons are characterized by long, cold winters (temperature range = -31° to -4° C) and short, warm (temperature range = 3° to 22° C) summers. Mean monthly temperatures for Eagle, Alaska, approximately 60 km southeast of the study area, are -25° C in January and 16° C in July (National Weather Service).

The study area was moderately to severely burned by 2 wildfires approximately 24 years prior to my study. In 1967, the Dewey Creek fire burned 996 ha, and 2 years later the more widespread and severe Butte Creek fire burned 213,000 ha (Bureau of Land Management, unpublished data). Prior to those fires, the study area probably had not been burned for about 80 years (G. Ahlstrand, National Park Service, personal communication). Vegetation was a mosaic of post-fire successional stages. The tall shrub-sapling stage (Foote 1983:77) predominated, characterized by an understory of dwarf birch (*Betula glandulosa*), labrador tea (*Ledum* spp.), and berries (*Vaccinium* spp.). Well-drained slopes were characterized by regenerating stands of quaking aspen (*Populus tremuloides*). Severely burned areas throughout the study area were in a prolonged moss-herb stage (Foote 1983:76). Unburned inclusions were primarily needleleaf woodlands or forests (Vioreck et al. 1992) with mixed overstories of black and white spruce (*Picea mariana* and *P. glauca*, respectively). Coarse woody debris was present throughout the study area primarily as standing, fire-killed trees and dead-falls.

At least 39 species of mammals are present in the study area (Clough 1976). Potential mammalian prey species of martens include shrews (*Sorex* spp.), snowshoe hare (*Lepus americanus*), red squirrel (*Tamiasciurus hudsonicus*), and microtine rodents (*Microtus* spp. and *Clethrionomys rutilus*). Large mammal carrion, especially moose (*Alces alces*) and caribou (*Rangifer tarandus*) also may be present. Spruce grouse (*Falciennis canadensis*) and willow ptarmigan (*Lagopus lagopus*) are also common residents.

Marten Livetrapping and Density Estimation

We livetrapped martens each year (1991-93) for 3 to 6 weeks (July to mid August) using single-door, folding box traps (Model 205, 66 x 23 x 23 cm, National Live Trap, Tomahawk, Wisconsin). Traps were spaced at 250-m intervals along traplines that followed creeks and ridgetops. Traps were wired to sloping poles 1-1.5 m above the ground; the traps were baited with jam and scented with marten lure (Stanley Hawbaker, Fort Loudon, Pennsylvania). Traps were covered with spruce boughs and moss to minimize exposure of trapped martens to inclement weather.

Traps were examined daily. Unmarked martens were restrained with a holding cone (V. Hawley, Canadian Wildlife Service, unpublished data) and immobilized with ketamine hydrochloride (20-30 mg/kg body mass, Wright 1983). Martens were eartagged at the base of both ears with serially numbered, monel tags (Style 1005, size 3, National Band and Tag, Newport, Kentucky). Males and females were fitted with 55 and 40 g radiocollars, respectively. We examined dentition to classify martens as juvenile (<1 yr) or adult (≥ 1 yr) based on the presence or absence of deciduous teeth, respectively (Brassard and Bernard 1939). Martens determined to be ≥ 1 yr were aged using cementum analysis of a first premolar (Matson's Laboratory, Milltown, Montana). We used a log-linear model to evaluate variation in the sex and age structure of the captured sample each year. Field procedures were approved by the Institutional Animal Care and Use Committee at the University of Alaska Fairbanks and conducted under scientific permits issued by the Alaska Department of Fish and Game.

We estimated marten abundance each year for 5 consecutive days during August using live-trapping on the study area in conjunction with radiotelemetry locations obtained daily. Using program NOREMARK (White 1996), we calculated abundance estimates with the IEJHE (Neal et al. 1993:440) that allowed for immigration-emigration of martens from the study area. We converted abundance to density by dividing the abundance estimate (\hat{N}_{IEJHE}) by the area trapped ($\hat{A}(w)$). We defined the area trapped using the boundary-strip method proposed by Dice (1938).

Small Mammal Population Index

We measured relative abundance of small mammals along transects using snap-traps and pitfall traps. We opportunistically chose transects along established marten traplines to optimize trapping opportunity and to distribute trapping effort across the study area. We divided transects between burned [open low shrubs dominant; primarily dwarf birch (*Betula* sp.), labrador tea (*Ledum* sp.), blueberry (*Vaccinium* sp.)] and unburned [needleleaf woodland/forest (*Picea* sp.) and a deep moss layer] habitats. Quantitative methods were not used to characterize vegetation present on the 2 types of sampling sites; however, we believe that the 2 habitats sampled were representative of those across the study area. Transects were 300 m long with 20 stations spaced 15 m apart (Buskirk and MacDonald 1984). Two rat traps (Woodstream Corp., Lititz, Pennsylvania) baited with a peanut butter and oat mixture and 1 pitfall trap (90 oz. round, plastic pail, Freund Can Company, Chicago, Illinois) were placed at each station. Snap-traps were placed on opposite sides and within 1 m of the pitfall trap. During August,

transects were set for 3 consecutive nights in 1991 and 5 consecutive nights in 1992 and 1993. For each capture, we recorded station number and type of trap. Microtines were identified to species and weighed. Shrews were measured, weighed, and the skull removed and saved to aid in future species identification. We calculated estimates of simple relative abundance (captures/100 trapnights) for each year, habitat type, and small mammal taxon. Trapnights were corrected for sprung traps (Nelson and Clark 1973). Mammal nomenclature follows Hall (1981).

Weather Summary

Temperature and snowfall records were summarized for Eagle, Alaska ($64^{\circ} 47'N$, $141^{\circ} 12'W$). First, we compared the long-term mean temperatures during April and May with those recorded for the same 2 months during each year of this study. Second, we compared total snowfall for each year of this study with the long-term mean annual snowfall as an index of winter severity. Finally, we compared April and May monthly snowfall totals with the long-term average snowfall for these months.

Population Parameters

Home Range and Residency Status

Martens were located aurally 3-4 times per week from August-March for each study year (i.e. 1991-92, 1992-93, and 1993-94) with Super Cub or Cessna 185 aircraft. Signals were isolated within 360° aircraft turns with radii ≤ 500 m at an altitude ≤ 150 m. Locations of martens were recorded on 1:63,360 scale maps during 1991-92, but during 1992-93 and 1993-94, we used onboard GPS units to calculate locations. Although we

did not test the accuracy of location estimates, frequent visual sightings of radiocollared martens suggested that location accuracy was satisfactory to meet study objectives.

Home ranges were calculated for animals with ≥ 10 locations using the minimum convex polygon method (Mohr 1947). We did not choose a modern estimator of home range (e.g. kernel) because sample sizes were too small. Because we recorded few locations/individual, no attempt was made to separate home ranges into seasons. We tested for sex and year effects on home range size with 2-factor analysis of variance (ANOVA) (Zar 1984). We also used the Wilcoxon signed-ranks test to detect changes in home range size between monitoring periods for martens captured in consecutive summers (Conover 1980).

Weckwerth and Hawley (1962) categorized residency status as transient, temporary, or resident based on live-trapping histories. We used only 2 categories: transient and resident. We determined residency status for adults each year by evaluating home range size and location, number of radiolocations on the study area, and live-trapping history. Resident adults were located on the study area ≥ 3 months and maintained home ranges on the study area. Transient martens were only livetrapped once, had large or no definable home ranges or were located long distances from the study area. We defined juvenile dispersal as a one-way movement away from the live-trapping area (White and Garrott 1990).

Survival

We estimated monthly survival of adult and juvenile martens using the Kaplan-Meier method (Pollock et al. 1989). For each year, we calculated survival rates for all martens during the 8 months (Aug-Mar) that we located radiocollared martens. We did not investigate most suspected mortalities, so we considered martens dead if we radiolocated a marten at the same location repeatedly or the radiocollar was transmitting in the mortality mode. We withheld martens during each interval when they were not radiolocated (lost contact), but added them in subsequent intervals if they were relocated again (Bunck et al. 1995). To evaluate the effect of trapping on the survival of the radiocollared sample, we documented trap locations and numbers, chronology of the harvest, and the sex and age composition of martens harvested on the study area during 1991-92.

Productivity

We obtained adequate samples of female martens for 3 consecutive trapping seasons (1990-91 through 1992-93) to examine reproductive parameters. Although placental scars provide a more reliable estimate of the number of young born than counts of corpora lutea, we chose to use corpora lutea counts because the reliability of detecting placental scars from thawed and decomposed carcasses is questionable (Mead 1994). We determined juvenile martens using radiography of canine teeth (Dix and Strickland 1986) and aged adults using cementum analyses (Matson's Laboratory, Milltown, Montana) of the fourth premolar.

Ovaries were dissected from the ovarian bursa and preserved in 10% neutral-buffered formalin. Pairs of ovaries for adults (≥ 1.5 years) were sent for micro-histology analysis to determine the number of corpora lutea present (Matson's Laboratory, Milltown, Montana). We used the presence of corpora lutea as a criterion to categorize females as reproductively active. Ovulation rates were tested for differences among years with the G statistic (Zar 1984). Mean number of corpora lutea was calculated for ovulating females over all years, within years, and within yearling (1.5 yrs) and adult (≥ 2.5 yrs) age classes. We compared mean corpora lutea counts between yearling and adult females with the t -test. We compared mean corpora lutea counts among years for ovulating yearling females with the Kruskal-Wallis test (Conover 1980). We compared mean corpora lutea counts among years for ovulating females ≥ 2.5 years with ANOVA and conducted multiple comparisons with the Tukey test (Zar 1984). Fecundity rate was calculated by multiplying the ovulation rate by the mean corpora lutea count (Strickland and Douglas 1987).

RESULTS

Sex/Age Structure and Density

We captured 65 martens during 7,009 trapnights. New martens captured were 30 [15 adult (8 M:7 F); 15 juvenile (12 M:3 F)], 14 [9 adult (6 M:3 F); 5 juvenile (3 M:2 F)], and 21 [9 adult (5 M:4 F); 12 juvenile (11 M:1 F)] for 1991-93, respectively. Study-related mortalities were 2, 1, and 1 for 1991-93, respectively. We estimated total number of martens (i.e., \hat{N}_{IEJHE}^*) using the study area to be 29, 19, and 25 for 1991-93,

respectively. Estimates of the mean number of martens (i.e., \hat{N}_{TEJHE}) using the study area were 27-47% lower (Table 2.1). Marten density declined 43% between 1991 and 1992 and remained low during 1993 (Table 2.1).

Age structure of captured martens was 49% juvenile (<1 yr), 26% yearling (<2 yr), and 25% adults (≥ 2 yr). Juvenile martens composed 50%, 36%, and 57% of the live-trapped sample for 1991-1993, respectively. Sex and age composition of captured martens varied among years ($G = 4.37$, 1 df, $P = 0.037$) because few juveniles were trapped in 1992. The sex ratio for adult martens was 1.14:1, 2.00:1, and 1.25:1 (M:F) for 1991-1993, respectively, and was not significantly different among years ($P = 0.80$).

Small Mammal Population Trends

We captured 558 small mammals during 4,459 trapnights (Table 2.2). The most abundant taxa captured were *Clethrionomys rutilus* (54%), *Sorex* spp. (29%), and *Microtus xanthognathus* (16%). Composition of taxa was similar among years except for the captures of 2 brown lemmings (*Lemmus sibiricus*) during 1992. Capture rates of microtines between years declined an average of 53% on burned transects, whereas capture rates increased (i.e., 58%) between 1991 and 1992, but declined (i.e. 78%) between 1992 and 1993 on unburned transects. Relative abundance of shrews on all transects declined sharply (i.e. 82%) between 1991 and 1992, but the average increase on both burned and unburned transects was 562% from 1992 to 1993.

Temperature and Snowfall

Long-term (i.e. 1949-1999) mean temperatures for Eagle during April and May were -2.3°C and 7.3°C , respectively. During 1992, mean temperatures in April and May were 2.0°C and 2.7°C , respectively, below the 42-year means for these months. In contrast, average temperatures during April and May for both 1991 and 1993 were nearly 3.7°C and 1.7°C above average, respectively.

The mean annual snowfall for Eagle was 149.1 cm. The highest seasonal snowfall recorded was 221.0 cm during 1978-79. Total snowfall for 3 years of this study averaged 28% higher than the long-term average of 149.1 cm. Indeed, winters of 1991-92 and 1992-93 were the 3rd and 4th (209.6 and 207.0 cm) highest snowfalls recorded since 1948 ($n = 22$ years).

Mean monthly snowfall for April and May was 9.4 cm ($n = 34$ years) and 1.7 cm ($n = 37$ years), respectively. The maximum snowfall recorded for April was 49.5 cm and for May was 11.4 cm. Both records were set during 1992.

Population Responses

Residency Status and Home Range

We monitored 56 martens for 7,922 radiodays ($\bar{x} = 120$, $SE = 8.4$) during 1991-1993. Monitoring was limited by transmitter battery life to Aug-Mar each year. Only 14% of 65 martens were captured during consecutive years, and only 1 juvenile marten was recaptured in a subsequent year as a yearling. We monitored 22 adults for at least 3 months each year.

Mean number of radiolocations used to delineate 32 annual home ranges for 26 adult martens (15 M, 11 F) was 21.7 (range 11-33, SE = 1.2). Male home ranges averaged 6.2 km² ($n = 20$, SE = 0.9, range = 2.0 - 17.5 km²) compared with 13.5 km² ($n = 12$, SE = 6.6, range = 1.8 - 75.9 km²) for females. Nonetheless, if 2 yearling females captured in 1992 with unusually large home ranges (i.e., 75.9 and 43.6 km²) are excluded, then female home ranges averaged 4.2 km² ($n = 10$, SE = 0.6, range = 1.8 - 7.8 km²). Home-range size did not differ significantly between sexes ($P = 0.245$) or among years ($P = 0.085$). For 5 martens (2 M, 3 F) monitored during both 1991 and 1992, home ranges were significantly larger during 1992 ($\bar{x} = 6.3$ km) than 1991 ($\bar{x} = 3.7$ km) ($Z = -2.03$, $P < 0.022$). Male home ranges increased an average of 33% ($n = 2$) whereas females increased 51% ($n = 3$). For 4 male martens monitored during 1992 and 1993, home ranges were not significantly different between years ($Z = -1.461$, $P = 0.144$).

Survival

We followed 56 radiocollared martens an average of 120 days (range 9-237 days) each year before we determined their fate or lost radio contact (i.e., censored). Survival rates for adult martens were 0.51 (SE = 0.06), 0.83 (SE = 0.07), and 0.73 (SE = 0.13) for 1991-1993, respectively. Only 3 radiocollared, adult martens were trapped during the study, and they were harvested during 1991 on the study area; otherwise, the survival rate of adults during 1991 would be 0.77. Within years, mortality was equal between the sexes (3 M, 3 F for 1991 and 1 M, 1 F for both 1992 and 1993). Juvenile survival rates (i.e., 0.26 (SE = 0.11), 0.50 (SE = 0.35), and 0.28 (SE = 0.24) for 1991-1993,

respectively) were lower than adult rates for all years. Causes of mortality were categorized as 28% natural and 72% trapped. We lost radio contact with 13 juvenile martens.

Productivity

We obtained corpora lutea counts and determined ovulation rates with 171 pairs of ovaries from 226 females ≥ 1.5 yrs old collected during 3 trapping seasons (1990-91 through 1992-93). Ovulation rate was lowest (52%) for martens 1.5 yrs old, but increased to 84% for females ≥ 2.5 yrs old (Table 2.3). Ovulation rates were not significantly different among years for females of all ages, yearling (1.5 yrs), or adult (≥ 2.5 yrs) age classes ($G = 1.778$, $P = 0.411$; $G = 4.820$, $P = 0.090$; and $G = 0.069$, $P = 0.966$, respectively) (Table 2.3). Nonetheless, between years, ovulation rates for yearlings varied 10-25%, whereas adult rates varied only 0-3% (Table 2.3). With years pooled, the proportion of ovulating yearlings was significantly lower ($G = 21.737$, $P < 0.001$) than older (≥ 2.5 yrs) females.

Corpora lutea counts ranged from 0-5 ($\bar{x} = 2.50$ per female, $SE = 0.14$, $n = 171$) corpora lutea per female, although no martens had only 1 corpus luteum (Table 2.3). Ovulating females averaged 3.63 ($SE = 0.07$, $n = 118$) corpora lutea. Mean corpora lutea counts for ovulating yearlings (1.5 yrs) ($\bar{x} = 3.55$, $SE = 0.12$, $n = 42$) and adults (≥ 2.5 yrs) ($\bar{x} = 3.67$, $SE = 0.08$, $n = 76$) were not significantly different ($P = 0.884$). Mean corpora lutea counts did not vary significantly among years for yearlings ($\chi^2 = 0.943$, 2 df, $P = 0.624$). In contrast, mean corpora lutea counts for adults (≥ 2.5 yrs) were

significantly different among years ($F = 5.323$, $P = 0.007$) (Table 2.3). Multiple comparisons between years showed that mean corpora lutea counts for adults (≥ 2.5 yrs) (Table 2.3) were significantly higher during 1990-91 than 1991-92 ($P = 0.006$). Mean fecundity ranged from 1.5 to 4.2 (Table 2.3). Mean fecundity was lowest for females aged 1.5 yrs (i.e., 1.9). Overall, mean fecundity was 39% lower for yearlings than adults (Table 2.3). Comparing 1990-91 and 1991-92 trapping seasons, mean fecundity declined 39% and 18% for yearling and adult martens, respectively. Mean fecundity increased for both age classes in 1992-93, but was still 13% and 6% below 1990-91, for yearlings and adults, respectively (Table 2.3). Nonetheless, mean fecundity was lowest during 1991-92 because of fewer corpora lutea per female and a lower ovulation rate. This result was the same for yearling and adult females (Table 2.3).

Trapping Success

Trapping on the Study Area

The study area was trapped for at least 10 years prior to this study. Trapping was primarily during November and December, and locations of traplines set each year were consistent. No trapping occurred adjacent (i.e. within 25 km) to the study area during any year. During November and December 1991, a local trapper set 188 traps on 57 km of traplines (i.e., within and adjacent to the boundaries of the live-trapping area) resulting in the harvest of 74 martens during 3,065 trapnights (i.e. 2.4 captures/100 trapnights). Six radiocollared martens (3 Adults, 3 Juveniles) were trapped on the study area during 1991. The study area was not trapped during 1992 or 1993.

Summary of Regional Trapping

We collected 1,235 martens harvested in and adjacent to the preserve during 5 trapping seasons (1989-90 to 1993-94) (Fig. 2.1). The number of trappers contributing carcasses and the number of carcasses collected peaked during 1991-92. Number of contributing trappers decreased 67% ($n = 12$ vs. $n = 4$) after 1992 resulting in a corresponding 85% decline in the mean number of carcasses collected.

Age ratios summarized annually from carcass collections showed that after 1989-90, the ratio of juveniles per adult female ≥ 2.5 yrs declined an average of 60% annually as the proportion of juveniles in the harvest declined each year until 1993-94 (Table 2.4). Proportion of juveniles in the harvest averaged 51% between 1989-90 and 1991-92, but only 26% during the 1992-93 trapping season.

DISCUSSION

Density of Martens

Marten density declined 43% between 1991 and 1992 and remained low during 1993. We believe that a decline in primary prey (i.e., microtine rodents) and increased environmental stress (i.e., cold temperatures and snow cover) contributed significantly to the decline in marten abundance. The numerical decline resulted from an absence of juveniles. Trapping success declined because few juveniles were available for harvest during 1992-93.

Effects of Reduced Food Abundance on Population Parameters

We assumed that martens on the study area were primarily dependent upon microtine prey as demonstrated by previous studies (Martin 1994). As in other studies, we observed that red-backed voles were ubiquitous across the 2 habitats sampled, whereas yellow-cheeked voles were most abundant in the burned habitat. Both species declined each successive year in both habitats except for a 42% increase of red-backed voles between 1991 and 1992 in the unburned habitat. Shrew abundance also declined substantially between 1991 and 1992, but rebounded near or above 1991 levels in 1993. Shrew abundance fluctuated drastically between years. Value in the diet, however, only may be important when other prey are not available (Weckwerth and Hawley 1962). Cowan and Mackay (1950) hypothesized that the strong smell of shrews may affect their palatability to martens.

Population structure of martens is dynamic, especially with respect to residency during a decline in food abundance (Hawley and Newby 1957, Weckwerth and Hawley 1962, Thompson and Colgan 1987). Weckwerth and Hawley (1962) documented fewer juveniles and resident adults during the first year of a decline in food abundance. In contrast, Thompson and Colgan (1987) observed a 2-year lag before the resident population of males declined. Population composition changed during this study, as demonstrated by the low recapture of radiocollared individuals (14%) from 1 year to the next, and the fact that only 1 juvenile marten maintained residency and was recaptured as a yearling. Similar to the Ontario study (Thompson and Colgan 1987), adult composition

on my study area was probably maintained by the movement of transient adults from adjacent habitat into unoccupied territories on the study area.

Sex ratios commonly favor males in samples of live-trapped martens (Buskirk and Linstedt 1989). The sex ratio of live-trapped adults was not significantly different among years, but males were twice as abundant during 1992. The resident trapper, however, caught 3 adults (1 M, 2 F) during 1991-92 trapping season and this alone could account for the disparate sex ratio during 1992. Alternatively, a skewed ratio during 1992 also may reflect increased mortality of adult females. Hawley and Newby (1957) were the first to suggest that females were more vulnerable to mortality during reduced food abundance because of the energetic demands of rearing young. In an untrapped population of martens in Maine, Hodgman et al. (1997) reported that 67% of adults that died from natural causes were females.

Survival rates are the result of interactions between weather, food abundance, habitat (Thompson and Colgan 1987), and trapping (Hodgman et al. 1994). My data on survival present no clear relationship among factors. We detected higher survival of martens during 1992 than any other year, contrary to the expected decrease in survival documented for other studies of martens during a prey decline (Thompson and Colgan 1987). Most importantly, survival is influenced primarily by trapping for juvenile martens that range widely, and this may be more pronounced during periods of low food abundance. Juveniles have the added energetic burden of growth along with foraging competition with adults. Hawley and Newby (1957) suggested that juvenile and female

marten survival is compromised when food is scarce because they have higher energy requirements than adult males. Juvenile females may have higher rates of mortality than juvenile males and that outcome may account for their low numbers in the live-trapped samples during all years.

Energetic requirements related to food abundance also may affect home range size (Katnik et al. 1994). Thompson and Colgan (1987) reported that both male and female home ranges increased significantly during years when food was scarce. Although sample size was small, we observed that home ranges were significantly larger during 1992 than 1991 for individual martens monitored both years. Male and female home ranges in southeast Alaska also increased by 36% and 133%, respectively, during the same year that a small mammal abundance index indicated an 82% decline in potential small mammal prey (Flynn 1993). Because home range size also is influenced by intraspecific interactions (e.g. mating pattern) (Powell 1994), we hypothesize that prey abundance was a contributing factor influencing the increases in home range sizes.

The reproductive potential of marten populations varies with respect to rates of ovulation and pregnancy. Maximum fecundity rates are a product of the proportion of females that are pregnant and ovulation rates. Moreover, both rates have been shown to vary between years because of changes in food abundance (Thompson and Colgan 1987, Flynn and Blundell 1992). Ovulation rates for adults were constant for the 3 winters preceding each summer live-trapping session; however, mean number of corpora lutea/female was lowest during winter 1991-92, so that the reproductive potential for

summer 1992 was lower than any other year. In addition, ovulation rates in 1990-91 were significantly higher than 1991-92. Corpora lutea counts may overestimate productivity because intrauterine mortality may result from environmental stress (Mead 1994).

Fecundity rate for adults in this study was similar to other areas in North America when food was not a limiting factor. Nevertheless, mean fecundity was lowest during 1991-92 and remained low during 1992-93. Yearling females (≥ 1 yr) usually have significantly lower pregnancy rates and slightly lower ovulation rates compared with older females (Strickland and Douglas 1987). Ovulation rates for yearlings declined 25% between 1990-91 and 1991-92. Young females also showed reduced rates of ovulation during a food shortage in northern Ontario (Thompson and Colgan 1987). Despite lower fecundity, yearlings are the largest proportion of the age structure and can affect overall reproductive potential of a population.

Effects of Weather

We suggest that the consequences of below-normal temperatures during April and May 1992 were 2-fold. First, increased metabolic needs to thermoregulate required increased energy expenditure to forage. Also, the burden of lactation for 6 weeks (Wynne and Sherburne 1984) and food provisioning of young for an additional 12-14 weeks increased female energy demands. Second, newborn marten are small (i.e., 28 g), sparsely furred (Brassard and Bernard 1939) and, therefore, are dependent upon a warm microclimate or direct heat transfer from the female to prevent hypothermia. Henry et al. (1997) reported that females spent more time at dens prior to weaning, presumably to

provide warmth and milk. By observing dental development (Brassard and Bernard 1939) of live-trapped juveniles in July and assuming a gestation period of nearly 1 month (Jonkel and Weckwerth 1963), we concluded that martens may be born as early as mid-March. Live-trapping data, specifically the increase in juvenile captures, suggest that juvenile independence occurs approximately 20 weeks after parturition. Those data indicate that timing of the early May snowfall closely corresponded with the period that young were still dependent upon the female for food provisioning.

We hypothesize that cooler than normal spring temperatures, and the subsequent record snowfall in May increased the energetic demands of lactating females and may have thermally stressed young martens thereby increasing their neonatal mortality prior to den emergence. Frost and Krohn (1997) documented that cold and wet weather (i.e., a severe ice storm) caused mortality of young fishers (*Martes pennanti*) in captivity even when nest boxes were provided.

Trapping Success

We maintained a consistent effort from 1990-91 through 1993-94 to collect carcasses from local trappers; however, the number of trappers contributing carcasses and the number of martens harvested declined substantially beginning in 1992-93. We attribute the decline to the decreased trapping success that trappers encountered early during the trapping season in 1992 and subsequently during 1993-94. Juvenile martens typically represent a substantial proportion of the harvest (Strickland 1994). Juvenile martens were virtually absent from the harvest during winter 1992-93 (Table 2.4). This

result was consistent with livetrapping from summer 1992, when only 5 juveniles were captured (i.e., 36% of the live-trapped sample). The 1992-93 sample had the lowest proportion of juvenile martens documented in the harvest since a declining trend began in 1990-91. Juveniles increased to 57% of the live-trapped sample during 1993 and the subsequent carcass information collected during the following winter 1993-94 showed that juveniles increased to 93% of the harvest (Table 2.4).

Harvest Management

Martens are economically important furbearers to both subsistence and sport trappers in Interior Alaska. In contrast to western Canada, where registered traplines and quotas are established for each trapper (Slough et al. 1987), federal and state agencies in Alaska have no intensive regulatory system for furbearers besides regulating trapping methods and means and establishing seasons and bag limits. The demographics of marten populations in Interior Alaska have been inferred mostly by information obtained through carcass collections or trapper questionnaires. In Interior Alaska, this management system has been adequate because of limited access to large expanses of marten habitat that provide refugia (Archibald and Jessup 1984) and dispersing juvenile martens (De Vos 1951). Nonetheless, the long-term effects of intensive trapping on local populations may depend upon the ability of reservoir areas to provide transient martens to compensate for trapped martens (Archibald and Jessup 1984). Because home range size and dispersal may increase during a prolonged food shortage, long term population production may be compromised because "reservoir" martens become available for

harvest (Thompson and Colgan 1987). In addition, density independent events such as unfavorable weather should be considered as an important factor when managing harvest. Therefore, a conservative strategy of marten management cannot solely rely on trapping success as an index of population performance.

We agree with Thompson and Colgan (1987), who suggest a reservoir management strategy coupled with the flexibility to apply regulatory changes when food abundance is low. We also suggest that managers monitor peak abundance of small mammals in autumn as an initial predictor of population performance. Managers subsequently could monitor the composition of the harvest, especially the proportion of juveniles, in the harvest and the juvenile : adult female ≥ 2.5 yrs ratio. Fluctuations in these measures might offer guidelines for situations where early closure of the trapping season might be warranted.

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Table 2.1. Number of martens captured, abundance estimates, and density of martens, Yukon-Charley Rivers National Preserve, Alaska, August 1991-93.

Parameter	Year		
	1991	1992	1993
MNC ^a	28	19	25
\hat{N}_{IEJHE} ^b	19.0	11.9	12.2
95% CI	(17.6-21.7)	(11.8-13.3)	(12.2-13.3)
$\hat{N}_{IEJHE} / \hat{A}(w)$ ^c	0.45	0.26	0.28
95% CI	(0.42-0.52)	(0.26-0.29)	(0.28-0.31)

^a Number of martens captured and marked.

^b Estimated number of martens using the study area.

^c Density estimate of martens using the study area.

Table 2.2. Relative abundance (ie. individuals captured/ 100 trapnights) of small mammals captured during August 1991-1993 in 2 different habitats, Yukon-Charley Rivers National Preserve, Alaska.

Taxa	Habitat Type	
	Burned ^a	Unburned ^b
<i>Microtinae</i>		
1991	24.7	7.3
1992	11.9	11.5
1993	5.6	2.5
<i>Clethrionomys rutilus</i>		
1991	13.9	6.3
1992	7.8	10.8
1993	4.9	2.2
<i>Microtus xanthognathus</i>		
1991	10.8	0.9
1992	4.1	0.5
1993	0.7	0.2
<i>Soricidae</i>		
1991	6.8	4.2
1992	1.5	0.6
1993	7.1	3.9

^a Total trap-nights were 251, 1093, and 1107 for 1991-1993, respectively.

^b Total trap-nights were 331, 826, and 851 for 1991-1993, respectively.

Table 2.3. Corpora lutea counts by year, percentage of females ovulating, and fecundity rate for yearling (1.5 yrs) and adult (≥ 2.5 yrs) martens collected by trappers in and adjacent to Yukon-Charley Rivers National Preserve, Alaska, 1990-1993.

Age Class/ Year	Females Examined (<i>n</i>)	Females Ovulating (<i>n</i>)	Corpora Lutea (<i>n</i>)	% Females Ovulating	Mean corpora lutea per Ovulating female	Mean Fecundity
Yearling						
1990-91	37	24	85	65	3.5	2.3
1991-92	40	16	56	40	3.5	1.4
1992-93	4	2	8	50	4.0	2.0
Adult						
1990-91	17	14	58	82	4.1	3.4
1991-92	60	51	179	85	3.5	3.0
1992-93	13	11	42	85	3.8	3.2

Table 2.4. Annual age ratios for martens collected by trappers in and adjacent to Yukon-Charley Rivers National Preserve, Alaska, 1989-1994.

Year	<i>n</i>	Proportion Juveniles	Juveniles/Adult Female ≥ 2.5 yrs	Juveniles/Adult Female ≥ 1.5 yrs
1989-90	146	0.81	19.7	9.1
1990-91	386	0.55	10.0	3.0
1991-92	561	0.46	3.5	1.9
1992-93	85	0.26	1.2	0.8
1993-94	57	0.93	53.0	26.5
All years	1,235	0.54	5.5	2.7

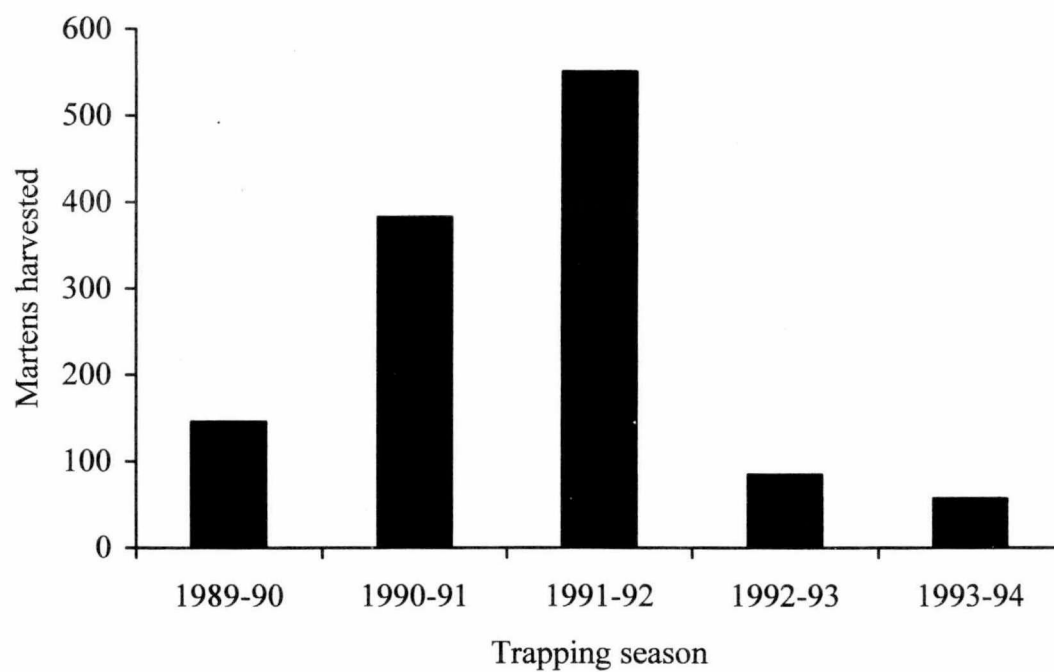


Figure 2.1. Number of martens collected from trappers in and adjacent to Yukon-Charley Rivers National Preserve, Alaska, 1989-1994.

CONCLUSIONS

My results indicate that marten abundance fluctuates daily and annually. Marten abundance was estimated with the IEJHE (Neal et al. 1993). The IEJHE accounted for the lack of geographic closure that I documented for my live-trapping study. Daily estimates varied because marten populations are transient. Capture rates were misleading as an index to abundance because capture rates vary among sex and age classes.

For useful comparisons of marten abundance among years or other studies, I converted abundance estimates to density with the boundary-strip method recommended by Dice (1938). A boundary-strip width equal to one-half of a home range diameter was adequate to describe the movements of most live-trapped martens. Estimates of density reported in the literature should be accompanied by empirical or qualitative descriptions of the effective area trapped.

Marten density declined significantly between 1991 and 1992-93. Population structure changed because juveniles were nearly absent during 1992. Capture rates of microtine rodents, especially *Clethrionomys rutilus* and *Microtus xanthognathus*, declined between years. As a result of decreased food, martens responded with larger home ranges and significantly lower ovulation rates. Mean fecundity also declined during the food shortage. I hypothesize that colder than normal spring temperatures and an unusual early summer snowfall during 1992 also reduced reproductive success.

The results of this study support the reservoir strategy for harvest management as long as managers have the flexibility to apply regulatory changes when food abundance is

low or density independent events such as unfavorable weather occur. Managers could measure peak small mammal abundance in autumn and adjust season length during the trapping season by monitoring the proportion of juveniles in the harvest and the juvenile : adult female ≥ 2.5 yrs ratio.

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APPENDIX A. Glossary of notation representing parameters, statistics, and estimators used in chapter 1.^a

Notation and Definition

T_i	Number of martens with radiocollars in the population at the time of the i^{th} survey, $i=1, \dots, k$ surveys.
M_i	Number of marked martens in the population that have been located within the effective area trapped at the time of the i^{th} survey.
m_i	Number of marked martens captured during the i^{th} survey.
u_i	Number of unmarked martens captured during the i^{th} survey.
n_i	Number of martens captured during the i^{th} survey, consisting of m_i marked animals and u_i unmarked animals, so that $n_i = m_i + u_i$.
w	boundary-strip width determined defined by the radius of an average adult male marten home range during this study.
A	The effective area trapped (a parameter).
$A(t)$	The area of the polygon defined by connecting the outermost traps on the study area.
$\hat{A}(w)$	The estimated effective area trapped defined as $A(t)$ plus the area added by w
\hat{N}_{JHE}	Population estimate using the JHE estimator (Bartmann et al. 1987).
\hat{N}_{IEJHE}^*	The estimated total marten population that has any chance of being observed on the study area (Neal et al. 1993).
\hat{N}_{IEJHE}	The mean, daily estimate of the number of martens on the study area (Neal et al. 1993).

^aNotation from Neal et al. (1993), White et al. (1982), and White (1996).

