DENSITY OF FISHERS IN THE SUB-BOREAL SPRUCE BIOGEOCLIMATIC ZONE OF BRITISH COLUMBIA

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ABSTRACT—Information on fisher (*Martes pennanti*) densities is needed for the management and conservation of this mid-sized carnivore in British Columbia. To address this knowledge gap, we estimated the density of fishers in an industrial forest in north-central British Columbia between 1996 and 2000 using a minimum number alive estimate derived from live-trapping and radio-telemetry data. Density estimates averaged ($\pm$ s) 11.2 $\pm$ 2.1 fishers/1000 km^2 (n = 4 capture sessions) on 31 October and 8.8 $\pm$ 1.1 fishers/1000 km^2 (n = 4 capture sessions) on 31 March. In comparison, the densities of fisher populations in eastern regions of North America were documented to be 6 to 49 times higher than our estimate for north-central British Columbia. The density of fishers in north-central British Columbia may be lower due to larger home range sizes and more widely dispersed individuals than elsewhere. Low-density fisher populations, such as in our study area, will require more conservative management strategies by trappers and wildlife agencies to ensure population persistence in these areas.

Key words: fishers, *Martes pennanti*, density, inventory, live-trapping, radio-telemetry, Sub-Boreal Spruce biogeoclimatic zone, British Columbia

Whether for conservation of vulnerable species or management of harvested wildlife, population management often necessitates an approximation of the density at which a species occurs. Density estimates and vital rate data are necessary information for modelling population changes under various management scenarios. Density estimates are also useful to wildlife and habitat managers because they provide benchmarks from which habitats can be ranked at both regional and landscape scales. Additionally, habitat-based density estimates and their resultant population estimates for identified areas are often integral inputs for analyses of population viability.

Fishers (*Martes pennanti*) are medium-sized carnivores of the family Mustelidae that are found in boreal and temperate coniferous and deciduous-coniferous forests across North America (Proulx and others 2004). Fishers are difficult to inventory because effective methods are generally labour-intensive and costly (Powell 1993). As a result, no universal method exists for estimating the density of fisher populations. In the past, fisher densities have been estimated using snow-track counts (de Vos 1952), fur-harvest returns (Douglas and Strickland 1987), live-capture and radio-telemetry data (Kelly 1977; Arthur and others 1989), and track plate surveys (Zielinski and Kucera 1995). Recently, Fuller and others (2001) estimated the density of fishers in Massachusetts by using mark-recapture information and territory mapping.

Fisher density estimates for eastern North America range from 50 to 385 fishers/1000 km^2 (Powell and Zielinski 1994; Fuller and others 2001), but Banci (1989) suggested that fisher densities were considerably lower in western North America. She cited only 2 studies that had quantitative data for this portion of the species' range; both provided rough estimates of $<$5 fishers/1000 km^2. One of these estimates was from northeastern British Columbia where, due to differential habitat quality across the landscape, substantial areas of land were not thought to be occupied by fishers (Quick 1953). Similarly, Jones (1991) surmised that the low densities of fishers in the west were the result of generally poorer quality habitats.

Fishers in British Columbia are currently managed as a furbearer that can be legally harvested by trappers on registered traplines between 1 November and 15 February. However, harvests of fishers have declined considerably in British Columbia over the past 30 y, which has contributed to its current status as ''vulnerable'' in the province (Weir 2003). Due to the lack of relevant density estimates for fisher populations in western North American, and particularly in north-central British Columbia, harvest management may be incorrectly based on estimates from other jurisdictions. We estimated the density of fishers in an industrial forest landscape in north-central British Columbia to provide wildlife managers and trappers with data to better regulate harvest levels and help facilitate population persistence.

METHODS

Study Area

Our study area covered approximately 1930 km^2 and was centred 70 km NW of Mackenzie, British Columbia (55°19′16″N, 123°6′42″W; Fig. 1). The topography was characterized by a gently rolling plateau rising from the Williston Reservoir in the east to the lower slopes of the Wolverine and Swannell mountain ranges in the west. Our study area represented a relatively closed fisher population because it was bounded to the east and south by a large water body (Williston Reservoir) and to the west by a mountain range comprised of generally low-suitability habitats (for example, alpine). The boundary of the study area was defined by the extent of the Sub-Boreal Spruce (SBS) biogeoclimatic zone (BCMF 2004).

The study area lies at the northern extent of the SBS zone at elevations between 670 m (valley bottom) and 1100 m. Mean annual temperature during the study period was 2°C and ranged between −52°C and 36°C. Snow cover in the study area generally lasts from mid-November until mid-April, with average depths of approximately 40 to 50 cm throughout most of the winter. Annual precipitation averages between 690 mm and 905 mm with total snowfall averaging between 335 cm/y and 1075 cm/y (MacKinnon and others 1990).

Forests were dominated by hybrid spruce (*Picea glauca* × *engelmannii*), lodgepole pine (*Pinus contorta*), black spruce (*Picea mariana*), and subalpine fir (*Abies lasiocarpa*), with trembling aspen (*Populus tremuloides*) and paper birch (*Betula papyrifera*) also present. Black cottonwoods (*Populus balsamifera trichocarpa*) occurred as notable elements in riparian-type ecosystems and occasionally in other areas with subhygric or wetter ecological moisture regimes.

The study area included portions of 5 registered fur-harvesting traplines. Trapping occurred to varying degrees during the study, as evidenced by the harvest of between 28 and 154 American martens (*M. americana*) per year on each trapline, totalling 352 between November 1996 and February 2000 (Provincial Wild Fur Harvest Database, Ministry of Environment, Victoria, British Columbia, Canada). Between 1 and 3 fishers were harvested each year among these traplines, with a total of 8 fishers harvested during the 4 y of our study; 3 of these 8 fishers, however, were taken on portions of the traplines outside of our study area.

Live-trapping and Tagging

We captured and radiotagged fishers during the fall and winter to determine the minimum number of fishers that were alive in the study area by the end of winter (late March) each year. We attempted to capture and radiotag fishers in 4 annual intensive capture sessions conducted during the late-fall and winters of 1996–1997 to 1999–2000. We set live traps so that they were continuously operational for between 12 to 22 d for 2 to 6 time-periods during each of these annual capture sessions.

We used 3 types of live trap sets to capture fishers: wire-cage, log-cabin, and metal-barrel traps. The majority of live traps that we set were wire-cage traps, which were approximately 24.5 × 31 × 81 cm (Havahart Models 1081 and 1089). The log-cabin sets (approximately 1.2 × 0.8 × 2.4 m) were made of intermeshing logs, with a trigger mechanism that released a log door when bait was pulled from inside the trap (Copeland and others 1995). Barrel traps, used relatively infrequently, consisted of a 30-gal metal drum with a sliding door cut into one end (Banci 1987), similar in design to culvert traps used to capture bears.

We took several actions to enhance the efficacy of the traps. We selected trap locations

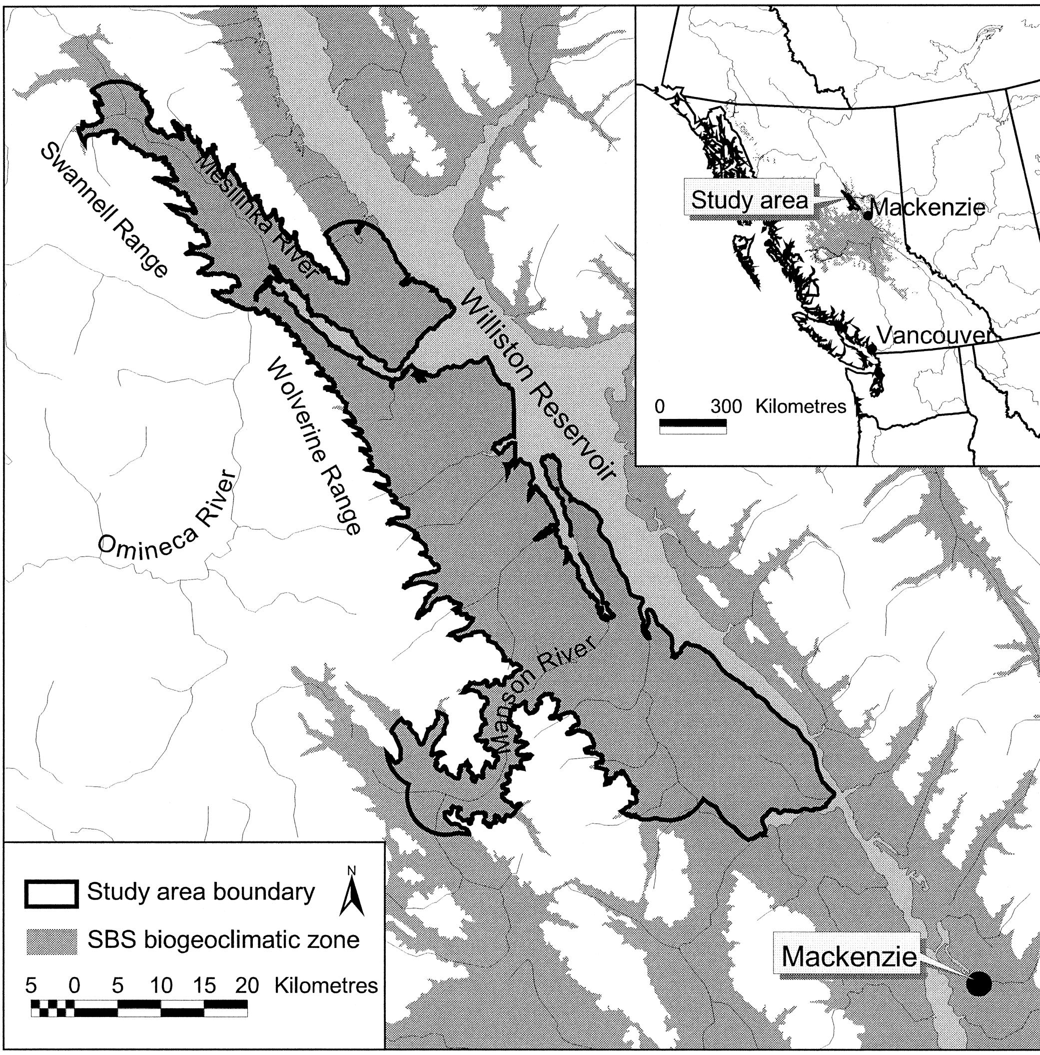

FIGURE 1. Location of the study area in north-central British Columbia. Delineation of the study area was based upon the extent of the Sub-Boreal Spruce (SBS) biogeoclimatic zone in the area. Inset map shows distribution of the SBS (in grey) within British Columbia.

within patches that had microsite attributes, such as coarse woody debris or clusters of immature trees, that fishers have been reported to use (Weir and Harestad 2003). We baited each wire-cage trap with approximately 500 g of salmon, moose carcass, or grouse carcass. Logcabin and barrel traps were baited with whole salmon (1 to 4 kg) or pieces of moose carcass (1.5 to 3 kg). At each trap location, several nearby trees were scented with a combination of commercial fisher, marten, and skunk oil lure. We checked live traps daily and assessed the functioning of each trap every 2 to 3 d.

Fishers were immobilized using either a 10:1 mixture of ketamine HCl:xylazine HCl, a 5:1 mixture of ketamine HCl:meditomadine HCl, or a 1:1 mixture of tiletamine HCl:zolazepam HCl (Telazol®) prior to radiotagging. From most fishers, we removed a premolar 1 for cementum annuli analysis (Strickland and others 1982) to determine age. For individuals from which we could not extract a tooth, we classed fishers as adult or juvenile by palpating the saggital crest and examining the level of tooth wear (Powell 1993). We considered fishers that were ≤1 y old as juveniles, between 1 and 2 y old as subadults, and those ≥2 y old as adults. We applied unique marks to each fisher by using inguinal tattoos and, during the first capture session, 3.4 × 1.0-cm nylon ear tags.

We used 2 methods to radiotag the fishers. During the first 2 y of the study, we tagged fishers with radiocollars (Holohill MI-2M [1996–97] or Telonics MOD-080 [1997–98]). In subsequent years, we surgically implanted fishers with intraperitoneal transmitters (Telonics IMP/200L or IMP/300L). All capture, handling, and tagging protocols were reviewed and approved by the provincial government's wildlife veterinarian.

Density Estimate

We calculated the density of fishers at the start and end of each annual capture session. We estimated a late-winter (31 March) density by dividing the area that was effectively sampled during the annual capture session (see below) by the number of fishers known to be alive at the end of that capture session (minimum number alive, MNA; Krebs 1966). We also estimated a fall (31 October) density using the same effectively sampled area and the fall MNA, which was derived by tallying all of the fishers known to be alive at the start of each annual capture session. This latter number included animals captured during the subsequent capture session plus those fishers that were previously tagged and still alive based on radio-telemetry data. Thus, the late-winter estimate was based on the fall estimate minus known mortalities.

The fall density estimate relied upon the assumption that juvenile and subadult fishers that were caught during the subsequent capture session were present in the sampled area on 31 October. Although juvenile and subadult fishers are generally believed to be transient (Powell 1993), our data for transient radiotagged individuals (2F, 1M) showed that the net dispersal distance (that is, the distance between the centres of each fisher's maternal home range and their respective established home ranges) was between 0.7 km and 41.3 km ($\bar{x}$ = 20.2 km, s = 20.4 km, n = 3). Based on this low dispersal distance and the very low suitability of habitats surrounding much of the study area (alpine tundra to the west, large reservoir to the east), it is unlikely that many animals dispersed into or out of the project area. Also, our data and that of Weir (1995) suggested that fishers establish their home ranges, and thus become resident, by the end of March, so we likely would have captured transient individuals within the study area by the end of the capture session (31 March).

We estimated the area that we sampled during each capture session by considering the ''effective area'' that each live trap sampled. As a 1st step in delineating the sampled area, we identified live traps that were operational for a sufficient time to capture a fisher based on the latency to 1st detection (LFD; Zielinski and Stauffer 1996). Derived from empirical data, the LFD was 13.7 d for resident fishers that we captured (s = 12.3 d until capture, n = 18 fishers). We did not include captures of 3 fishers in our LFD calculation because these animals later proved to be transient and may not have been exposed to live traps as consistently as fishers with established home ranges. For our estimate of area sampled, we only included live traps that were operational for ≥16 d during each capture session to ensure that only traps that had surpassed the LFD criteria were used.

Second, we determined the effective area sampled by each live trap. We assumed that a fisher would have a reasonable likelihood of encountering traps on its day-to-day travels throughout its home range. We considered the 75% isopleth of the animal's utilization distribution (UD) during the winter (that is, a capture session) as the smallest area that a fisher was likely to use consistently during our sampling. Based on our calculated 75% isopleths (range = 18.8 to 34.9 km^2, n = 5 females), we selected the smallest 75% isopleth (18.8 km^2) to represent the area that was effectively live-trapped. Consequently, a 4.89-km buffer, which circumscribed an area that was equivalent to our smallest 75% isopleth, was placed around each live trap that was active during the capture session. Portions of the buffer that overlapped the inundation area of the Williston Reservoir were excluded from the area sampled. In addition, because we were attempting to produce a density estimate for the SBS zone and because we live-trapped exclusively within this zone, we excluded any areas that fell out-

TABLE 1. Fall (31 October) and late-winter (31 March) density estimates derived from the minimum number alive (MNA) estimate for areas sampled during each annual capture session in north-central British Columbia, 1996–2000.

Capture session[a]	Trap-nights[b]	# of traps	MNA 31 October ad	sub	juv	Σ	MNA 31 March ad	sub	juv	Σ	Area sampled[c] (km^2)	Density (fishers/1000 km^2) 31 October	31 March
1996–1997	3255	77	7	3	1	11	5	3	1	9	1135	9.7	7.9
1997–1998	3033	110	5	0	9	14	5	0	6	11	1069	13.1	10.3
1998–1999	2088	101	6	6	1	13	4	4	0	8	1009	12.9	7.9
1999–2000	1348	79	8	0	0	8	8	0	0	8	873	9.2	9.2

[a] November to March, but including September and October in 1997–98.
[b] 1 trap-night = 1 live trap set for one 24-h period.
[c] Estimated using a 4.89-km diameter buffer around each live trap that was operational for ≥16 trap-nights and the 95% isopleths of resident tagged animals that were alive during the capture session, excluding the Williston Reservoir and areas outside the Sub-Boreal Spruce biogeoclimatic zone.

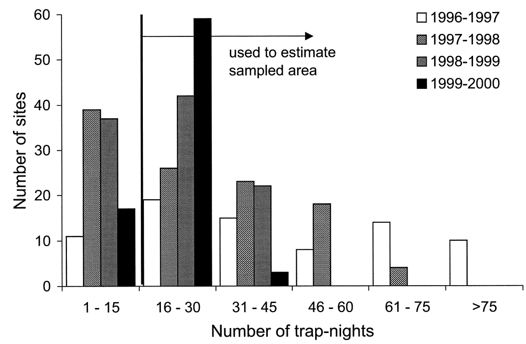

FIGURE 2. Intensity of live-trapping effort (trap-nights per site) for fishers during each capture session in north-central British Columbia, 1996–2000. Sites for which ≥16 trap-nights were conducted per session (to right of vertical line) were included in the calculation of sampled area. n = 9724 trap-nights.

side this zone, including other forested areas. We felt confident in excluding these other areas because ≤7% of the amalgamated home ranges of all fishers included these outlying areas.

Lastly, to delineate the entire area that we effectively sampled, we also included all portions within the SBS of the home ranges (that is, 95% isopleths of the annual UD) for radio-tagged fishers that were alive during the annual capture session that fell outside of the livetrapped area as defined above. This resulted in small areas outside the livetrapped area (6% to 8% of the total area) being included in the effective area that, although unlikely, may have included portions of the home ranges of untagged resident animals.

RESULTS

We had 281 different live trap sets operational for 9724 trap-nights (1 trap operational for one 24-h period) over the 4 annual capture sessions (Table 1). On average, sites were active for 42 trap-nights during 1996–97 (range: 3 to 98, n = 77), 28 trap-nights during 1997–98 (range: 1 to 75, n = 110), 21 trap-nights during 1998–99 (range: 4 to 45, n = 101), and 17 trap-nights during 1999–2000 (range: 2 to 37, n = 79). Most trap sites were operational for ≥16 d during each capture session (Fig. 2). We sampled a larger area in the early stages of the project and focused sampling efforts in later years (Table 1, Fig. 3). Trap-night density was higher in the first 2 capture sessions (2.87 and 2.84 trap-nights/km^2, respectively) than in the 1998–99

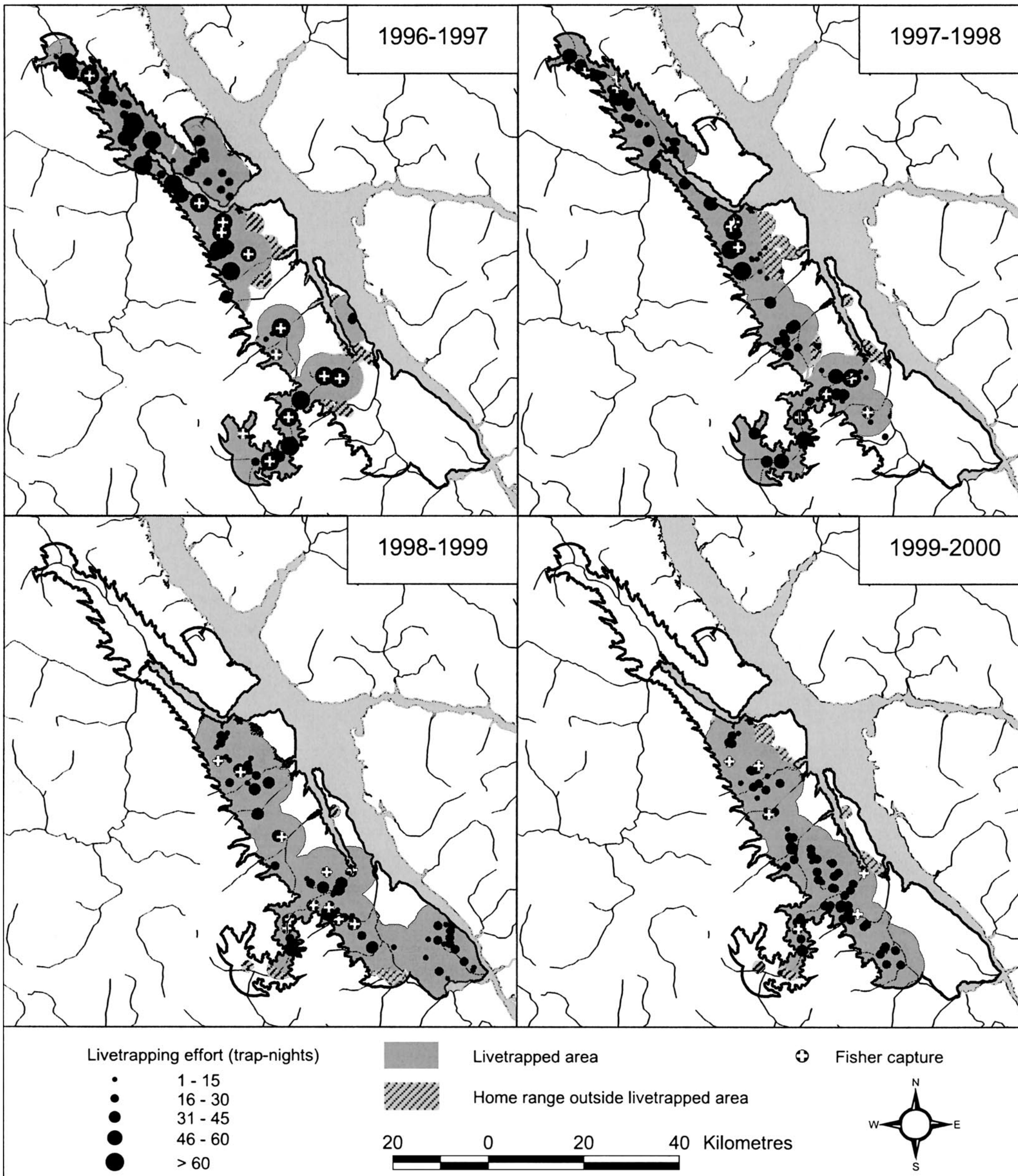

FIGURE 3. Spatial distribution of live-trapping effort and effective area sampled for fishers during each of 4 capture sessions conducted in north-central British Columbia, 1996–2000. Grey shading represents portions of the effective area that were livetrapped; cross-hatched shading were portions of home ranges of resident fishers that occurred outside of the livetrapped areas.

and 1999–2000 sessions (2.07 and 1.54 trap-nights/km^2, respectively).

We captured 21 fishers (15 F, 6 M) during the 4 annual capture sessions. At first capture, 7 were adults, 8 were subadults, and 6 were juveniles. Additionally, 1 untagged adult male fisher was kill-trapped by a trapper within our sampling area during the 1996–97 capture session.

We assumed that we either captured or had previously tagged all of the fishers within our sampled areas by the end of each capture session. Many areas that we livetrapped appeared to be unoccupied by fishers. Conversely, small portions of several fisher home ranges occurred outside of the livetrapped area. In only one instance after the 1st capture session did we capture a previously untagged adult fisher (3-y-old male) in the study area. Data from 2 other males that we radiotagged suggested that subadult males were transient until at least 2 y of age. Thus, we assumed that this male was present in the sampled area during the 1998–99 capture session (that is, as an adult), but not prior to this.

The average ($\pm$ s) density for the 4 y of sampling was 11.2 $\pm$ 2.1 fishers/1000 km^2 on 31 October and 8.8 $\pm$ 1.1 fishers/1000 km^2 on 31 March (Table 1). The estimated density varied among years, ranging from 7.9 to 13.1 fishers/1000 km^2.

Discussion

Although our estimates were greater than the only other reported density estimate for British Columbia (4.8 fishers/1000 km^2; Quick 1953), the density of fishers in our study area was still substantially lower than that reported from elsewhere within the species' range. By comparison, populations from eastern North America were 6 to 49 times denser than our study area (Douglas and Strickland 1987; Powell and Zielinski 1994; Garant and Crête 1997; Fuller and others 2001). In fact, the densities that we calculated were among the lowest that we encountered in the literature.

For species that have intrasexually exclusive home ranges and polygamous males, such as fishers (Powell 1994), density will largely be dependent upon the home range sizes of each sex and the distances among home ranges. The magnitude of both these variables is likely a function of the quality and spatial distribution of habitats. Given similar mortality parameters among areas, areas with homogeneous, high-quality habitat, which supplies all of an animal's life requisites in a small space, will generally have smaller, closer-spaced home ranges (Harestad and Bunnell 1979), and thus a higher density of individuals, than areas with patchy, high-quality habitat.

Indeed, the low density that we observed may be related to the home range size and spacing of individuals within our study area. Powell (1994) summarized the size of fisher home ranges from across North America and derived a mean home range size of 38 km^2 for males and 15 km^2 for females. In comparison, fishers in our study area and a site elsewhere in the SBS zone of central British Columbia had home ranges that averaged ($\pm$ s) 162 $\pm$ 105 km^2 for males (n = 3) and 38 $\pm$ 18.6 km^2 for females (n = 11) (Weir 1995; Peace/Williston Fish and Wildlife Compensation Program, unpubl. data). Consequently, based on home range size alone, we would expect that fishers in the SBS zone would occur at ½ to ⅓ of the density of other fisher populations. In addition, our livetrapping and radio-telemetry data indicated that not all of the sampled area was inhabited by fishers (Peace/Williston Fish and Wildlife Compensation Program, unpubl. data), likely causing greater disparity with other fisher populations where the habitat is more spatially uniform and of higher quality (Arthur and others 1989; Garant and Crête 1997; Fuller and others 2001).

Fisher densities fluctuate temporally, sometimes in excess of an order of magnitude (Powell 1994), as populations respond to various factors. Changes in prey abundance and vulnerability, such as that caused by the 10-y snowshoe hare (*Lepus americanus*) cycle, can have a dramatic effect on fisher populations (Powell 1993; Powell and Zielinski 1994), although Bulmer (1974) did not detect significant cycling of fisher populations in British Columbia. Kill-trapping for fur harvest can also affect the local density and spatial organization of fisher populations (Arthur and others 1989) because harvest pressure is usually spatially and temporally uneven (Powell and Zielinski 1994). Although fur harvesting affected the density of fishers in our study area (5 of the 22 fishers that were detected in our sampled area were later killed by trappers) and this was included in our density estimates, we do not feel that it overtly affected our estimate compared to other trapped populations that did not account for losses due to kill-trapped animals. Our data indicated that density varied during our 4-y monitoring period, but the confounding factors of different sampling areas, fur harvest, unknown prey abundance, and low sample size limited what we could conclude about these differences.

Enumeration indices that rely on capturing individuals, such as our MNA technique, produce an underestimate of the population or density (Jolly and Dickson 1983; Tuyttens 2000; McKelvey and Pearson 2001). An alternative to the enumeration approach is to use estimators that involve marking captured individuals and evaluating proportions of marked to unmarked individuals in subsequent sampling (mark-recapture; Krebs 1989:15). Mark-recapture estimates have been shown to have low bias and relatively high precision in their estimates of population size and are often preferred to enumeration techniques (Jolly and Dickson 1983; Tuyttens 2000). However, mark-recapture estimators were not appropriate for our data because 2 assumptions required for these methods were violated: not every individual had the same probability of being caught and it was unlikely that marked individuals in our population had the same probability of survival among sampling periods.

We chose to use MNA enumeration methods to estimate population size in our study area for 2 additional reasons. In their review of population estimators, McKelvey and Pearson (2001) suggested that, for populations of <50 individuals, the number of unique individuals captured (that is, MNA) was the population measure with the lowest variance and sensitivity to sources of variation. Also, they found that the MNA performed better than estimators, such as mark-recapture methods, when population attributes (for example, capture probabilities that vary across time, individuals and capture history) were unknown and the variation in capture probabilities was very different from null expectations. In light of these factors, we chose the known negatively biased MNA technique to best estimate our population size.

Several aspects of our sampling regime likely minimized the negative bias of our population and density estimate. Adult male and juvenile fishers are reported to be the most susceptible segments of the population to capture, whereas adult female fishers are believed to be the most difficult to catch (Douglas and Strickland 1987; Powell 1994). Therefore in a biased sample, one would expect juveniles and adult males to dominate captures, and adult females to be much less common. However, 46% of our captures (29 of 63) were of adult females, whereas we captured adult males 11 times and juveniles 7 times during the term of the project. Animals that are in poor body condition may also be more susceptible to capture because they would likely be more desperate for food (trap bait) than healthy animals. Although we had no quantitative measure of health (for example, fat levels), all adult fishers that we caught appeared to be in good physical health based on external and, where possible, internal examination (M McAdie, DVM, and R Weir; pers. obs.). Thus, the intensive effort expended to capture fishers in the study area, the relatively high frequency with which we caught adult females relative to other age-sex classes, the apparent good health of fishers and, as well, the anecdotal observation that fisher tracks were not observed during the winter period in any area that did not have a captured animal, suggests that the negative bias in our estimate was likely minimal.

Although the MNA estimate may have been slightly negatively biased, the area effectively sampled was also, if anything, negatively biased. This is because our estimate of the area that an individual trap was assumed to sample was based on the 75% UD of the smallest winter home range for our adult females. We occasionally caught radiotagged fishers at traps outside of their winter 75% UD, which suggests that the effective area sampled by each trap may have been larger than the 4.89-km buffer that we used. Consequently, the negative bias of the sampled area may have somewhat ameliorated the MNA bias.

Minimum number alive estimates, even though they are negatively biased to some extent and require an intensive capture effort to get reasonably accurate population indices, are likely the most appropriate method to census the small population of fishers in our study area. Lower-intensity capture methods, such as non-invasive molecular tagging (Mowat and Paetkau 2002), may be a more cost-effective way of estimating population size and density of fishers in north-central British Columbia.

Although our study area has undergone intensive forest harvesting since 1972, we believe it is representative of the current state of the SBS zone because of similarities in forest harvesting and fur-trapping pressure among areas. Because the SBS zone is typically comprised of productive conifer-dominated forests located on rolling terrain at lower elevations of British Columbia's interior region (Meidinger and Pojar 1991), this area is a large and integral component of the forest-harvesting landbase and has among the most suitable habitat for fishers in the province (Weir 2003). Thus, our density estimate should be representative of similar landscapes elsewhere in the SBS zone.

Until new data demonstrates otherwise, wildlife managers in British Columbia can use the density of between 7.9 and 13.1 fishers/1000 km^2 to help them manage populations of fishers in the SBS zone and possibly elsewhere in the province. Specifically, wildlife managers and trappers may use these data to estimate sustainable harvest rates on traplines of interest within the SBS. This density estimate may also be applied to habitat suitability data to estimate population sizes in other areas of British Columbia. Further studies are required to expand on our results and describe fisher population demographics in other biogeoclimatic zones in British Columbia and other western landscapes. Information is also needed on the relationships among densities, population dynamics, habitat, and prey to help guide the management and conservation of fisher populations in the dynamic and industrialized forest landscapes of British Columbia.

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LITERATURE CITED

ARTHUR SM, KROHN WB, GILBERT JR. 1989. Home range characteristics of adult fishers. Journal of Wildlife Management 53:674–679.

BANCI V. 1987. Ecology and behaviour of wolverine in Yukon [thesis]. Burnaby, BC: Simon Fraser University. 178 p.

BANCI V. 1989. A fisher management strategy for British Columbia. Victoria, BC: British Columbia Ministry of Environment, Wildlife Branch. Wildlife Bulletin B-63. 117 p.

[BCMF] BRITISH COLUMBIA MINISTRY OF FORESTS. 2004. Biogeoclimatic zones of British Columbia [map]. Victoria, BC: Province of British Columbia.

BULMER MG. 1974. A statistical analysis of the 10-year cycle in Canada. Journal of Animal Ecology 43:701–718.

COPELAND JP, CESAR E, PEEK JM, HARRIS CE, LONG CD, HUNTER DL. 1995. A live trap for wolverine and other forest carnivores. Wildlife Society Bulletin 23:535–538.

DE VOS A. 1952. Ecology and management of fisher and marten in Ontario. Toronto, ON: Ontario Department of Lands and Forests. Technical Bulletin, Wildlife Service Number 1. 90 p.

DOUGLAS CW, STRICKLAND MA. 1987. Fisher. In: Novak M, Baker JA, Obbard ME, Malloch B, editors. Wild furbearer management and conservation in North America. North Bay, ON: Ontario Trappers Association. p 511–529.

FULLER TK, YORK EC, POWELL SM, DECKER TA, DEGRAAF RM. 2001. An evaluation of territory mapping to estimate fisher density. Canadian Journal of Zoology 79:1691–1696.

GARANT Y, CRÊTE M. 1997. Fisher, *Martes pennanti*, home range characteristics in a high density untrapped population in southern Québec. Canadian Field-Naturalist 111:359–364.

HARESTAD AS, BUNNELL FL. 1979. Home range and body weight—a reevaluation. Ecology 80:389–402.

JOLLY GM, DICKSON JM. 1983. The problem of unequal catchability in mark-recapture estimation of small mammal populations. Canadian Journal of Zoology 61: 922–927.

JONES JL. 1991. Habitat use of fisher in north-central Idaho [thesis]. Moscow, ID: University of Idaho. 147 p.

KELLY GM. 1977. Fisher (*Martes pennanti*) biology in the White Mountain National Forest and adjacent areas [dissertation]. Amherst, MA: University of Massachusetts. 178 p.

KREBS CJ. 1966. Demographic changes in fluctuating populations of *Microtus californicus.* Ecological Monographs 36: 239–273.

KREBS CJ. 1989. Ecological methodology. New York, NY: Harper & Row. 654 p.

MACKINNON A, DELONG C, MEIDINGER D. 1990. A field guide for identification and interpretation of ecosystems of the northwest portion of the Prince George Forest Region. Victoria, British Columbia, Canada: British Columbia Ministry of Forests. Land Management Handbook Number 21. 116 p.

MCKELVEY KS, PEARSON DE. 2001. Population estimation with sparse data: the role of estimators versus indices revisited. Canadian Journal of Zoology 79:1754–1765.

MEIDINGER D, POJAR J. 1991. Ecosystems of British Columbia. Victoria, BC. British Columbia Ministry of Forests. Special Report Series 6. 330 p.

MOWAT G, PAETKAU D. 2002. Estimating marten *Martes americana* populations using hair capture and genetic tagging. Wildlife Biology 8:201–209.

POWELL RA. 1993. The fisher: life history, ecology, and behavior. 2nd ed. Minneapolis, MN: University of Minnesota Press. 237 p.

POWELL RA. 1994. Structure and spacing of *Martes* populations. In: Buskirk SW, Harestad AS, Raphael MG, Powell RA, editors. Martens, sables, and fishers: biology and conservation. Ithaca, NY: Cornell University Press. p 101–121.

POWELL RA, ZIELINSKI WJ. 1994. Fisher. In: Ruggiero LF, Aubry KB, Buskirk SW, Lyon LJ, Zielinski WJ, Technical editors. The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the western United States. Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. p 38–72.

PROULX G, AUBRY KB, BIRKS JDS, BUSKIRK SW, FORTIN C, FROST HC, KROHN WB, MAYO L, MONAKOV V, PAYER DC, SANTOS-REIS M, WEIR RD, ZIELINSKI WJ. 2004. World distribution and status of the genus *Martes.* In: Harrison DJ, Fuller AK, Proulx G, editors. Martens and fisher (*Martes*) in human-altered environments: an international perspective. Norwell, MA: Kluwer Academic Publishers. p 21–78.

QUICK HF. 1953. Wolverine, fisher, and marten studies in a wilderness region. In: Transactions of the Eighteenth North American Wildlife Conference. p 513–533.

STRICKLAND MA, DOUGLAS CW, BROWN MK, PARSONS GR. 1982. Determining the age of fisher from cementum annuli of the teeth. New York Fish and Game Journal 29:90–94.

TUYTTENS FAM. 2000. The closed-subpopulation method and estimation of population size from mark–recapture and ancillary data. Canadian Journal of Zoology 78: 320–326.

WEIR RD. 1995. Diet, spatial organization, and habitat relationships of fishers in south-central British Columbia [thesis]. Burnaby, BC: Simon Fraser University. 135 p.

WEIR RD. 2003. Status of the fisher in British Columbia. Victoria, BC: Ministry of Sustainable Resource Management, Conservation Data Centre, and Ministry of Water, Land and Air Protection, Biodiversity Branch. Wildlife Bulletin Number B-105. 47 p.

WEIR RD, HARESTAD AS. 2003. Scale-dependent habitat selectivity by fishers in south-central British Columbia. Journal of Wildlife Management 67: 73–82.

ZIELINSKI WJ, KUCERA TE. 1995. American marten, fisher, lynx, and wolverine: Survey methods for their detection. Albany, CA: US Department of Agriculture, Forest Service, Pacific Southwest Research Station. General Technical Report PSW-GTR-157. 163 p.

ZIELINSKI WJ, STAUFFER HB. 1996. Monitoring *Martes* populations in California: survey design and power analysis. Ecological Applications 6:1254–1267.

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