

Home Range and Population Density of Fishers in Eastern Ontario

ERIN L. KOEN, *Ottawa Carleton Institute of Biology, University of Ottawa, 30 Marie-Curie Street, Ottawa, ON K1N 6N5, Canada*

JEFF BOWMAN, *Wildlife Research and Development Section, Ontario Ministry of Natural Resources, Trent University DNA Building, 2140 East Bank Drive, Peterborough, ON K9J 7B8, Canada*

C. SCOTT FINDLAY,¹ *Institute of the Environment, 555 King Edward Street, Ottawa, ON K1N 6N5, Canada, and Ottawa-Carleton Institute of Biology, University of Ottawa, 30 Marie-Curie Street, Ottawa, ON K1N 6N5, Canada*

LIGANG ZHENG, *Natural Resources Canada, CANMET Energy Technological Center, 1 Haanel Drive, Ottawa, ON K1A 1M1, Canada*

ABSTRACT Fishers (*Martes pennanti*) were almost extirpated in Ontario, Canada, south of the French and Mattawa rivers by the 1940s but have recolonized much of their former range over the past several decades. We assessed the effect of the current harvest quota on a fisher population in eastern Ontario by estimating home range size and population density from a sample of radiocollared animals. Mean (\pm SD) adult home ranges (based on annual 95% min. convex polygons) were consistently smaller than those reported in the literature (M: 11 ± 4.4 km²; F: 2.1 ± 0.8 km²), with up to 71% overlap of adjacent intrasexual home ranges. This yielded an estimated adult fisher population density of 32.7/100 km² of suitable habitat, as defined by the habitat composition within observed home ranges. We further estimated that between 2003 and 2005, trappers harvested 17.8–42.3% of the pretrapping population. These results suggest that although current fisher population density is high in our study area compared to reported densities in other areas, harvest rate is also high and an increase in quota is unwarranted. (JOURNAL OF WILDLIFE MANAGEMENT 71(5):1484–1493; 2007)

DOI: 10.2193/2006-133

KEY WORDS fisher, home range, *Martes pennanti*, Ontario, population density, radiotelemetry error, trapping.

Fisher (*Martes pennanti*) populations in North America have fluctuated dramatically since the 1800s (Obbard et al. 1987), likely in response to changes in harvest intensity and the abundance of suitable habitat (Powell 1993a). By 1944, there were few fishers south of the French and Mattawa rivers in Ontario, Canada (Rand 1944, Hagmeier 1956). Since then, abandoned farmland has reverted to second growth forests, increasing the abundance of suitable fisher habitat (Powell 1993a; P. A. Lancaster, J. Bowman, and B. A. Pond, Ontario Ministry of Natural Resources [OMNR], unpublished data). Coincidentally, Ontario has seen an increase in fisher population density and the recolonization of much of its former range (de Vos 1964, Gibilisco 1994). Currently, fishers are distributed throughout most of Ontario (Gibilisco 1994, Thompson 2000), although systematic estimates of local and regional population densities in Ontario are lacking.

Currently in eastern Ontario, fur managers set fisher quotas at one fisher per trapper plus one fisher per 1.62 km² of trapline. Strickland and Douglas (1981) found that, in the Algonquin region of Ontario, ratios of >4 juveniles per adult female fisher in the harvest have coincided with an increasing population and ratios of <4 juveniles per adult female fisher in the harvest have coincided with a decreasing population. Managers in Ontario estimate this ratio annually for local fisher populations from the canine tooth extracted from the skulls of harvested fishers that are voluntarily submitted by trappers. Quotas are then adjusted based on these results. The extent to which these data reflect fisher population characteristics in eastern Ontario is unknown.

The recolonization and apparent population increase of fishers in eastern Ontario has prompted calls from fur

harvesters for an increase in fisher quotas. However, the historical decline of fisher populations, presumably in part due to overharvesting, has led the OMNR to adopt a precautionary policy such that quotas will not be increased unless there is substantial evidence that local populations can support increased harvesting mortality. To assess the adequacy of the existing fisher quota management system, we assessed the effect of the current fur harvest on fisher populations in eastern Ontario by estimating the proportion of the pretrapping population harvested and evaluating whether the current harvest is indeed sustainable.

STUDY AREA

Our study area included the townships of Edwardsburgh, Augusta, and North Grenville (approx. 44°50'N, 75°30'W) in Leeds and Grenville County, Ontario, Canada; a 975-km² area with an average human population density of 17/km² in 2001 (Statistics Canada 2001). The landscape was a mixture of field and agriculture, swamp and wetland, and forest (Table 1), composed mainly of white cedar (*Thuja occidentalis*), larch (*Larix laricina*), sugar maple (*Acer saccharum*), and red maple (*A. rubrum*). Elevation ranged from 80 m to 130 m above sea level. Temperatures in 2003 and 2004 ranged from a January average of -14.5° C to an August average of 20.7° C; the mean annual temperature was 6.0° C. Our study area received a total of 851 mm and 772 mm of rain and 194 cm and 168 cm of snow in 2003 and 2004, respectively (Environment Canada 2005).

METHODS

Trapping and Radiocollaring Procedure

Between 15 January and 2 March 2003, 10 local fur trappers set 170 Tomahawk live traps (Tomahawk Live Trap Co.,

¹ E-mail: findlay@uottawa.ca

Table 1. The proportion of 4 land cover classes in our study area (894 km²) and Leeds and Grenville County (3,390 km²), Ontario, Canada, based on land cover data from the 1978 Forest Resource Inventory.^a

Land cover class	Study area	County
Field	0.44	0.52
Coniferous	0.22	0.12
Deciduous	0.20	0.26
Wetland	0.14	0.10

^a Land cover data are from 1978 Forest Resource Inventory mapping and the wetland layer is from the Natural Resource Values Information System, both from the Ontario Ministry of Natural Resources.

Tomahawk, WI, model 106 or 108) throughout our study area to trap fishers for our study, although not all traps were set for the entire period. Traps were checked every 24 hours and we paid trappers \$50 for each live-trapped fisher. Trappers used baits such as sardines, beaver, and muskrat based on availability. Additionally, the Rabies Research and Development Unit (RRDU) of the OMNR live-trapped fishers for our study between 3 June and mid-July 2003 during their trap–vaccinate–release program. Fishers trapped during this period were incidental catches as trappers were primarily targeting raccoons (*Procyon lotor*).

We weighed fishers in the live trap using a linear spring scale to the nearest 0.25 kg. We administered a 10:1 mixture of ketamine–xylazine intramuscularly at 20 mg/kg using a sterile, disposable syringe. To inject the drug, we first pinned the fisher to the bottom of the trap (Tomahawk 106) using a smaller trap (Tomahawk 105) to prevent the animal from moving. The drug took effect within 5 minutes. We reversed xylazine with 0.1 mg/kg yohimbine. We covered the trap containing the fisher as the fisher recovered from the drugs (approx. 2 hr). Once the fisher was fully conscious, we released it at the initial trap site.

We removed the upper, first premolar from live-trapped animals for aging by loosening it with a dental elevator to cut the gum away from the tooth and removing it with pliers (Strickland et al. 1982). Rabies Research and Development Unit personnel aged the fishers as juvenile (<1 yr old) or adult (≥1 yr old) using a combination of cementum annuli counts and pulp cavity size (Poole et al. 1994). When possible, they determined the exact age. We applied an antibiotic ointment (hibitane) to the tooth socket to prevent infection. We put one ear tag (1005-3 National Band and Tag Co., Newport, KY) in each ear.

We used radiocollars (SMRC-3, Lotek Wireless Inc., Newmarket, ON, Canada) in the 155-MHz frequency range with a pulse rate of 35 bpm, a mortality sensor at 70 bpm, and a minimum battery life of 18 months. The collars had a 28-cm adjustable leather belt with a protruding whip antenna and weighed 45–50 g each. Three radiocollars (MI-2, Holohil, Carp, ON, Canada) had enclosed whip-antennas and weighed 37 g. All collars weighed <5% of the body weight of an adult fisher. We received signals with the Communications Specialists R1000 (Communication Specialists Inc., Orange, CA), the Lotek Suretrack

STR_1000-W1, or the Lotek SRX_400 (Lotek Wireless Inc., Newmarket, ON, Canada).

We estimated most locations by triangulation from the ground with a handheld 2-element directional H-antenna (Telonics Inc., Mesa, AZ). The signal could often be heard as an arc (usually about 100°) rather than a point; we took the bearing at the midpoint of this arc, either by recording the direction of the loudest signal or by recording the signal null on either side of the arc and calculating the midpoint (Springer 1979). We took ≥3 bearings such that the angle between bearings was approximately 90–100° (Zimmerman and Powell 1995).

Fishers that we could not locate from the ground were located from a Cessna 172 airplane using 2 wing-mounted H-antennas. We flew transects across our study area that extended 20–40 km outside of our study area at an altitude of 750–950 m and at an altitude of 1,500 m along the perimeter of the transect grid to increase the coverage by the receiving system along the edge of the grid. Transects were 10 km wide because the receiving system picked up signals within 6 km in any direction from the airplane.

We usually located each animal at least once per week. We ensured that there was >16 hours between locations for individual fishers to reduce spatial autocorrelation, as recommended by Arthur et al. (1989). We used sampling intervals that maximized efficiency and ensured that we did not sample individuals at the same time of the day on consecutive days.

Fishers are primarily crepuscular (Arthur and Krohn 1991) but are also active during the day and night (Powell 1979, 1993a). On average, we took 7.8% (SD = 2.3, range = 5.5–14.0%) of the locations at night so as not to bias our home range estimates if space use is different at night (Beyer and Haufler 1994). We pooled day and night locations in the home range estimates because there were insufficient night data to assess differences between nocturnal and diurnal locations.

Triangulation Error

Stationary transmitters.—We used maximum likelihood estimation (MLE; Lenth 1981) to estimate locations from triangulation data with Location of a Signal (Ecological Software Solutions 3.0.2, Urnäsch, Switzerland) software. We estimated triangulation accuracy and precision using the location error method (LEM; Zimmerman and Powell 1995) by placing radiocollars in 35 locations throughout the study area and calculating the distance between estimated and true locations.

Moving transmitters.—Volunteers placed one radiocollar in the forest to imitate a resting fisher and walked through the forest carrying another collar to mimic a moving fisher. The volunteers walked along trails at an average speed of 0.6 (SD = 0.19) m/second for 20 minutes in fairly straight lines, through a variety of habitats that fishers were known to occupy. We estimated the triangulation error of moving collars as the distance between estimated and true transmitter locations, averaged over the set of all sequential bearings (Fig. 1).

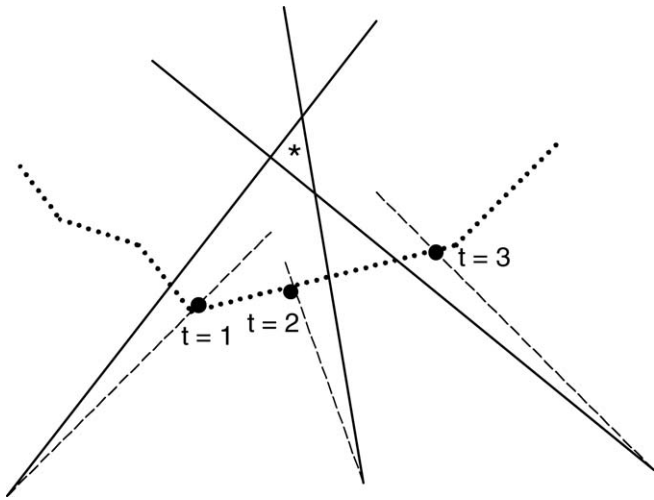


Figure 1. An example of how we estimated the location error of moving transmitters on fishers in Leeds and Grenville County, Ontario, Canada, 2003–2004, showing the actual path (dotted line) and actual transmitter (●) location at times $t = 1, 2,$ and 3 . The solid line is the estimated bearing at time $t = 1, 2,$ and 3 , and the dashed line is the true bearing to the transmitter at each time. The star is the estimated location based on the 3 observed bearings. Location error is the average distance between the star and the dot at $t = 1, 2,$ and 3 .

Home Range Estimation

We estimated home ranges using 3 methods: 100% minimum convex polygon (MCP), 95% MCP, and 95% fixed kernels (Worton 1989) with the bandwidth estimated using least squares cross validation (Silverman 1986). We calculated the 100% MCP and 95% kernel estimates using the Animal Movement Analysis ArcView extension version 2.04 (Hooge and Eichenlaub 2000) and we calculated the 95% MCPs using the Home Range Extension version 1.1 (Rodgers and Carr 1998), both in ArcView 3.2 Geographic Information System. For calculation of the 95% MCPs, we removed outlying locations farthest from the arithmetic mean of all locations and then recalculated the mean. We repeated this procedure until 5% of the locations were excluded (Kenward 1987). Although we present results for all 3 methods, as recommended by Harris et al. (1990), we use only 95% MCP home ranges for further analyses.

We estimated home ranges of fishers with ≥ 25 locations during one or both of 2 time intervals: annually (Mar 2003–Feb 2004 or Jun 2003–May 2004 for those fishers radiocollared in Jun 2003) and during the nonbreeding period (Jun 2003–Feb 2004). We used a Student's t test to compare mean 95% MCP home range size between the sexes. We ran separate tests for the annual and non-breeding periods because the samples were not independent; fishers that had an annual home range usually had a nonbreeding season home range, although the converse was not always true if the fisher died before the annual home range measure was complete.

Effect of triangulation error.—We considered variation in nonbreeding period home range size within individuals due to triangulation error in addition to variation among individuals. We randomly drew 100 locations from the 95% LEM confidence circles of each location from a normal

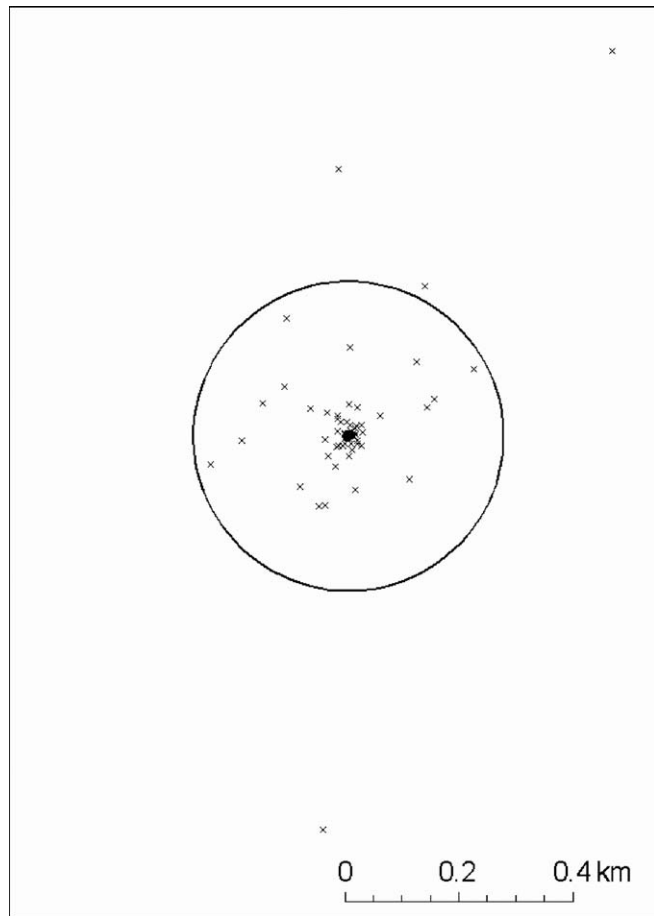


Figure 2. An example of 100 locations (x) sampled from a normal distribution centered on the estimated location (●) of a radiocollared fisher in Leeds and Grenville County, Ontario, Canada, 2003–2004, with variance estimated from the regression of location error on distance between the receiver and transmitter. We show the 95% location error method confidence circle with a radius of 272 m.

distribution centered on the estimated location (Fig. 2). We estimated the variance of this distribution from a regression of location error on the distance between the receiver and estimated transmitter location (d) by calculating the midpoint of the prediction interval for a given d and dividing by $t_{\alpha(2), (n-2)}$. Thus, 5% of the resampled locations fell outside of the confidence circle. We used batch home range processing in the Animal Movement Analysis ArcView extension (Hooge and Eichenlaub 2000) to create 100 home ranges (100% MCP and 95% kernel) per animal using one of the 100 locations selected from each 95% LEM confidence circle. This method is similar to that of Samuel and Kenow (1992), who sampled locations from 95% MLE confidence ellipses. We chose to use 95% LEM confidence circles (Zimmerman and Powell 1995) because we found that they contained the actual location 94% of the time, whereas 95% MLE confidence ellipses contained the actual location 88% of the time (Koen 2006). Other studies have also reported that 95% MLE confidence ellipses contained as few as 70% (Zimmerman and Powell 1995), 60% (Withey et al. 2001), and 41% (Garrott et al. 1986) of the actual locations.

To assess whether the difference between male and female home range size was still apparent when we considered the within-individual variation, we compared male and female home range size with a randomization test. First, we randomly drew a home range estimate from the set of 100 home ranges for each fisher, and then we calculated the difference in mean home range size between males and females. We repeated this 1,000 times and calculated the mean difference in mean home range size between the sexes. We then randomized the set of home range estimates over sex (i.e., we randomly assigned each home range estimate to a sex), recalculated the difference in the mean home range size between males and females, and repeated 1,000 times. Finally, we compared the mean of the former to the distribution of the latter.

Spacing Patterns

We defined intrasexual percent home range overlap for each individual, i , as the percentage of i 's home range shared by ≥ 1 other collared fisher of the same sex (Poole 1995). We estimated the average intrasexual percent overlap of entire home ranges (95% MCPs and 95% kernels) and core areas (50% MCPs and 50% kernels) during the period of time when we monitored both fishers. We omitted the breeding period (Feb–Apr) for male fishers due to potentially unstable home ranges during that time (Leonard 1986, Arthur et al. 1989). We only included fishers whose home ranges overlapped ≥ 1 other intrasexual home range; to include all home ranges would underestimate overlap because we did not know whether they overlapped with the home range of an uncollared fisher. We used nonparametric tests to compare the amount of home range overlap between males and females and between home ranges (95% MCP) and core areas (50% MCP). First, we compared differences in overlap of home ranges and core areas between the sexes with 2-sample Kolmogorov–Smirnov tests. Then, we pooled the data over sex and compared the amount of overlap between home ranges and core areas with a Wilcoxon signed-rank test.

Population Density

We estimated population density by territory mapping of radiotagged animals (Arthur et al. 1989, Garant and Crête 1997, Fuller et al. 2001). Fishers are typically intrasexually territorial (Arthur et al. 1989; Powell 1993a, 1994; Garant and Crête 1997; Fuller et al. 2001) with sex-specific, exclusionary home ranges being maintained. Home ranges of males will overlap those of females, with large male home ranges overlapping those of several females' (Arthur et al. 1989). We used estimated 95% MCP home ranges during the nonbreeding period to generate 2 maps of the set of home ranges of radiocollared individuals, one for each sex. Kernohan et al. (2001) recommended the use of noncontouring methods, such as MCPs, when the outer boundary of the home range is of interest, because contouring methods, such as kernels, tend to overestimate boundaries. Where suitable fisher habitat existed, we assumed an uncollared fisher of the same sex inhabited

Table 2. Proportions of land cover classes within 26 (10 M, 16 F) adult fisher home ranges (95% min. convex polygon; between Jun 2003 and Feb 2004) in eastern Ontario, Canada.^a

Land cover class	Min.	Max.	\bar{x}	SD
Coniferous	0.01	0.67	0.31	0.19
Deciduous	0.02	0.49	0.24	0.13
Wetland	0.00	0.82	0.19	0.24
Field	0.01	0.53	0.26	0.15

^a Land cover data are from 1978 Forest Resource Inventory mapping and the wetland layer is from the Natural Resource Values Information System, both from the Ontario Ministry of Natural Resources.

an unoccupied, circular area of average home range size (6.4 km² for M and 2.1 km² for F). We defined suitable habitat as an area composed of no less or no more than the minimum and maximum proportions, respectively, of each habitat type found within the home ranges of radiocollared fishers (Table 2). We allowed the assumed home ranges of uncollared fishers to overlap: 57% of the male and 25% of the female assumed home ranges overlapped ≥ 1 other intrasexual home range, and the area of overlap was always <16% and <10% of the home range for males and females, respectively. We used a 100% MCP around locations for all fishers included in the density estimate to define the boundary of our study area (894 km²).

RESULTS

In Ontario, it is mandatory for trappers to annually report their harvest to OMNR, who maintain a database (Fur Management Information System [FURMIS]) of all reported harvest. These data can be used to estimate the number of (reported) trapped fishers per unit area; the fisher harvest density in Leeds and Grenville County, calculated from FURMIS data, was 11.4 fishers, 11.7 fishers, and 13.1 fishers/100 km² in 2002–2003, 2003–2004, and 2004–2005, respectively.

We trapped and radiocollared 50 fishers between 15 January and 2 March 2003 and 7 fishers between 3 June and mid-July 2003. The sample was composed of 22 adult males, 19 adult females, 1 juvenile male, 14 juvenile females, and 1 female of unknown age. Juveniles trapped in January and February were adults by March of the same year, as fishers are usually born in March (Wright and Coulter 1967, Leonard 1986). We used only adult animals in home range size estimates. The average weight of radiocollared fishers at the time of capture was 4.8 kg (SD = 1.0 kg, range = 3.0–7.0 kg) for males and 2.5 kg (SD = 0.5 kg, range = 1.5–4.0 kg) for females.

Triangulation Error

We estimated the locations of the 35 stationary radiocollars placed in our study area by triangulation multiple times, for 66 estimated locations. The average d was 1,014 (SD = 446) m. There was a significant positive relationship between the location error (cube root transformed) and the average

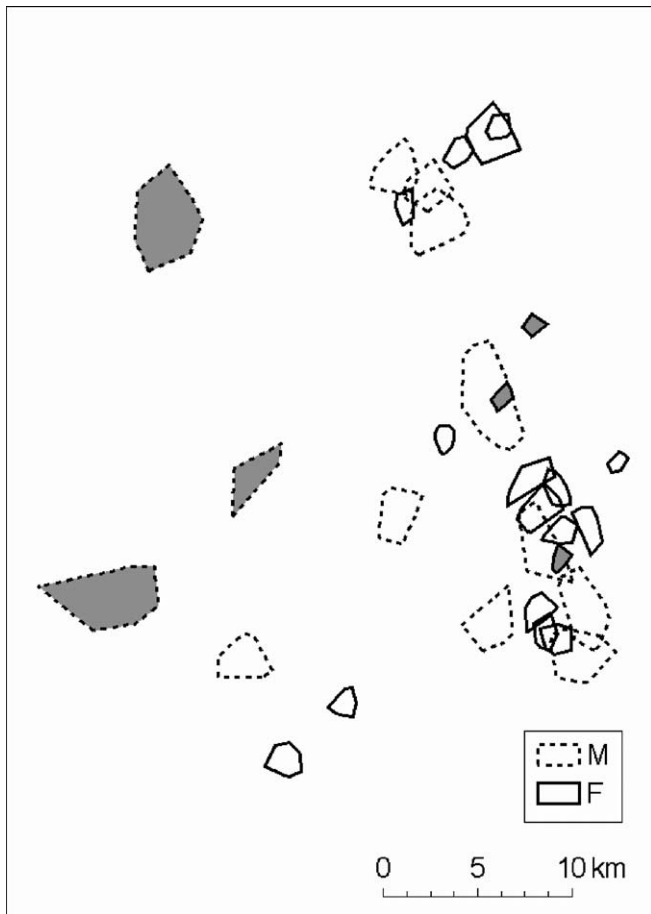


Figure 3. Home ranges (95% min. convex polygon) for 10 adult male and 16 adult female fishers during the nonbreeding period (Jun 2003–Feb 2004) in eastern Ontario, Canada. Shaded polygons are for 3 adult male and 3 adult female fishers with incomplete home ranges (based on 13–18 locations).

d ($t = 6.95$, $df = 64$, $P < 0.001$, $r^2 = 0.43$); the equation of the fitted model was

$$(\text{location error})^{1/3} = 3.360 + (0.002 \times d)$$

The mean location error was 234 (SD = 200) m and 95% of the estimated locations were <600 m from the actual location. The mean area of the 95% confidence ellipse for transmitter locations was 0.99 (SD = 1.46) km².

The mean location error for stationary and moving transmitters ($n = 19$) was 158 (SD = 169) m and 236 (SD = 150) m, and the mean distance between transmitter and receiver was 513 (SD = 359) m and 580 (SD = 317) m, respectively. The mean location error was 49% larger for mobile than for stationary transmitters ($t = -3.083$, $df = 18$, $P = 0.006$).

We estimated aerial telemetry error by comparing the linear distance between estimated and true locations; mean location error was 729 (SD = 422) m ($n = 7$), therefore we did not use any locations obtained from aerial telemetry when estimating home ranges.

Home Range Estimates

We estimated home ranges for 26 (10 M, 16 F) fishers (Fig. 3). Estimated 95% MCP home ranges (Table 3) of male

Table 3. Mean annual (Mar 2003–Feb 2004 or Jun 2003–May 2004) and nonbreeding period (Jun 2003–Feb 2004) home range size (km²) of adult fishers in eastern Ontario, Canada, and nonbreeding period home range size (km²) averaged over 1,000 trials of randomly drawing one home range from the set of 100 for each individual, as estimated using different methods (min. convex polygon [MCP] or kernel [K]).

Sex	<i>n</i>	100% MCP		95% MCP		95% K	
		\bar{x}	SD	\bar{x}	SD	\bar{x}	SD
M ^a	8	14	5.8	11	4.4	16	6.2
F ^a	15	3.6	1.7	2.1	0.8	3.6	1.3
M ^b	10	8.5	2.7	6.4	2.3	11	5.8
F ^b	16	3.0	1.1	2.1	1.1	3.3	1.2
M ^c	10	9.2	2.8			12	5.6
F ^c	16	3.4	1.3			3.7	1.3

^a Annual home range.

^b Nonbreeding period home range.

^c Home ranges are based on random locations selected from error circles around each observed location. We simulated 100 home ranges/individual fisher, randomly selected 1 home range/fisher, calculated the \bar{x} size across individuals, and repeated 1,000 times. We have reported the \bar{x} size and SD across 1,000 trials.

fishers were 424% and 205% larger than that of females for annual ($t = -6.03$, $df = 7$, $P < 0.001$) and nonbreeding period ($t = -5.38$, $df = 12$, $P < 0.001$) home ranges, respectively.

Effects of triangulation error.—When we considered the variation in nonbreeding period 100% MCP home range size both among individuals and within individuals (due to triangulation error), male home ranges were 170% larger than females' home ranges ($P < 0.001$; Table 3).

Home range shifts.—During our study, 2 adult female fishers shifted their home ranges (Fig. 4a, b), and 2 adult male fishers moved outside of their established home ranges following the breeding season of 2004 (Fig. 4c, d). Other male fishers either showed no breeding season movements (1 M) or there were insufficient data during this period to discern these movements (2 M).

Spacing Patterns

Six of the 13 male (2 groups of 3 M) and 9 of the 19 female (3 groups of 3 F) home ranges overlapped ≥ 1 other intrasexual home range (Table 4). There was no significant difference between males and females in 95% MCP home range overlap ($P = 0.217$) or 50% MCP core area overlap ($P = 0.778$). Overlap of 95% MCP home ranges was 287% greater than overlap of 50% MCP core areas ($P = 0.026$).

Population Density

The estimated population density of resident, adult fishers in the 894-km² area, as determined by territory mapping assuming suitable habitat saturation, was 32.7/100 km² (M: 8.8/100 km², 79 individuals; F: 23.8/100 km², 213 individuals; Figs. 5 and 6). We confirmed the presence of fishers in parts of our study area not occupied by radiocollared fishers by plotting locations for an additional 9 male and 13 female radiocollared fishers that we did not use in the density estimates due to an insufficient number of telemetry locations (Figs. 5 and 6).

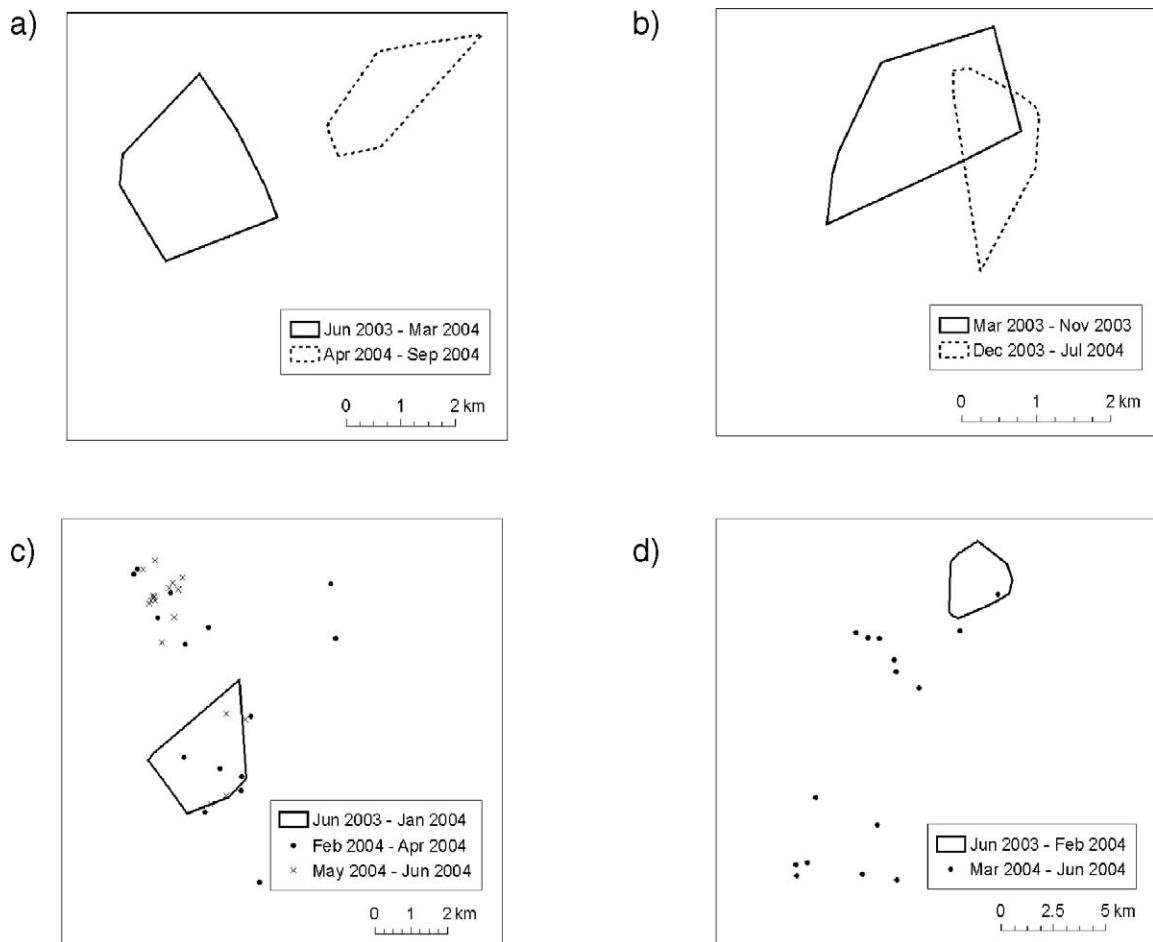


Figure 4. Home range shifts (95% min. convex polygon) for 2 adult female fishers (a and b) and breeding season movements of 2 adult male fishers (c and d) in eastern Ontario, Canada, in 2003 and 2004. Note the difference in spatial scales.

Trapping Mortality

We obtained an estimate of the proportion of fishers trapped in Leeds and Grenville County during the 2003–2004 and 2004–2005 trapping seasons by combining the FURMIS harvest records with population density estimates based on territory mapping. Assuming that the habitat composition of our study area was a representative sample of the county (Table 1), and, thus, the resident adult fisher population density (32.7/100 km²) estimated for our 894-km² study area was representative of all of Leeds and Grenville County (3,390 km²), we estimated approximately 1,108 resident adult fishers in Leeds and Grenville County

Table 4. Average intrasexual percentage of overlap of fisher home ranges and core areas (min. convex polygon [MCP] and kernel [K]) in eastern Ontario, Canada, in 2003 and 2004.^a

Sex	95% MCP		50% MCP		95% K		50% K	
	\bar{x}	SD	\bar{x}	SD	\bar{x}	SD	\bar{x}	SD
M	14.5	10.7	10.4	16.1	35.7	20.9	10.9	17.5
F	32.8	29.3	4.04	5.78	46.2	23.8	2.49	3.81

^a Six of 13 M (2 groups of 3 M) and 9 of 19 F (3 groups of 3 F) home ranges overlapped for 6–16 months. We included only those home ranges that overlap ≥ 1 other home range.

in 2003 and 2004. We revised this estimate to reflect varying levels (60% and 80%) of suitable habitat saturation by fishers, yielding a range of estimates of the number of fishers in Leeds and Grenville County (665 and 886 resident ad fishers at each respective level).

As the preharvest population contains both resident adult and transient juvenile fishers, we adjusted our estimates of the preharvest population size to account for these transient juvenile fishers (Arthur et al. 1989). Paragi et al. (1994) estimated that in Maine, fisher recruitment (no. of fisher kits/ad F that survive from birth until the trapping season, corrected for the estimated denning rate) was between 0.8 and 1.4. Assuming that this also applies to eastern Ontario, in addition to the 1,108 resident animals, there were also between 646 and 1,131 transient juvenile fishers in the preharvest population. If fishers occupied as little as 60% of the suitable habitat, then we estimate the number of transient juveniles in the population to range from 388 to 679.

Based on the FURMIS records, 398 fishers (ad and juv) were harvested in Leeds and Grenville County during the 2003–2004 trapping season. Therefore, between 17.8% and 37.8% of the fishers in the pretrapping population (depending on assumptions of suitable habitat saturation by fishers)

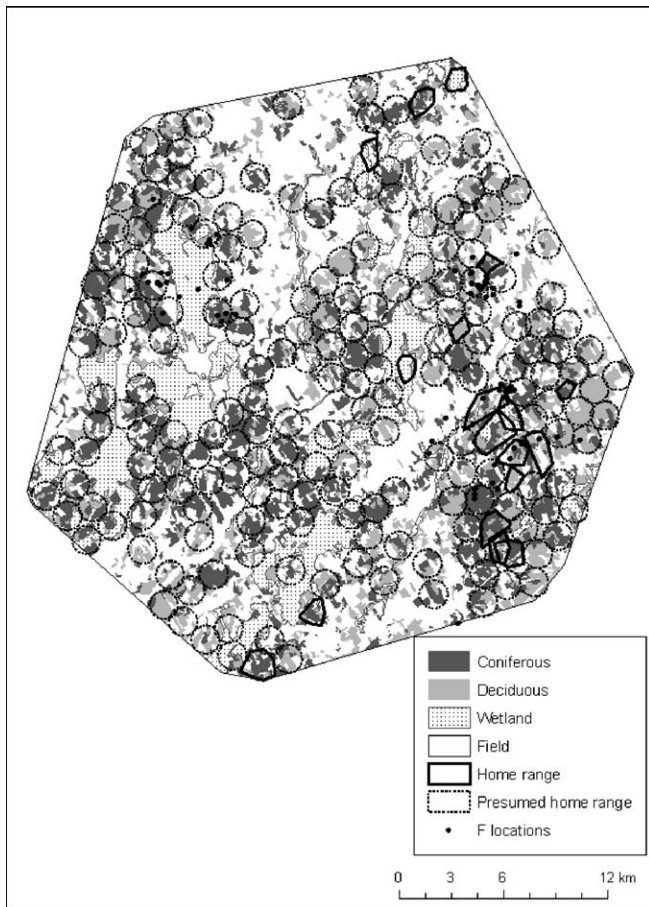


Figure 5. Adult female fisher population density estimate during the nonbreeding period (Jun 2003–Feb 2004) in our study area in eastern Ontario, Canada. We estimated home ranges of collared females using 95% minimum convex polygons and we based presumed home ranges of uncollared fishers on the estimated average home range size for collared females during this time. Female locations are from individuals for whom we did not have sufficient data to estimate home range. Land cover data are from 1978 Forest Resource Inventory mapping and the wetland layer is from the Natural Resource Values Information System, both from the Ontario Ministry of Natural Resources.

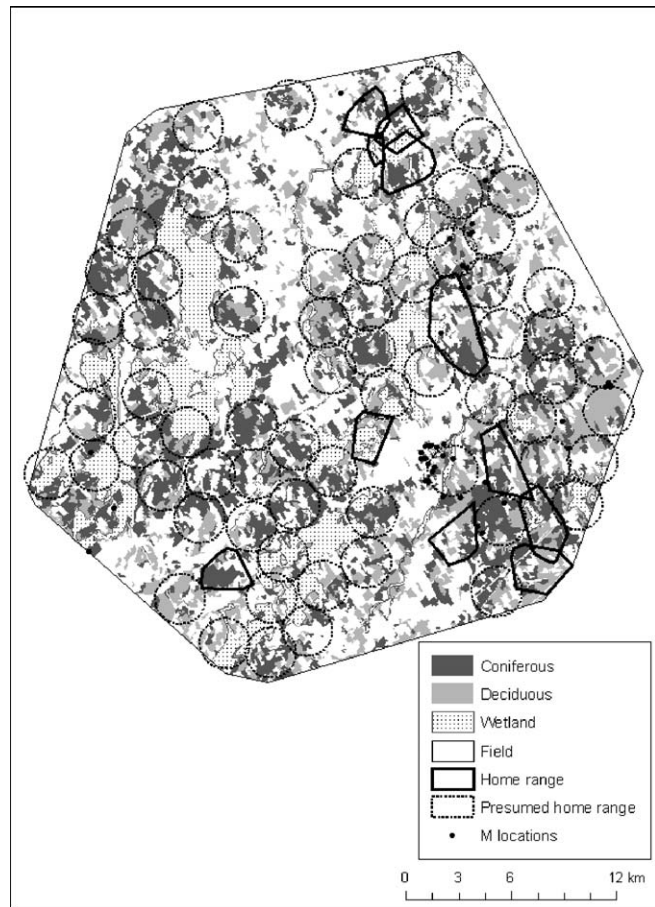


Figure 6. Adult male fisher population density estimate during the nonbreeding period (Jun 2003–Feb 2004) in our study area in eastern Ontario, Canada. We estimated home ranges of collared males using 95% minimum convex polygons and we based presumed home ranges of uncollared fishers on the estimated average home range size for collared males during this time. Male locations are from individuals for whom we did not have sufficient data to estimate home range. Land cover data are from 1978 Forest Resource Inventory mapping and the wetland layer is from the Natural Resource Values Information System, both from the Ontario Ministry of Natural Resources.

were harvested in the 2003–2004 trapping season in Leeds and Grenville County (Table 5). In the 2004–2005 trapping season, 445 fishers were harvested, resulting in a harvest of between 19.9% and 42.3% of the pretrapping population (Table 5).

DISCUSSION

Home Range Estimates

Average male home ranges were larger than females' and the inclusion of intra-individual variability in home range size due to triangulation error did not affect this conclusion. We found that fisher home ranges in our study (Table 3) were smaller than those reported in the literature: Tully (2006) reported mean annual 95% MCP home ranges of 38.7 (SE = 0.6) km² and 29.9 (SE = 15.6) km² for male and female fishers, respectively, in Algonquin Park, Ontario; Fuller et al. (2001) reported mean annual 95% MCP home ranges of 10.0 (range = 6.5–16.6) km² and 7.6 (range = 2.9–11.1) km² for male and female fishers, respectively, in Massachusetts;

Arthur et al. (1989) found that mean 100% MCP home ranges measured from May to December were 31 (SE = 9.3) km² and 16 (SE = 4.7) km² for male and female fishers, respectively, in Maine. One study reported similar home range estimates to our study: Garant and Crête (1997) presented mean 100% MCP home ranges of 9.2 (SE = 1.8) km² and 5.4 (SE = 0.9) km² for male and female fishers, respectively, in Gatineau Park, Quebec.

Spacing Patterns

We found as much as 71% overlap of intrasexual fisher home ranges (95% MCP), and up to 32% overlap of intrasexual core areas (50% MCP). Our results indicate that although home ranges of adjacent fishers of the same sex may overlap, fishers share a significantly smaller percentage of their core areas. Our results contrast with previous work on fishers that reported minimal (Arthur et al. 1989, Fuller et al. 2001) or no (Garant and Crête 1997) overlap of intrasexual home ranges. Powell's (1993a, 1994) modeling of territoriality predicts that carnivores in general (Powell

Table 5. Estimates of the number of fishers in the pretrapping population and the percentage of the pretrapping fisher population harvested in Leeds and Grenville County, Ontario, Canada, at varying estimates of habitat saturation.^a

% saturation ^b	<i>N</i> ^c	% harvested 2003–2004	% harvested 2004–2005
60	1,052–1,343	29.6–37.8	33.1–42.3
80	1,403–1,791	22.2–28.4	24.8–31.7
100	1,754–2,239	17.8–22.7	19.9–25.4

^a During the trapping seasons of 2003–2004 and 2004–2005, 398 and 445 fishers, respectively, were harvested in Leeds and Grenville County. We based total no. harvested on Fur Management Information System data.

^b % of suitable habitat saturated by fishers.

^c We based *N* (ad and juv) for Leeds and Grenville County on estimates from territory mapping. We calculated the number of juveniles by multiplying the no. of ad F by the range of probable recruitment values (0.8–1.4; Paragi et al. 1994).

1993*b*) and fishers specifically (Powell 1993*a*, 1994), should vary their spacing based on prey population density and vulnerability. When prey densities are very low, fishers are expected to be transient. As prey population densities increase, fishers should permit a gradient of overlap of home range, such that at low prey density fishers will maintain exclusive territories, at medium prey density they will defend intrasexual territories, and at high prey density fishers should permit extensive home range overlap (Powell 1993*a*, 1994). If fisher spacing depends on food availability, as hypothesized by Powell, then the relatively small home ranges and large intrasexual home range overlap in our study might be explained, in part, by high prey population densities in the study area.

Population Density

Adult fisher population densities in the study area are higher than those reported in other areas: estimates range from 12/100 km² in Maine (Arthur et al. 1989) to 19–25/100 km² in Massachusetts (Fuller et al. 2001). Population densities we reported are comparable to those in Gatineau Park, Quebec (27–30/100 km²), <100 km north of our study area (Garant and Crête 1997). However, DNA microsatellite analysis has shown that these 2 populations are distinct (Carr et al. 2007).

Fuller et al. (2001) and Garant and Crête (1997) found that territory mapping gave similar population density estimates as camera mark–resight and track counting techniques, respectively. We marked roughly 10% of the population (9% of F, 15% of M), which is much lower than that recommended by Fuller et al. (2001). Thus, we presented a range of population estimates based on varying levels of habitat saturation by fishers to address the possibility that some areas with suitable habitat may not be occupied by uncollared fishers.

Trapping Mortality

The issue of the sustainability of the current harvest revolves around the balance between recruitment and survival, and, in particular, the contribution of harvesting mortality to

total mortality. Douglas and Strickland (1987) and Paragi et al. (1994) estimated that harvesting >25% of the preharvest population resulted in a population decline the following year in Ontario and Maine, respectively. Similarly, Douglas and Strickland (1987) summarized unpublished data from Minnesota and concluded that harvests of 15–20% of the pretrapping fisher population resulted in a stable population, whereas harvests of >20% resulted in population decline. Even when considering the best-case scenario, which assumes the upper limit of possible recruitment and that 100% of the suitable habitat within the county was saturated by fishers, the harvest (17.8% and 19.9% of the pretrapping population in 2003–2004 and 2004–2005, respectively) was close to the threshold for decline in Douglas and Strickland (1987) and Paragi et al. (1994). This estimated threshold for population decline need not apply to Leeds and Grenville County; it will depend on both recruitment and nonharvest-related mortality. We know that the proportion of nonharvest-related deaths in Leeds and Grenville County is high (Koen et al. 2007) relative to estimated proportions in Maine (Krohn et al. 1994). This implies that unless recruitment in Leeds and Grenville County is substantially higher than in Maine (we have estimates of annual recruitment for the study area [Koen et al. 2007] but these estimates cannot be compared to autumn recruitment estimates used in the Paragi et al. [1994] model), the harvest threshold in Leeds and Grenville County will be less than the 25% calculated for Maine. Additionally, the number of fishers recorded as harvested may be less than or equal to the total number of fishers actually trapped due to high grading; as such, harvest estimates were likely biased low, which could mean that a larger proportion of the population was harvested than we estimated here.

Ancillary data also indicate an overharvest according to the model of Strickland and Douglas (1981): the ratio of juveniles to adult females in the harvest was 1.81 (*n* = 55) in Leeds and Grenville County during the 2003–2004 trapping season (S. Smithers, OMNR, unpublished data; no data was available for the 2004–2005 trapping season). Conversely, capture data from the RRDU's trap–vaccinate–release program in eastern Ontario suggest that fisher population density in the study area peaked in 2001 and has remained relatively stable since (Bowman et al. 2006), with finite population increases of 0.83 (Bowman et al. 2006) and 1.28 (J. Bowman, OMNR, unpublished data) between the summers of 2003 and 2004, and 2004 and 2005, respectively. However, the population is likely supplemented by immigration of fishers from the Adirondack region of New York (Carr et al. 2007).

We used recruitment values reported for Maine (Paragi et al. 1994) in our estimate of juvenile population density, thus making the assumption that fisher recruitment does not vary across space or time. Future research could address the validity of this assumption by estimating the degree of variation in fisher recruitment in one area over time and during one time interval across space. Large fluctuations in

recruitment across time or space would inform managers that, in fact, these assumptions are not reasonable, and study-specific estimates of recruitment should be used.

MANAGEMENT IMPLICATIONS

Although the estimated population density in Leeds and Grenville County is high relative to other areas, our study indicates that a high proportion of the population was harvested. In keeping with a precautionary approach to fisher management, we therefore recommend that fisher quotas in eastern Ontario not be increased.

ACKNOWLEDGMENTS

Thanks to J. Ritchie, S. J. Leroux, G. Borne, T. Buchanan, E. G. W. Smith, B. VanRyswyk, J. and C. Baker, local fur trappers, RRDU and OMNR personnel, and volunteers for help with data collection. A. Silver and P. Bachmann of the RRDU aged the teeth. Thanks to A. C. Algar for analytical advice, S. Smithers and K. Coleman for logistical help, and 2 anonymous reviewers for comments on a previous draft. The OMNR, the Ontario Fur Managers Federation, and the Natural Sciences and Engineering Research Council (C. S. F.) funded this project.

LITERATURE CITED

- Arthur, S. M., and W. B. Krohn. 1991. Activity patterns, movements, and reproductive ecology of fishers in southcentral Maine. *Journal of Mammalogy* 72:379–385.
- Arthur, S. M., W. B. Krohn, and J. R. Gilbert. 1989. Home range characteristics of adult fishers. *Journal of Wildlife Management* 53:674–679.
- Beyer, D. E., and J. B. Haufler. 1994. Diurnal versus 24-hour sampling of habitat use. *Journal of Wildlife Management* 58:178–180.
- Bowman, J., D. Donovan, and R. C. Rosatte. 2006. Numerical response of fishers to synchronous prey dynamics. *Journal of Mammalogy* 87:480–484.
- Carr, D., J. Bowman, C. J. Kyle, E. Koen, S. M. Tully, J.-F. Robitaille, and P. J. Wilson. 2007. Rapid homogenization of multiple sources: genetic structure of a recolonizing population of fishers. *Journal of Wildlife Management* 71:in press.
- de Vos, A. 1964. Range changes of mammals in the Great Lakes region. *American Midland Naturalist* 71:210–231.
- Douglas, C. W., and M. A. Strickland. 1987. Fisher. Pages 510–529 in M. Novak, J. A. Baker, M. E. Obbard, and B. Malloch, editors. *Wild furbearer management and conservation in North America*. Ontario Ministry of Natural Resources, Toronto, Canada.
- Environment Canada. 2005. National climate archive. <<http://www.climate.weatheroffice.ec.gc.ca>>. Accessed 7 Jan 2006.
- Fuller, T. K., E. C. York, S. M. Powell, T. A. Decker, and R. M. DeGraaf. 2001. An evaluation of territory mapping to estimate fisher density. *Canadian Journal of Zoology* 79:1691–1696.
- Garant, Y., and M. Crête. 1997. Fisher, *Martes pennanti*, home range characteristics in a high density untrapped population in southern Quebec. *Canadian Field-Naturalist* 111:359–364.
- Garrott, R. A., G. C. White, R. M. Bartmann, and D. L. Weybright. 1986. Reflected signal bias in biotelemetry triangulation systems. *Journal of Wildlife Management* 50:747–752.
- Gibilisco, C. J. 1994. Distributional dynamics of modern *Martes* in North America. Pages 59–71 in S. W. Buskirk, A. S. Harestad, M. G. Raphael, and R. A. Powell, editors. *Martens, sables, and fishers: biology and conservation*. Cornell University Press, Ithaca, New York, USA.
- Hagmeier, E. M. 1956. Distribution of marten and fisher in North America. *Canadian Field-Naturalist* 70:149–168.
- Harris, S., W. J. Cresswell, P. G. Forde, W. J. Trehwella, T. Woollard, and S. Wray. 1990. Home-range analysis using radio-tracking data—a review of problems and techniques particularly as applied to the study of mammals. *Mammal Review* 20:97–123.
- Hooge, P. N., and B. Eichenlaub. 2000. Animal movement extension to ArcView. Version 2.04. Alaska Science Center—Biological Science Office, U.S. Geological Survey, Anchorage, Alaska, USA.
- Kenward, R. 1987. *Wildlife radio tagging: equipment, field techniques and data analysis*. Academic Press, San Diego, California, USA.
- Kernohan, B. J., R. A. Gitzen, and J. J. Millsbaugh. 2001. Analysis of animal space use and movements. Pages 125–166 in J. J. Millsbaugh and J. M. Marzluff, editors. *Radio tracking and animal populations*. Academic Press, San Diego, California, USA.
- Koen, E. L. 2006. Home range, population density, habitat preference, and survival of fishers (*Martes pennanti*) in eastern Ontario. Thesis, University of Ottawa, Ontario, Canada.
- Koen, E. L., J. Bowman, and C. S. Findlay. 2007. Fisher survival in eastern Ontario. *Journal of Wildlife Management* 71:1214–1219.
- Krohn, W. B., S. M. Arthur, and T. F. Paragi. 1994. Mortality and vulnerability of a heavily trapped fisher population. Pages 137–145 in S. W. Buskirk, A. S. Harestad, M. G. Raphael, and R. A. Powell, editors. *Martens, sables, and fishers: biology and conservation*. Cornell University Press, Ithaca, New York, USA.
- Lenth, R. V. 1981. On finding the source of a signal. *Technometrics* 23:149–154.
- Leonard, R. D. 1986. Aspects of reproduction of the fisher, *Martes pennanti*, in Manitoba. *Canadian Field-Naturalist* 100:32–44.
- Obbard, M. E., J. G. Jones, R. Newman, A. Booth, A. J. Satterthwaite, and G. Linscombe. 1987. Furbearer harvests in North America. Pages 1007–1034 in M. Novak, J. A. Baker, M. E. Obbard, and B. Malloch, editors. *Wild furbearer management and conservation in North America*. Ontario Ministry of Natural Resources, Toronto, Canada.
- Paragi, T. F., W. B. Krohn, and S. M. Arthur. 1994. Using estimates of fisher recruitment and survival to evaluate population trend. *Northeast Wildlife* 51:1–11.
- Poole, K. G. 1995. Spatial organization of a lynx population. *Canadian Journal of Zoology* 73:632–641.
- Poole, K. G., G. M. Matson, M. A. Strickland, A. J. Magoun, R. P. Graf, and L. M. Dix. 1994. Age and sex determination for American martens and fishers. Pages 204–223 in S. W. Buskirk, A. S. Harestad, M. G. Raphael, and R. A. Powell, editors. *Martens, sables, and fishers: biology and conservation*. Cornell University Press, Ithaca, New York, USA.
- Powell, R. A. 1979. Ecological energetics and foraging strategies of the fisher (*Martes pennanti*). *Journal of Animal Ecology* 48:195–212.
- Powell, R. A. 1993a. The fisher: life history, ecology, and behavior. Second edition. University of Minnesota Press, Minneapolis, USA.
- Powell, R. A. 1993b. Why do some forest carnivores exhibit intrasexual territoriality and what are the consequences for management? Pages 268–273 in I. D. Thompson, senior editor. *International Union of Game Biologists XXI Proceedings*, 15–20 August 1993, Halifax, Nova Scotia, Canada.
- Powell, R. A. 1994. Structure and spacing of *Martes* populations. Pages 101–121 in S. W. Buskirk, A. S. Harestad, M. G. Raphael, and R. A. Powell, editors. *Martens, sables, and fishers: biology and conservation*. Cornell University Press, Ithaca, New York, USA.
- Rand, A. L. 1944. The status of the fisher, *Martes pennanti* (Erleben), in Canada. *Canadian Field-Naturalist* 58:77–81.
- Rodgers, A. R., and A. P. Carr. 1998. HRE: The home range extension for ArcView. Ontario Ministry of Natural Resources, Centre for Northern Forest Ecosystem Research, Thunder Bay, Canada.
- Samuel, M. D., and K. P. Kenow. 1992. Evaluating habitat selection with radio-telemetry triangulation error. *Journal of Wildlife Management* 56:725–734.
- Silverman, B. W. 1986. *Density estimation for statistics and data analysis*. Chapman and Hall, London, United Kingdom.
- Springer, J. T. 1979. Some sources of bias and sampling error in radio triangulation. *Journal of Wildlife Management* 43:926–935.
- Statistics Canada. 2001. 2001 census of Canada. <<http://www12.statcan.ca/english/census01/home/index.cfm>>. Accessed 7 Jan 2006.
- Strickland, M. A., and C. W. Douglas. 1981. The status of fisher in North America and its management in southern Ontario. Pages 1443–1458 in J. A. Chapman and D. Pursley, editors. *Worldwide Furbearer Conference Proceedings*, 3–11 August 1980, Frostburg, Maryland, USA.

- Strickland, M. A., C. W. Douglas, M. K. Brown, and G. R. Parsons. 1982. Determining the age of fisher from cementum annuli of the teeth. *New York Fish and Game Journal* 29:90–94.
- Thompson, I. D. 2000. Forest vertebrates of Ontario: patterns of distribution. Pages 54–73 in A. H. Perera, D. L. Euler, and I. D. Thompson, editors. *Ecology of a managed terrestrial landscape: patterns and processes of forest landscapes in Ontario*. UBC Press, Vancouver, British Columbia, Canada.
- Tully, S. M. 2006. Habitat selection of fishers (*Martes pennanti*) in an untrapped refugium: Algonquin Provincial Park. Thesis, Trent University, Ontario, Canada.
- Withey, J. C., T. D. Bloxton, and J. M. Marzluff. 2001. Effects of tagging and location error in wildlife radiotelemetry studies. Pages 43–75 in J. J. Millsbaugh and J. M. Marzluff, editors. *Radio tracking and animal populations*. Academic Press, San Diego, California, USA.
- Worton, B. J. 1989. Kernel methods for estimating the utilization distribution in home range studies. *Ecology* 70:164–168.
- Wright, P. L., and M. W. Coulter. 1967. Reproduction and growth in Maine fishers. *Journal of Wildlife Management* 31:70–87.
- Zimmerman, J. W., and R. A. Powell. 1995. Radiotelemetry error: location error method compared with error polygons and confidence ellipses. *Canadian Journal of Zoology* 73:1123–1133.

Associate Editor: Ransom.