Research Note

Fisher Survival in Eastern Ontario

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ABSTRACT Fishers (*Martes pennanti*) have recolonized eastern Ontario, Canada, but little is known about the survival of this harvested population. We estimated fisher survival and cause-specific mortality in Leeds and Grenville County, Ontario, from 2003–2005. The overall 2-year survival rate (95% CI) was 0.35 (0.21–0.56, $n = 59$). We attributed observed mortality rates mainly to natural causes (28.6%) and nuisance trapping (21.4%). Given reported recruitment rates, our estimated fisher mortality has likely led to population declines in the study area, especially during 2003. Thus, we do not recommend an increase in fisher harvest quotas in the study area at this time. (JOURNAL OF WILDLIFE MANAGEMENT 71(4):1214–1219; 2007)

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KEY WORDS cause-specific mortality, fisher, *Martes pennanti,* Ontario, radiotelemetry, survival, trapping.

Knowledge of survival rates and cause-specific mortality is crucial information for the effective management of wildlife populations, especially those exposed to both natural and human-induced mortality (McLellan et al. 1999, Hebblewhite et al. 2003). For species subject to trapping, managers often have estimates of the numbers of individuals legally harvested each year, but illegal harvest related to poaching or high-grading (keeping valuable pelts and disposing of pelts that would cause the trapper to exceed a quota) reduces the accuracy of these estimates. Animals are also killed on roadways or die due to natural causes, and these deaths often go undetected. Radiotelemetry provides an opportunity to document and, at least in principle, quantify all deaths.

Fishers (*Martes pennanti*) are currently harvested in eastern Ontario, Canada, but harvest mortality relative to non-harvest mortality is unknown. This issue is of particular concern to managers for 2 reasons: 1) a previous local extirpation of fishers in eastern Ontario (de Vos 1964) was linked to both overharvest (Powell 1993) and habitat loss (Powell 1993; P. A. Lancaster, J. Bowman, and B. A. Pond, Ontario Ministry of Natural Resources [OMNR], unpublished data); and 2) there is pressure from the fur-trapping community and local residents in eastern Ontario to raise fisher harvest quotas. Here, we use radiotelemetry data to estimate the survival and cause-specific mortality of a harvested fisher population in eastern Ontario in 2003 and 2004, and to assess whether recruitment is likely to balance observed mortality.

STUDY AREA

The 975-km^2 study area encompassed the townships of Edwardsburgh, Augusta, and North Grenville in Leeds and Grenville County, Ontario, Canada (approx. 44°50′N, 75°30′W). 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 (Environment Canada 2005). Elevation ranged from 80 m to 130 m above sea level. The landscape was a mixture of abandoned field, pasture and agriculture, swamp, and forest; the forested areas were composed mainly of white cedar (*Thuja occidentalis*), larch (*Larix laricina*), sugar maple (*Acer saccharum*), and red maple (*Acer rubrum*). The average human population density in Leeds and Grenville County in 2001 was 17/km^2 (Statistics Canada 2001).

The fur-trapping season for fishers in Leeds and Grenville County was open from 25 October to 15 January in 2003–2004 and 2004–2005. Fur-trappers were permitted to harvest one fisher each season, and one additional fisher for every 1.62 km^2 of trap-line; a trapper's quota is, thus, based on the amount of trap-line allocated to him or her. The fisher harvest density in Leeds and Grenville County was 11.4, 11.7, and 13.1 fishers per 100 km^2 in 2002–2003, 2003–2004, and 2004–2005, respectively (Fur Management Information System, OMNR). Although reporting is mandatory, not all harvest is reported every year; therefore, these estimates are less than or equal to the total harvest.

METHODS

We radiocollared 61 fishers in Leeds and Grenville County in 2003. Local trappers caught 50 of the fishers with Tomahawk live-traps (Tomahawk Live Trap Co., Tomahawk, WI; model 106 or 108) between 15 January and 2 March 2003. Additionally, the Rabies Research and Development Unit (RRDU) of the OMNR live-trapped 7 and 4 fishers between 3 June and mid-July 2003, and 2 and 29 October 2003, respectively, during a raccoon (*Procyon lotor*) live-trapping program. We immobilized fishers with an intramuscular injection of 10:1 ketamine:xylazine at 20 mg/kg and reversed xylazine with a 0.1 mg/kg injection of yohimbine. We removed the upper, first premolar of each fisher for aging (Strickland et al. 1982). Rabies Research and Development personnel aged 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). We

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put one ear tag (1005–3 National Band and Tag Co., Newport, KY) in each ear. Radiocollars (SMRC-3 [Lotek Wireless Inc., Newmarket, ON, Canada] and MI-2 [Holohil, Carp, ON, Canada]) weighed $<5\%$ of the body weight of an adult fisher. We equipped all collars with mortality sensors.

We monitored the status (alive or dead) of radiocollared fishers weekly from the time of radiocollaring until the time of death or censorship, approximately February 2003–January 2005. We monitored fishers either from the ground or from the air in a Cessna 172 (Cessna Aircraft Co., Wichita, KS) airplane with 2 wing-mounted H-antennas. We flew 10-km-wide transects across the study area at an altitude of 750–950 m and extended 20–40 km outside of the study area on the western, northern, and eastern edges. We flew the perimeter of the transect grid at an altitude of 1,500 m to increase the coverage by the receiving system along the edge of the grid.

The survival function, $S(t)$, is the probability of an individual surviving t time units from the beginning of the study. We estimated fisher survival in S-Plus (Version 6.0; Insightful Corp., Seattle, WA) using the Kaplan–Meier (Kaplan and Meier 1958) estimator with staggered entry (Pollock et al. 1989*a*). We calculated the sampling variance of $\hat{S}(t)$ using the Greenwood (1926) method (Pollock et al. 1989*a*) and calculated 95% confidence intervals as described in Pollock et al. (1989*a*). Although we relocated many fishers weekly, we relocated some less frequently due to time constraints or difficulty in finding certain individuals. Consequently, we used 2-week intervals for the survival analysis. We defined time of death as the midpoint between the last known location and when the death was detected when this interval was >2 weeks (Krohn et al. 1994, Paragi et al. 1994*b*).

Bunck et al. (1995) discussed the bias introduced into survivorship estimators when the probability of relocating a radiotagged animal is <1 and suggested a modified approach to survival analysis whereby animals that are not relocated are temporarily censored, and then reentered when they are relocated. Three fishers in our study had a relatively low probability of being relocated because there were few roads in the area, hindering relocation. Additionally, 3 fishers had radiocollars with wrap-around antennas (MI-2; Holohil, Carp, ON, Canada); these collars had a reduced range of signal transmission relative to collars with external antennas, possibly as much as 20–50% (Anderka 1987) and, as such, also had a relatively low probability of relocation. Thus, we only considered these individuals to be at risk for those intervals in which we relocated them (Bunck et al. 1995).

We assumed that we had an equal probability of relocating alive and dead fishers within the area covered by the flight transects. Thus, we censored, in the first interval that we did not relocate them, only those fishers that permanently emigrated from this area whether they lived or died. We also censored fishers that we trapped after the completion of the study. We excluded from the survival analysis 2 fishers that died in the 2-week interval following their initial capture as we were unable to determine the cause of death and, therefore, could not rule out the possibility that these deaths were capture-related.

We censored 31 of the 59 collared fishers included in the survival analysis over the 2-year study period. We calculated minimum and maximum survival rates by presuming, in the former case, that all censored animals died during the interval in which we censored them, and for the latter, that all censored animals lived until the end of the study (Heisey and Fuller 1985; Pollock et al. 1989*a*, *b*; Winterstein et al. 2001).

We used Cox's (1972) proportional hazards model to examine the effect of sex on fisher survival. We did not investigate age, another obvious covariate, due to the small sample of juvenile fishers. With the exception of 2 female fishers captured in October, all fishers were adult within the first 2 months of the study. Thus, we pooled survival estimates over age. We tested the ratio of the hazards for proportionality using scaled Schoenfeld residuals (see Schoenfeld 1982, Hess 1995).

We calculated cause-specific mortality rates for 3 categories: 1) anthropogenic, further subdivided into a) fur-trapping, b) nuisance trapping, and c) other; 2) natural; and 3) unknown causes of death. We used 3 methods to estimate cause-specific mortality rates: 1) a simple proportion, calculated by multiplying the overall 2-year mortality rate $(1 - S)$ by the proportion of total deaths in each category; 2) the nonparametric cumulative incidence function estimator described by Heisey and Patterson (2006); and 3) the 1 − KM method, where, for each cause, we calculated $(1 - S)$ using the Kaplan–Meier estimator, censoring all deaths due to other causes.

Henny et al. (1970) derived an equation to estimate annual population change that has been applied to populations of many species, including river otters (*Lontra canadensis*; Tabor and Wight 1977), martens (*Martes americana*; Hodgman et al. 1994), and fishers (Paragi et al. 1994*b*). If a population is stable (i.e., production equals mortality), then:

$$1 = m_1 S_0 + m_2 S_0 S_1 + m_3 S_0 S_1 S_2 + \dots$$

(Henny et al. 1970:691), where m_x is the age-specific recruitment rate and S_x is the age-specific survival rate. This expression was simplified by Paragi et al. (1994*b*:4) to give:

$$1 = m S_0 S + S, \tag{1}$$

where m is the mean recruitment rate, or the number of female offspring per adult female (≥ 2 yr old) that survive from birth until the trapping season. The recruitment rate is assumed to be the same for all females ≥ 2 years old (fishers reproduce for the first time in their second yr [Wright and Coulter 1967]). S_0 is the annual survival rate of juvenile females (<1 yr old), and S is the annual survival rate of female fishers ≥ 1 year old. We calculated the recruitment necessary to have a stable fisher population by solving for m in (1), using observed survival rates. As we did not measure juvenile survival, we substituted a range (0.05–0.85) of

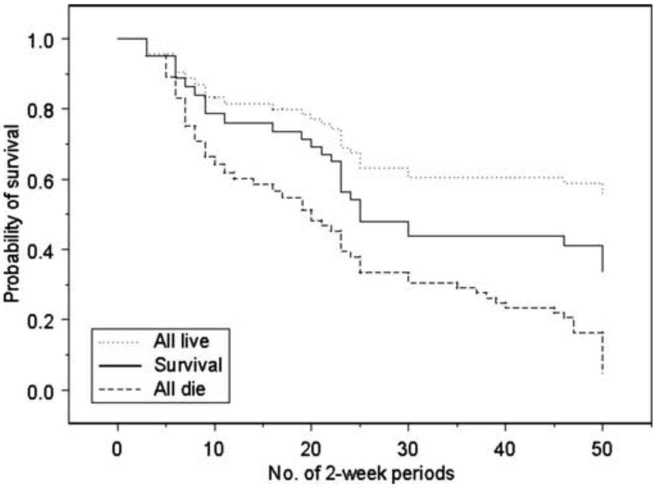

Figure 1. Two-year Kaplan–Meier survivorship for fishers in eastern Ontario, Canada, between February 2003 and December 2004 ($n = 59$). The measured survival curve for the period (survival) is compared to survival curves when all censored fishers are presumed to have lived to the end of the study (all live) and all censored fishers are presumed to have died in the interval that they were censored, except those that lived beyond the study period (all die).

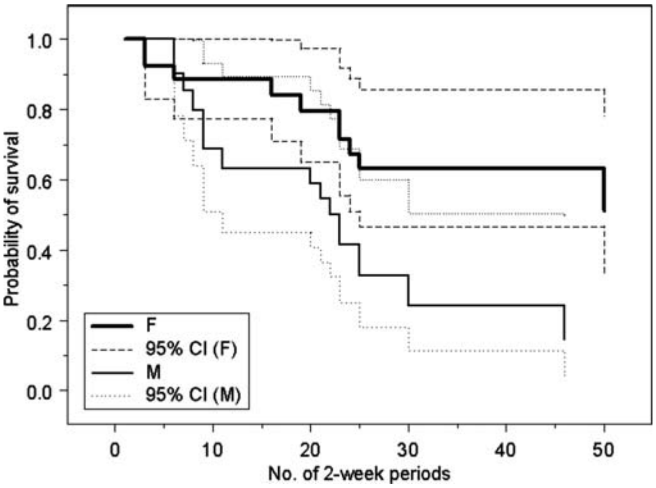

Figure 2. Two-year Kaplan–Meier survivorship and 95% confidence intervals for female and male fishers in eastern Ontario, Canada, from February 2003 until December 2004 ($n = 59$).

possible juvenile survival rates for S_0 in (1), assuming that juvenile survival was less than adult survival (Krohn et al. 1994).

RESULTS

We monitored survival of 59 fishers (24 M, 35 F) for a total of 17,528 fisher-days; we monitored 21 radiocollared fishers (6 M, 15 F) for >1 year. The overall 2-year survival rate (95% CI) was 0.35 (0.21–0.56, $n = 59$). Assuming that the 28 censored fishers (excluding 3 that were still alive but censored at the completion of the study) died during the interval in which we censored them, the 2-year survival rate (95% CI) was 0.05 (0.02–0.14), compared to 0.56 (0.44–0.71) if we assume that all censored animals survived to the end of the study (Fig. 1).

Estimated annual survival rates (95% CI) in 2003 and 2004, respectively, were 0.33 (0.18–0.60) and 0.45 (0.24–0.83) for males, and 0.63 (0.47–0.86) and 0.81 (0.72–0.91) for females. Female and male 2-year survival rates (95% CI) were 0.51 (0.34–0.78) and 0.15 (0.04–0.50), respectively (Fig. 2); hence, the estimated 2-year survival rate for males was almost 2 times lower than that of females (Cox proportional hazards model, coeff. = 0.54, exponentiated coeff. = 1.72, $P = 0.007$). Scaled Schoenfeld residuals (Schoenfeld 1980, 1982) were independent of time ($\chi^2 = 0.40$, $P = 0.525$), suggesting that, indeed, the hazard functions for males and females were proportional to each other.

Twenty-eight tagged fishers died in 2003 and 2004: 12 (42.8%) due to anthropogenic causes (trapping [6 due to nuisance trapping, 3 due to fur-trapping], road kill, or other human causes), 8 (28.6%) to natural causes (injuries as a result of attack, emaciation, canine distemper virus [CDV], bronchopneumonia, septic peritonitis [likely pancreatitis], and possible drowning), and 8 (28.6%) to unknown causes. Observed mortality rates can be attributed mainly to natural causes and nuisance trapping; trends in cause-specific mortality rates across causes of mortality were similar between the 3 estimation methods (Table 1).

We used equation (1) to estimate the recruitment necessary to ensure a stable fisher population given observed annual adult female mortality ($1 - S$). Depending on juvenile survival, the annual female recruitment necessary to maintain a stable population ranged from 11.7 to 0.69 in 2003 and 4.69 to 0.28 in 2004 (Fig. 3).

DISCUSSION

Our estimated annual adult female survival rates are comparable to those reported by Paragi et al. (1994*b*) of 0.65 (95% CI = 0.50–0.96) for adult female fishers in Maine, USA. We attributed 23% of known deaths during the trapping season ($n = 13$) to fur-trapping, whereas ≥61% of the deaths were due to nonharvest-related causes during this period. This proportion of nonharvest deaths is considerably greater than the estimate obtained by Krohn et al. (1994) in Maine, where 40 of the 41 deaths during the trapping season were due to fur-trapping. There seems little doubt that nonharvest mortality contributed to the estimated high mortality rates observed during the 2 trapping seasons we monitored in eastern Ontario.

Of the 8 documented natural deaths, 2 were the result of attacks. We do not know whether the attacks were by conspecifics or predators; in neither case was the carcass consumed. One fisher died of CDV. There was evidence of CDV in 5 of the 12 carcasses that were necropsied, although this was not determined to be the cause of death for these 5 individuals (D. Campbell and K. M. Welch, Canadian Cooperative Wildlife Health Centre, personal communication).

We estimated male mortality to be almost twice that of females (exponentiated coeff. 1.72), consistent with Strickland and Douglas (1981), who speculated that this could be due to intraspecific conflict between males. Although

Table 1. Cause-specific mortality rates for fishers in eastern Ontario between February 2003 and January 2005, calculated using 3 methods: a simple proportion[a]; the nonparametric cumulative incidence function estimator (CIF)[b]; and 1 − KM.[c]

		CIF		1 − KM	
Cause	Proportion	Rate	95% CI	Rate	95% CI
Anthropogenic					
Nuisance	0.14	0.15	0.03–0.26	0.21	0–0.40
Fur	0.07	0.08	0–0.19	0.17	0–0.36
Other	0.07	0.07	0–0.15	0.13	0–0.28
Natural	0.19	0.18	0.05–0.30	0.22	0.06–0.36
Unknown	0.19	0.20	0.08–0.31	0.22	0.07–0.34

[a] Estimated by multiplying the 2-yr mortality rate by the proportion of deaths in each category.

[b] Described by Heisey and Patterson (2006).

[c] Estimated by calculating (1 − *S*) using the Kaplan–Meier estimator for each cause of death while censoring deaths due to all other causes.

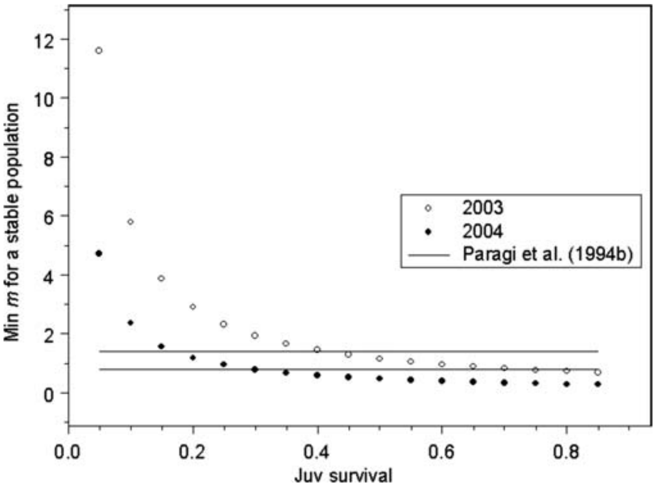

Figure 3. Annual female recruitment per adult female fisher (*m*) necessary to maintain a stable population in eastern Ontario, Canada, given annual adult female survival rates of 0.63 for 2003 and 0.81 for 2004, for varying estimates of juvenile survival (S_0), using equation (1). Horizontal lines are the range of estimates of *m* (0.8–1.4) reported by Paragi et al. (1994*b*). Dots above these lines show the conditions for which mortality is greater than recruitment, resulting in population decline in Leeds and Grenville County in 2003 and 2004.

Buskirk and Lindstedt (1989) noted that the sex ratio of a trapped sample of mustelids generally tends to be male-biased, of the 13 fishers trapped for fur or as nuisance animals in our study, including those trapped outside of the study area or beyond the end of the study, only 8 were male. Of the 19 fishers that died of nontrapping-related causes, 11 were male. Thus, we cannot unambiguously attribute the observed higher adult male mortality rate, relative to that of females, to either trapping or nontrapping mortality.

Survival estimators assume that live-trapping and radiocollars do not influence survival. According to necropsies performed on radiocollared fishers, we did not attribute any deaths to capture or the radiocollar, with the exception of 2 fishers whose deaths may have been related to capture; we censored these individuals from the study (D. Campbell and K. M. Welch, Canadian Cooperative Wildlife Health Centre, personal communication). Some fishers had broken canine teeth from chewing the live traps; Arthur (1988) also reported fishers with broken teeth from cage traps. In our study, 7 of the 16 male fishers and 4 of the 10 female fishers that we examined after they had worn a radiocollar had worn-off guard hairs or neck abrasions. Most radiotelemetry studies using collars on medium to large terrestrial mammals have not reported negative effects of the collars on survivorship (Withey et al. 2001). In contrast, several studies on fishers have reported effects of radiocollars ranging from minor skin irritations (Paragi et al. 1994*b*) to worn-off fur and guard hairs on the necks of collared fishers (Arthur 1988, Krohn et al. 1994).

In Maine, Paragi et al. (1994*b*) estimated annual juvenile survival (95% CI) to be 0.27 (0.14–0.50). If we assume this value for juvenile survival in our study, then in 2003 and 2004, 2.17 and 0.87 female young per adult female, respectively, would have to survive the first year to ensure population stability. Sex ratios for fisher young are close to 1:1 (Douglas and Strickland 1987); therefore, ≥4.34 and 1.74 young (2*m*) per adult female (2003 and 2004, respectively) must have been born and have survived the first year for the population to have remained stable. Mean litter size for fishers ranges between 2 and 3 (Powell 1993, Mead 1994, Paragi et al. 1994*a*). Therefore, even if every female fisher whelped young (note that the estimated denning rate is <100%: 81% [Leonard 1986]; 63% [Paragi et al. 1994*b*]; 75% [Arthur and Krohn 1991]), these calculations suggest a declining population in 2003. Catch-per-unit-effort data from the study area support this contention, as independent estimates between the summers of 2003 and 2004, and 2004 and 2005 place the annual population growth rate (lambda) at 0.83 (Bowman et al. 2006) and 1.28 (J. Bowman, OMNR, unpublished data), respectively. This suggests that either recruitment exceeded the 2*m* estimate of 1.74 young per adult female in 2004 or that juvenile survival was >0.27. The population trend since 2000 in the study area appears to be relatively stable (Bowman et al. 2006).

Given the lambda values (above) estimated from catch-per-unit effort data, observed adult female survival, and the estimate of juvenile survival (95% CI) from Paragi et al. (1994*b*) of 0.27 (0.14–0.50), we estimate *m* (95% CI) in equation (1) to be 1.18 (0.63–2.27) in 2003 and 2.15 (1.16–4.14) in 2004. These estimates suggest that, especially in 2004 where estimates of required recruitment (2*m*) are high (4.30), juvenile survival was closer to the upper limit of 0.50 reported by Paragi et al. (1994*b*).

Equation (1) assumes that, for a stable population, total mortality equals total production; it does not consider immigration or emigration. The recolonization of eastern Ontario by fishers is comparatively recent (de Vos 1964). Carr (2005) used DNA microsatellite analysis to determine that fisher populations in the study area are recent migrants from the Adirondack region of New York State, USA. As such, it is possible that immigration from New York is supplementing fisher populations in Leeds and Grenville County.

MANAGEMENT IMPLICATIONS

We do not recommend an increase in harvest quotas in eastern Ontario since current nontrapping mortality in adult fishers is relatively high in the region, and we do not know whether the harvest is compensatory (Strickland and Douglas 1981, but see Douglas and Strickland 1987, Krohn et al. 1994). This recommendation is corroborated by our observed mortality rates that, in some recent years at least, are high enough that recruitment cannot balance mortality.

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