DENSITY OF FISHERS (*PEKANIA PENNANTI*) AT THE SOUTHWESTERN EDGE OF THE SPECIES' RANGE IN BRITISH COLUMBIA

LARRY R DAVIS

Davis Environmental Ltd, PO Box 306, 108 Mile Ranch, BC V0K 2Z0 Canada; rldavis@shaw.ca

RICHARD D WEIR

Ministry of Environment and Climate Change Strategy, PO Box 9338 Stn Prov Govt, Victoria, BC V8W 9M1 Canada; rich.weir@gov.bc.ca

ABSTRACT—Fishers (*Pekania pennanti*) are a species of conservation concern in central British Columbia for which distribution and abundance information is needed to help guide conservation efforts. We conducted a DNA-based spatial capture-recapture study in the Bridge River watershed to gain a better understanding of their density in the dry forests at the southwestern edge of the species' range in the province. We established and monitored baited hair traps at 152 sites spread throughout 771.4 km^2 over 4 mo in early 2012, detecting 8 individual Fishers (3 females, 5 males) at 16 different sites. We used spatially explicit capture-recapture methods to estimate the density of Fishers to be 13.1 Fishers/1000 km^2 (95% CI: 6.3 to 27.4 Fishers/1000 km^2) when we constrained the plausible sampling area to biogeoclimatic zones that are known to support Fishers. This study provides resource managers and trappers with a snapshot of local Fisher densities at the southern edge of the species range in British Columbia that will help estimate sustainable harvest levels and refine the estimate of the provincial population of Fishers.

Key words: British Columbia, density, Fishers, Interior Douglas-fir biogeoclimatic zone, Montane Spruce biogeoclimatic zone, *Pekania pennanti*

Fishers (*Pekania pennanti*) are medium-sized, forest-dependent carnivores of the weasel family that are an important component of healthy ecosystems. Several aspects of the ecology of Fishers, including their use of rare structural elements found primarily in late-successional forests (Raley and others 2012), make them susceptible to changes in the forested landbase resulting from large-scale insect infestations, hydroelectric development, forest-harvest activities, and oil and gas development (Naney and others 2012). Fishers are also a harvested furbearer in British Columbia that can be legally trapped in the central and northern portions of the province between 1 November and 15 February. During the past 30 y, the harvest of Fishers has declined in British Columbia, leading to concern about the population status of this species. Given these threats, Fishers are considered a species at risk under the Identified Wildlife Management Strategy (Province of British Columbia 2004) and the Columbian population is red-listed (S2) in British Columbia (British Columbia Conservation Data Centre 2020). Fishers are also considered a high priority for conservation efforts by the provincial government (Province of British Columbia 2008).

Between 2,236 and 3,715 Fishers were estimated to occur in British Columbia in the early 2000s, based on 243,542 km^2 of moderate- to very-high-capability habitat mapped in the province (Lofroth 2004). This habitat-based population estimate was built on a density estimate from the moderate-capability Williston region ($\bar{x}$ = 8.8 Fishers/1000 km^2; Weir and Corbould 2006), but was corroborated by later work in high-capability habitats in northeastern British Columbia where the predicted density (10.4–15.4 Fishers/1000 km^2; Lofroth 2004) was very near the observed density ($\bar{x}$ = 16.3 Fishers/1000 km^2; Weir and others 2011). These estimates are between 4 and 33% of those reported in eastern North America and California (Weir and others 2011). The reasons for the much lower

densities in British Columbia are unknown but may stem from lower prey densities and deeper snow conditions found at higher latitudes that may affect Fisher locomotion (Raine 1983).

Because Fisher density varies considerably among regions in response to habitat quality, surveys of Fishers are needed in representative ecosystems to provide better population estimates for British Columbia. To date, surveys have been limited to the relatively higher-productivity ecosystems of the Sub-Boreal Spruce (Weir and Corbould 2006) and Boreal White and Black Spruce (Weir and others 2011) biogeoclimatic zones, and we currently have no published inventory information for the dry forests found in the southern one-third of the species' range in British Columbia. To ensure prudent population management, density estimates are needed from this ecologically different portion of the provincial range of this species.

Fishers are secretive and difficult to inventory (Powell and Zielinski 1994), and a variety of methods (for example, minimum number alive, mark-resight, territorial mapping) have been used to estimate Fisher densities. Spatial capture-recapture models (Royle and others 2014) are a relatively recent advance that uses hierarchical models of animal detection and activity to generate unbiased, spatially explicit estimates of animal abundance and density. The objective of this study was to conduct a DNA-based spatial capture-recapture study to estimate the density of Fishers in the dry forests of the Bridge River watershed at the southwestern edge of the species' range in British Columbia, to compare these estimates to estimates from other ecosystems in British Columbia, and to help refine population estimates for the species in the province.

METHODS

The 771.4-km^2 study area (UTM Zone 10, 527000, 5636000) lies in the Gun, Tyaughton, and Yalakom drainages to the northwest of Lillooet, British Columbia, and occurs within the Southern Chilcotin Range and Central Chilcotin Range ecosections (Ministry of Environment and Climate Change Strategy 2019). The area is dominated by the Interior Douglas-fir (IDF, 356.0 km^2, 46% of study area), Montane Spruce (MS, 175.6 km^2, 23%), and Engelmann Spruce–Subalpine-fir (ESSF, 233.1 km^2, 30%) biogeoclimatic zones with a small amount (6.7 km^2; 1%) of high-elevation and treeless Interior Mountain-Heather Alpine zone (IMA) (Meidinger and Pojar 1991; Ministry of Forests, Lands, Natural Resource Operations and Rural Development 2019). The study area is dominated by broad lower valleys with steep-sided slopes at elevations ranging from 650 m near the Carpenter Reservoir to approximately 3000 m in the rugged peaks at the headwaters of the watershed. The study area lies in the traditional territory of the St'át'imc First Nation, encompasses portions of 3 registered traplines, and is located at the southeastern edge of the distribution of Fishers within the province (Fig. 1). Much of the area is also part of the forest-harvesting landbase, with clearcut logging being the dominant harvesting system.

Valley bottoms supported mixed coniferous-deciduous forests, with coniferous forests dominating higher elevations. Coniferous tree species included Douglas-fir (*Pseudotsuga menziesii*) and occasionally Ponderosa Pine (*Pinus ponderosa*) at low- to mid-elevations, with Lodgepole Pine (*Pinus contorta*) in seral stands throughout the area. Hybrid Spruce (*Picea engelmannii* x *glauca*) were more common with increasing elevation and found at all elevations in moist habitats. Black Cottonwood (*Populus balsamifera* var *trichocarpa*), Trembling Aspen (*Populus tremuloides*), and Paper Birch (*Betula papyrifera*) were the dominant broadleaf trees. Small areas of Western Redcedar (*Thuja plicata*) were found in wetter isolated sites and Sub-alpine Fir (*Abies lasiocarpa*) occurred at higher elevations and on north aspects.

We conducted a spatial capture-recapture survey using genetic fingerprinting of remotely collected hair samples to estimate the density of Fishers within the study area. We originally divided the area into 45, 20.3-km^2 hexagonal cells, each of which approximated the smallest expected size of a female home range in this region (that is, lower quartile of documented sizes; Weir and others 2009). We accessed each cell by foot, truck, snow machine, and helicopter for sampling. Seven cells could not be accessed safely and were not surveyed, resulting in 38 cells being sampled.

Within each cell, we established sampling sites to passively collect hair and follicle samples containing genetic material from individual Fishers attracted to baited hair traps. We deployed hair traps fashioned after the design

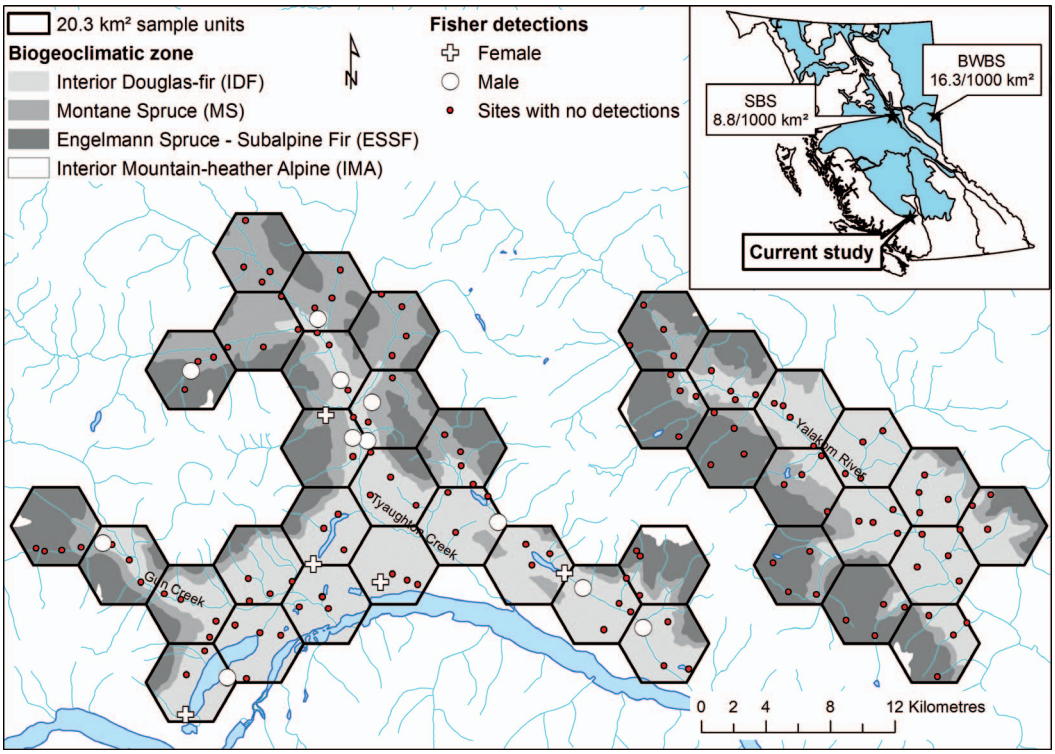

FIGURE 1. Sampling for Fishers in the Bridge River study area and location of the study area within the distribution of Fishers in British Columbia (shaded area with black boundary in inset; Weir and Lara Almuedo 2010). Two other density estimates in the province are also shown (SBS, Williston, Weir and Corbould 2006; BWBS, Kiskatinaw, Weir and others 2011). Areas falling in the ESSF and IMA biogeoclimatic zones were excluded from the habitat mask used to estimate the local population of Fishers.

of Foran and others (1997), with two pieces of board ($2 \times 19 \times 60$ cm) screwed together along the long edge to form a triangle against the bole of a tree. Hair traps had four pieces (approximately 2×7 cm) of adhesive-based mouse-glue boards attached to the inner surface to collect hair from Fishers that tried to access the bait inside the trap. We baited hair traps with chicken and used commercial beaver castor and Fisher lure as attractants. We attached traps vertically to a tree, fastened a small board as a roof above to protect hair samples from precipitation, and applied attractants to jute string hung on branches adjacent to the traps. As each hair trap had a single piece of bait that was removed by the first individual that passed the glue pads, we were confident that these were essentially single-catch traps, whereby genetic material from only one individual was sampled during each session. This contention was further supported by the lack of hair samples that came from multiple individuals (D Paetkau, personal communication). All sampling occurred under Wildlife Act permit KA11-75934 and conformed to welfare standards of the Canada Council on Animal Care.

To maximize detection, we established hair traps at sampling sites in the best available habitat (Weir 2003; Davis 2009) in each cell based on the field crew's discretion. Typically, these were productive stands with trees >15 m tall and connected to other similar stands. We deployed hair traps at each site for approximately 18 d, then moved the hair trap to a new location in the cell for another 18-d sampling period. Sampling sites were first established in mid-January 2012, then moved to a new location in each cell twice in February 2012, once in March 2012, and finally retrieved in early April 2012, for a total of four 18-d sampling sessions.

On consecutive sampling sessions, we moved the sites ≥1 km to reduce the likelihood of habituation, and consequent re-sampling, of resident animals. At the end of each sampling session, we checked each glue pad to assess if an animal had left hair and follicle samples. We removed each glue pad that had collected a sample, covered it with plastic paper, and then stored it in a paper envelope under dry conditions for processing by the laboratory. We calculated the latency to detection as the average number of sessions that needed to pass in a cell before a capture occurred, not including traps without captures.

We sent hair and follicle samples to a commercial genetics lab (Wildlife Genetics International, Nelson, British Columbia) for identification of species and genetic fingerprinting of each sample. The lab then used clipped roots of 10 guard hairs where available, or an entire clump of under-furs if guard hairs were not available, for DNA extraction. A commercial solvent was used when extraction required removal of embedded hairs from the glue pad. DNA was extracted using QIAGEN DNeasy Tissue kits following the manufacturer's instructions.

The lab conducted a mitochondrial prescreen using a sequence-based analysis of a segment of the mitochondrial 16S rRNA gene to identify those samples that came from Fishers. For samples identified as Fisher, individual identity was characterized using 7 microsatellite markers used in an earlier study on Fishers elsewhere in British Columbia (MP0055, MP082, MP0144, MP0114, MP0175, Mvis072, LUT604; Weir and others 2013) and the ZFX/ZFY/SRY gender system developed by the lab for mustelids (D Paetkau, Wildlife Genetics International, personal communication) for a total of 8 markers. A 3-phase approach was used to identify individuals beginning with a 1st pass of 8 markers on the samples. A clean-up phase reanalyzed weak or difficult-to-read samples (that is, through low-copy DNA) using 5 μL of DNA per reaction, up from the 3 μL used on first pass, which produced a complete 7-locus genotype for all Fisher samples.

We used spatial capture-recapture methods (Royle and others 2014) that use spatial and temporal detection histories of individual animals to generate an unbiased estimate of density (Borchers and Efford 2008). We used package 'secr' (Efford 2018) in the R programming language to estimate the density of Fishers in the assessment area. Briefly, 'secr' is a spatially explicit capture-recapture approach that uses maximum likelihood functions and the spatial location and timing of monitoring and captures of identifiable animals to estimate density.

The 1st aspect of the calculations involved constructing a 'habitat mask' to identify the bounds of the area of integration (that is, area over which density was evaluated) following the guidance of Efford (2018). We generated a habitat mask for an area that buffered 14 km from our array of monitoring sites, based on a preliminary analysis that suggested the scale parameter might be around 1200 m. The spacing of the mask-grid points was 600 m, which is roughly half of the preliminary scale parameter. Fishers do not typically cross large bodies of water or occur in the ESSF (Engelmann Spruce–Subalpine-fir) zone in British Columbia (Weir and Lara Almuedo 2010), so we excluded points from the habitat mask that occurred within this zone or fell in or on the non-sampled side of Carpenter Reservoir, which was a waterbody approximately 1000–1500 m wide.

Next, we used the spatial location and timing of monitoring and detections and a half-normal detection function to model the base detection probability (g0) and scale parameter (sigma) of the observation model. We expected the small number of detections to limit our ability to evaluate factors that may have affected either the detection probability or density, so we calculated density based on a simple fixed model that assumed uniform density across the sampled area and no behavioural or session-specific effects (that is, D∼1, g0∼1, sigma∼1; Efford 2018). We assessed fit of the estimated model using a simple Monte-Carlo goodness-of-fit test with 99 simulations (Efford 2018).

RESULTS

Between January and April 2012, we operated hair traps for 2,592 trap-nights (that is, 1 hair-trap active for a 24-h period) at 152 sample sites within the 38 surveyed cells, of which 134 stations occurred within the IDF and MS zones. We collected hair samples from 61 (40%) of these sample sites. Species were identified for 60 of the 61 samples, including 16 detections of Fishers (Table 1). All detections of Fishers occurred in

TABLE 1. Detections of Fishers and other species at hair traps operated between January and April 2012 in the Bridge River watershed, British Columbia. We calculated capture rate as the percentage of sampling sessions in which a capture occurred. Latency to detection was estimated as the average number of sessions that needed to pass in a cell before a capture occurred, not including traps without captures for that species.

Species	Captures	Capture rate (%)	Latency to detection (sessions)
Fisher	16	11.1	2.1
Pacific Marten	23	16.0	2.1
Red Squirrel (*Tamiascurus hudsonicus*)	11	7.6	2.6
Northern Flying Squirrel (*Glaucomys sabrinus*)	9	6.3	1.8
Wolverine	1	0.01	4.0
All species	60	41.7	1.9

the Gun and Tyaughton watersheds (Fig. 1); we detected no Fishers in the Yalakom watershed despite sampling 56 sites in the watershed over the 4 sampling sessions. Fishers were detected within cells by the second sampling session, on average.

All Fisher samples were successfully genotyped, and we identified 8 individual Fishers (3 females, 5 males). We detected 2 males at 4 different sampling sites each, 1 female at 3 different sampling sites, and the remaining 5 individuals were only detected at a single sampling site. We primarily detected Fishers in the IDF zone (13 detections; 81%) with the remaining 3 detections occurring in the MS zone (19%). We did not detect any Fishers at the 18 sites that were operated in the ESSF zone (Fig. 1). We also detected Pacific Martens (*Martes caurina*, $n = 23$ detections) and 1 Wolverine (*Gulo gulo*) in the course of our sampling.

We estimated the density of Fishers to be 13.1 Fishers/1000 km^2 (95% CI: 6.3 to 27.4 Fishers/1000 km^2) when we constrained the habitat mask to biogeoclimatic zones that are known to support Fishers (that is, IDF and MS). If we did not constrain the habitat mask and included ESSF zones as suitable habitat (that is, where no Fishers were detected or expected to occur), the estimated density reduced to 7.9 Fishers/1000 km^2 (95% CI: 3.7 to 16.9). The baseline probability of detection (g0) for Fishers that we detected was low, at 0.13 (SE = 0.06), although the detectors were estimated to attract Fishers from relatively long distances (sigma = 4994 m, SE = 1000). The simple Monte-Carlo goodness-of-fit test of the fitted model estimated a p-value that approached 1 (deviance df = 23.0).

Discussion

Our study used non-invasive genetic SCR methods to estimate the size of the local population of Fishers in the Bridge River watershed, British Columbia. The density of Fishers that we observed was similar to other productive areas in the province (for example, Boreal White and Black Spruce zone [BWBS]; Weir and others 2011), despite having relatively low-quality Fisher habitat over a relatively large portion of the study area (for example, ESSF and IMA zones). The relatively high estimate for the Bridge River watershed may result from a number of factors, including relative productivity of ecosystems among the different biogeoclimatic zones, methodological differences among studies, temporal factors, and edge effects owing to a relatively small study area.

The biological and environmental conditions in our study area likely influenced the density that we observed. The IDF zone comprised the majority of the study area, which was previously predicted by Lofroth (2004) to have high capability to support Fishers based on the climate, vegetation, and prey community. Other zones in the study area were predicted to have moderate (MS zone) or no (ESSF, IMA) capability to support Fishers. Our detections supported these predictions; 13 of 16 detections of Fishers occurred in the IDF zone, 3 detections were in the MS zone, and no Fishers were detected in the ESSF zone despite considerable effort. The effect of conducting a survey with sample cells that included considerable amounts of poor-capability biogeoclimatic zones had on our density estimate was unclear. Given that less than half of the study area was rated as high capability, it is possible that the overall density would have

been higher if our study area was limited to only the IDF biogeoclimatic zone.

Although our density estimate was relatively high, it is likely not substantially different from that in the Boreal White and Black Spruce biogeoclimatic zone of northeastern British Columbia, given the relatively low precision of our estimate. Weir and others (2011) estimated densities to be 11.4 to 20.8 Fishers/1000 km^2 over 3 y in the BWBS and 8.8 Fishers/1000 km^2 in the Sub Boreal Spruce zone (Weir and Corbould 2006). Both estimates were based on resident Fishers only, whereas our estimate likely also included juvenile and transient Fishers. This could result in us observing a higher population estimate in our study area than would have been obtained using the methods employed elsewhere in British Columbia. It is unknown what proportion of our estimate were non-resident Fishers, although it may be up to 1/3 of the individuals detected (that is, approximately 1/3 of harvested Fishers are non-resident juvenile age classes; Weir 2003).

Our use of non-invasive SCR sampling methods and the 'secr' package provided an economical method by which to estimate population density of a low-density species in a quick, efficient manner. However, the low number of recaptures and low probability of detection likely contributed to the relatively low precision of our estimate, despite the data not suggesting a poorly fit model. Increasing the number of sampling sessions and concentrating sampling in zones more likely to contain Fishers, such as lower-elevation biogeoclimatic zones, might have resulted in an improved detection rate, but would have limited the applicability of results to just those zones.

This study provides resource managers and trappers with a snapshot of local Fisher densities at the southern edge of the species' range in British Columbia that will help estimate sustainable harvest levels and refine the estimate of the provincial population of Fishers. Care must be taken in interpreting these results, however, given that the estimate is based on one winter of surveys and suffers from low precision. A single-year non-invasive survey also does not provide information on population demographics that are required to estimate sustainable harvest levels, nor does it capture variability in density that may occur through time. Finally, impacts such as mountain pine beetle infestation, forest harvesting, and large-scale fires are relatively recent in the study area, and habitat-related effects from these disturbances may still be occurring within the population.

ACKNOWLEDGEMENTS

Funding for this project was provided by BC Hydro's Fish and Wildlife Compensation Program-Coastal and the Habitat Conservation Trust Foundation. This project would also not have been possible without the support of M Manual and the Lillooet Tribal Council who provided dedicated field technicians, E Narcisse and C Leslie, for this project. Thanks go to E Lofroth who helped review initial drafts of this manuscript.

LITERATURE CITED

BORCHERS DL, EFFORD MG. 2008. Spatially explicit maximum likelihood methods for capture–recapture studies. Biometrics 64:377–385.

BRITISH COLUMBIA CONSERVATION DATA CENTRE. 2020. Conservation Status Report: *Pekania pennanti* pop. 5. Ministry of Environment and Climate Change Strategy. Victoria, British Columbia. Available at: http://a100.gov.bc.ca/pub/eswp/esr.do?id=351113 (accessed 19 August 2020).

DAVIS LR. 2009. Denning ecology and habitat use by Fisher (*Martes pennanti*) in pine dominated ecosystems of the Chilcotin Plateau [thesis]. Burnaby, BC: Simon Fraser University. 109 p.

EFFORD MG. 2018. secr: Spatially explicit capture-recapture models. R package version 3.1.5. Available at https://cran.r-project.org/package=secr (accessed 18 April 2018).

FORAN DR, MINTA SC, HEINEMEYER KS. 1997. DNA-based analysis of hair to identify species and individuals for population research and monitoring. Wildlife Society Bulletin 25:840–847.

*LOFROTH EC. 2004. Fisher (*Martes pennanti*) British Columbia Population Science Assessment Review, December 2004. Internal report available from Ministry of Environment, PO Box 9338 Stn Prov Govt, Victoria, BC V8W 9M1. 22 p.

MEIDINGER DV, POJAR J. 1991. Ecosystems of British Columbia. Special Report Series Number 6. Victoria, BC: British Columbia Ministry of Forests, Research Branch. 330 p.

MINISTRY OF ENVIRONMENT AND CLIMATE CHANGE STRATEGY. 2019. Ecosections - Ecoregion Ecosystem Classification of British Columbia [Spatial data]. Province of British Columbia. Victoria, British Columbia, Canada. Available at https://catalogue.data.gov.bc.ca/dataset/ecosections-ecoregion-ecosystem-

* Unpublished

classification-of-british-columbia (accessed 18 August 2019).

Ministry of Forests, Lands, Natural Resource Operations and Rural Development. 2019. Biogeoclimatic zones of British Columbia [Spatial data]. Province of British Columbia. Victoria, British Columbia, Canada. Available at https://catalogue.data.gov.bc.ca/dataset/bec-map (accessed 18 August 2019).

Naney RH, Finley LL, Lofroth EC, Happe P J, Krause AL, Raley CM, Truex RL, Hale LJ, Higley JM, Kosic AD, Lewis JC, Livingston SA, Macfarlane DC, Myers AM, Yaeger JS. 2012. Conservation of Fishers (*Martes pennanti*) in south-central British Columbia, Western Washington, Western Oregon, and California - Volume III: Threats assessment. Denver, CO: US Department of Interior, Bureau of Land Management. 65 p.

Powell RA, Zielinski WJ. 1994. Chapter 3: Fisher. In: Ruggiero LF, Aubry KB, Buskirk SW, Lyon LJ, Zielinski WJ, editors. The scientific basis for conserving forest carnivores: American Marten, Fisher, Lynx, and Wolverine in the western United States. Fort Collins, CO: United States Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. p 38–72.

Province of British Columbia. 2004. Fisher. Accounts and measures for managing identified wildlife – Accounts V.2004. Victoria, BC: Ministry of Forests and Ministry of Water, Land and Air Protection.

Province of British Columbia. 2008. Conservation framework results. Victoria, BC: Ecosystem Branch, Ministry of Environment, Available at: https://www2.gov. bc.ca/gov/content/environment/plants-animals-ecosystems/species-ecosystems-at-risk/setting-priorities/conservation-framework-results (accessed 19 August 2019).

Raine RM. 1983. Winter habitat use and responses to snow cover of Fisher (*Martes pennanti*) and Marten (*Martes americana*) in southeastern Manitoba. Canadian Journal of Zoology 61:25–34.

Raley CM, Lofroth EC, Truex RL, Yaeger JS, Higley JM. 2012. Habitat ecology of Fishers in western North America: A new synthesis. In: Aubrey KB, Zielinski WJ, Raphael MG, Proulx G, Buskirk SW, editors. Biology and conservation of Martens, Sables, and Fishers: A new synthesis. Ithaca, NY: Cornell University Press. p 231–254

Royle JA, Chandler RB, Sollmann R, Gardner B. 2014. Spatial capture-recapture. Waltham, MA: Academic Press. 577 p.

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

Weir RD, Corbould FB. 2006. Density of Fishers in the Sub-boreal Spruce biogeoclimatic zone of British Columbia. Northwestern Naturalist 87:118–127.

Weir RD, Lara Almuedo P. 2010. Fisher wildlife habitat decision aid. BC Journal of Ecosystems and Management 10:35–41.

Weir RD, Harestad AS, Corbould F.B. 2009. Home ranges and spatial organization of Fishers in central British Columbia. Canadian Field-Naturalist 123:126–132.

Weir RD, Lofroth EC, Phinney M. 2011. Density of Fishers in boreal mixed-wood forests of northeastern British Columbia. Northwestern Naturalist 92:65–69.

Weir RD, Lofroth EC, Phinney M, Harris LR. 2013. Spatial and genetic relationships of Fishers in boreal mixed-wood forests of northeastern British Columbia. Northwest Science 87:114–125.

Submitted 25 August 2020, accepted 14 February 2021. Corresponding Editor: Clayton Apps.