FISHER (*Pekania pennanti*) ARTIFICIAL REPRODUCTIVE DEN BOX STUDY

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Executive Summary

Fishers (*Pekania pennanti*) are a threatened species (S2) in British Columbia and are a high priority for conservation efforts. The species are also among the largest obligate tree-cavity users in North America and this study evaluated artificial den boxes for potential as reproductive denning habitat. Trees with characteristics of natural fisher dens are rare in managed landscape and changes to the forest landbase resulting from insect infestations, forest harvesting, large-scale fires, and hydro-electric development are likely to have further decreased the supply of these elements. This fifth and final report on the study details monitoring results during the last year of the project and summarizes fisher use of den boxes over the project life.

While marten (*Martes martes*) in the United Kingdom have been observed using artificial dens for reproduction, this is the only study that has documented fisher use of artificial dens for reproductive habitat. Similar to the last three years, monitoring during the reproductive season in 2018 identified two den boxes that were used for reproduction with both boxes located in the Chilcotin portion of the study area. One of the den boxes had been used previously by the same female in 2015 while the other was first used in 2018. Overall, 8 females made 12 reproductive uses of 9 den boxes as reproductive dens over the five-year project. Females were observed using the same and different den boxes both within and between years. Over the 5 years, an average of 1.6 kits per litter were observed on video at den boxes.

This project also provided opportunities for learning resulting in the den box design being updated to help protect kits. In 2017, a male fisher was observed chewing the entrance of a den box open sufficiently to allow entry and the killing of two kits. This is the only documented case of infanticide by fishers, although it has long been theorized that females choose dens with entrance sizes that exclude the larger male fishers for this reason. This incident helped identify a design flaw in the structures that has now been addressed. Squirrel chewing damage on plywood at the entrance of den boxes had enlarged the entrances of approximately 20% of structures and likely facilitated the male's entry into this den box. Solid wood moldings were subsequently fastened around the door openings and these did not show any evidence of squirrel damage over the period between June 2017 – 2018.

Other activities in this year included assessing natural fisher den trees for structural integrity and developing an estimate of den tree longevity for use in habitat supply modeling. The den trees included 11 cottonwoods (*Populus balsamifera ssp. trichocarpa*), 7 trembling aspens (*Populus tremuloides*), 4 lodgepole pines (*Pinus contorta*), 4 balsam poplars (Populus balsamifera), and 1 Douglas-fir (*Pseudotsuga menziesii*). Half of the trees were still functional as den trees, and, collectively, the trees had lasted at least 13 years since being first discovered. I lacked sufficient numbers of individual species for analysis, therefore, all *Populus* trees were lumped for the Kaplan-Meier survival analysis. *Populus* den trees lasted a mean of 16 years since being found and the median survival expectancy was 20 years. If we assume that den trees were discovered at the midpoint in their usable life, a component of *Populus* den trees may be viable for up to 40 years.

The project videos continue to provoke interest and now have a combined 34,734 views on Youtube™. After viewing the videos and soliciting project information, den boxes have been constructed and installed by the Toronto and Region Conservation Authority, Alberta Environment and Parks, in Minnesota, USA, and at the Site C Hydroelectric development in BC. Local dissemination of project information has taken place through presentations at Fisher Habitat Workshops in 100 Mile House (2020), Williams Lake (2019), Quesnel (2019), and Williams Lake (2018). In May 2019, I also presented the results of the den box project to wildlife researchers at a Mesocarnivore conference on Vancouver Island.

Lastly, the den boxes in this study have largely been placed in locations that appear to have sufficient habitat to sustain the local fisher population. Installing den boxes in locations where den trees are lacking in abundance would provide a more rigorous test of their utility as a conservation tool. Areas of BC where large-scale fire and/or salvage forest harvesting have impacted fisher habitat may provide suitable locations for such an evaluation.

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Introduction

Fishers (*Pekania pennanti*) are forest-dependent carnivores in 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, make them susceptible to changes to the forested landbase resulting from hydro-electric development, forest-harvest activities, and oil and gas development. As such, fishers are considered a species at risk under the Identified Wildlife Management Strategy and are red-listed (S2) in British Columbia (BC Conservation Data Centre 2020).

Fishers are a high priority for conservation efforts, as they are considered rank 2 under Goal 3 of the provincial Conservation Framework: Maintain the diversity of native species and ecosystems. Fishers are also the largest obligate tree-cavity user in North America, requiring trees that have cavities >30 cm inside diameter as reproductive dens during the rearing period (Weir and Corbould 2008). In British Columbia, reproductive dens are found in large-diameter black cottonwood (*Populus balsamifera ssp. trichocarpa*), balsam poplar (*Populus balsamifera*), trembling aspen (*Populus tremuloides*), lodgepole pine (*Pinus contorta*), and Douglas-fir (*Pseudotsuga menziesii*) trees (Weir and Corbould 2008, Weir 2009, Davis 2009), which are most common in late-successional ecosystems. The development of trees that support suitable cavities for fishers is uncommon and these critical habitat elements are rare in sub-boreal landscapes (Calabrese and Davis 2010, Davis 2012).

A decrease in the supply of denning structures may impact on the ability of landscapes to support sustainable populations of fishers. Experimental manipulation of cavity abundance in British Columbia found that tripling of the abundance of cavities using nest boxes resulted in a comparable increase in the total density of bird and mammal nests (Aitken and Martin 2012). Similarly, the addition of nest boxes in temperate forests of Mexico resulted in increases in the number of secondary cavity nesting birds in both mature and young forests (Lima and Garia 2016).

This project provides a unique opportunity to apply the knowledge gained from research funded by the Fish and Wildlife Compensation Program and the Habitat Conservation Trust Foundation (e.g., Davis 2012, Davis and Weir 2011, Weir 2000, Weir and Corbould 2008) to build recovery tools for fishers in areas where their habitat has been impacted. At a broad scale, the Bridge River watershed and Cariboo-Chilcotin are rated as having medium to high capability for fishers (Lofroth 2004). Habitat impacts from hydro-electric development, mountain pine beetle, large-scale fires, and salvage harvesting in these areas likely removed many of the large, cavity-bearing trees that fishers require for reproductive dens. A decrease in the supply of critical denning structures may impact on the ability of landscapes to support sustainable populations of fishers.

Previous work on fishers in these areas (Davis 2012, Calabrese and Davis 2010) has estimated that there are approximately 0.5 trees/ha with external features of reproductive dens in the remaining high value denning habitat. High value denning habitats are older stands that are becoming increasingly rare in the landscape. Further, even where present, not all den trees with external features characteristic of reproductive dens will contain a cavity large enough for fisher to use. The loss of denning opportunities may be affecting recruitment rates within the population and, therefore, the ability of the population to sustain itself. To potentially mitigate the impacts of resource development projects on fishers and their reproductive habitat, an increase in the supply of reproductive dens may be required. Work in the United Kingdom has found that artificial denboxes are used by pine marten (*Martes martes*) for reproduction in managed forests where the supply of natural denning habitat is low (Messenger *et al.* 2006, Croose et al. 2016). This project demonstrates that a similar structure can provide reproductive habitat for fishers in British Columbia.

Goals and Objectives

The objectives of this multi-year project were four-fold. Firstly, develop and install a den box design that accommodates fisher reproductive needs. Secondly, assess the extent of fisher use of the den boxes for reproduction. Thirdly, analyze attributes affecting the successful use of den boxes by fishers. Lastly, collect and analyze information on natural den tree longevity to aid in predicting the supply of natural den sites. Information from this project will provide land managers with better data upon which to evaluate mitigation options to augment reproductive habitat for this species.

Study Areas

This project is composed of several study areas in the central interior of BC. The 990-km² Bridge Watershed study area lies within the Gun, Tyaughton, and Yalakom drainages to the northwest of Lillooet, BC (Appendix 1). The Cariboo and Chilcotin study areas have a much wider distribution occurring between 100 Mile House and Williams Lake and between Horsefly and the Fraser River and Anahim Lake (Appendix 2).

The Bridge Watershed occurs within the Southern Chilcotin Range and Central Chilcotin Range ecosections. The area is dominated by the Interior Douglas-fir (IDF), Montane Spruce (MS), and Engelmann Spruce - Subalpine-fir (ESSF) biogeoclimatic zones with a small amount of high-elevation and treeless Interior Mountain-Heather Alpine zone (Meidinger and Pojar 1991). The study area encompasses portions of 3 registered traplines, occurs within the traditional territory of the St'át'imc First Nation, and is located at the southeastern edge of the distribution of fishers within the province. The area is mountainous with broad low valleys dominated by mixed stands of Douglas-fir (*Pseudotsuga menziesii var glauca*), hybrid spruce (*Picea engelmannii x glauca*), lodgepole pine (*Pinus contorta*), and trembling aspen (*Populus tremuloides*) while at higher elevations coniferous species such as hybrid spruce and subalpine fir (*Balsam lasiocarpa*) dominate. Fisher habitat in this area occurs primarily at low to mid elevation habitats in the IDF and MS biogeoclimatic zones.

The Chilcotin portion of the study area occurs west of the Fraser River on the Chilcotin Plateau in the traditional territory of the Tŝilhqot'in First Nation where forests are dominated by seral stands of lodgepole pine, hybrid spruce, and trembling aspen. Douglas-fir stands are patchily distributed at lower elevations in mixed and pure stands. Several biogeoclimatic zones are present including Sub-boreal Pine Spruce (SBPS), MS, and IDF. In the SBPS and MS, lodgepole pine is the leading species in the tree layer of most stands with white spruce and trembling aspen leading occasionally (Meidinger and Pojar 1991).

The Cariboo portion of the study area is located east of the Fraser River on the Cariboo Plateau in the traditional area of the Northern Secwepemc First Nation. The study areas are located in the Sub-boreal Spruce (SBS) biogeoclimatic zone east of Williams Lake and in the IDF biogeoclimatic zone west of 100 Mile House (Meidinger and Pojar 1991). In the IDF, Douglas-fir is the dominant forest cover but seral stands of lodgepole pine and trembling aspen are common and wetter sites are dominated by hybrid spruce. The SBS is dominated by hybrid spruce and subalpine fir with lodgepole pine, trembling aspen, and Douglas-fir forming large seral stands across the zone.

Project Background

Den boxes were designed, constructed, and installed between fall 2013 and fall 2014 (Davis 2014, Davis and Horley 2015). Two den box prototypes were first tested for thermal properties prior to being installed in the field. The two designs were a solid wood design with sides constructed of 38 mm thick spruce (laminated 2 x 6" lumber) and a layered plywood design (sides composed of two 19 mm thick pieces of plywood and a 19 mm rigid foam core). The inside dimensions were 28.5 cm by 28.5 cm with a box height of 95 cm. Both the lids and bottom were constructed of the same materials as the sides. A circular 10 cm diameter opening was created near the top of each box and 15 cm of wood shavings were placed in the bottom. Temperatures inside the solid wood and insulated plywood designs were compared over a 2-week period in early April when fishers typically use natal dens. A 7.5 W bulb was used in each design to provide a heat source that would represent the heat generated by fisher kits. The insulated design had greater buffering capacity than the solid design with cooler daytime and slightly warmer nightly temperatures. The solid design more closely tracked ambient temperatures outside the boxes, and at times the inside of the structure had warmer daytime temperatures than ambient temperatures, which could potentially result in heat stress for young kits. Based on these results, the insulated plywood design was chosen to proceed with for the project.

Female fishers are selective for the entrance dimensions to reproductive dens, presumably to exclude larger predators, including male fishers. The den box design uses a rectangular opening (7 x 12 cm) to mimic the size of entrance holes at natural fisher dens observed in the field (Davis 2009, Weir and Corbould 2008, Weir et al. 2012). The outsides of the boxes were treated with a brown coloured water-based stain to provide protection from precipitation, and 15 cm of wood shavings were placed in the box to improve its insulating properties (Davis 2014).

Twenty-five insulated den boxes were installed on trees in the Bridge River Watershed in the fall of 2013. The boxes were hung using plastic coated wire and clamps at approximately 3 m from the ground following the installation procedures of Messenger et al. (2006). In December 2013, lure was applied to jute string attached to the bottom of each box to increase the probability of fisher visiting the site. Each box had a hair snagger at the entrance and 10 trail cameras were rotated monthly between the boxes for monitoring. Over the winter of 2013-14, nine additional den boxes were installed on trees in the Cariboo-Chilcotin using funds donated by Davis Environmental Ltd, West Fraser Mills Ltd, and Tolko Industries Ltd in anticipation of the project being funded by HCTF in 2014-15. In 2014 HCTF became a funding partner leading to an additional 20 den boxes being constructed and installed in the Cariboo-Chilcotin.

In 2014 – 15, we also compared the thermal properties of den boxes in the field with nearby known fisher den cavities. We placed paired temperature probes inside and outside of 2 known fisher den trees and 2 nearby den boxes. Probes were placed inside at the bottom of den boxes and tree cavities and outside on the north side of the box or tree. We compared the daily low temperatures over 18 days inside and outside of den boxes and den trees. Both the fisher den trees and artificial den boxes had significantly warmer temperatures inside the tree/structure than ambient temperature. The sample size was small; however, den trees and den boxes had similar differences in temperature between inside and outside the structures (approximately 2° C). Mixed results were seen when comparing inside temperatures of the den trees and den boxes. One den box was significantly warmer inside than the closest den tree, while another den tree was significantly warmer than the closest den box (Davis and Horley 2015).

Over the period between 2014 – 2017, 6 different females used 8 den boxes for giving birth to or raising kits during the reproductive season (late March – June). The total number of kits observed at den boxes during this period was 15 yielding an average of 1.7 kits per litter.

Methods

I used a combination of motion detection cameras, hair snaggers, and observations of wildlife sign at den box locations to monitor for fisher use. A wildlife permit was obtained to allow the collection of hair samples (VI13-91889). Sticky pads that were fastened to the top of the box entrance allowed us to verify use at den boxes where no camera is present. Pads with hair were sent to a commercial genetics laboratory (Wildlife Genetics International) for analysis of species, sex, and individual identity. The combination of video and DNA evidence allowed me to tally the number of visits to each structure. During monitoring in the reproductive period, I also examined the interior of each den box for signs of reproductive use using a GoPro™ camera to capture any current evidence of use. Den boxes that were being used for reproduction had a trail cam installed to help document fisher use and reproductive parameters.

Each glue pad that had collected a hair sample was removed, covered it with plastic paper, and then stored it in a paper envelope under dry conditions for processing by the laboratory. Hair and follicle samples were sent 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 (with the number of hairs estimated) used instead of clipping roots for DNA extraction. Where extraction required removal from the glue pad, a commercial solvent was used. 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 et al. 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 first pass of 8 markers on the samples. A clean-up phase reanalyzed data points that were weak or difficult to read, producing a set of samples with complete 8-locus genotypes.

At each location, data associated with a medium-sized territorial carnivore detection station was collected (BC Ministry of Environment Lands and Parks 1998). This information was analyzed with the data on fisher use of the structures to identify factors influencing fisher use of artificial den boxes.

I also visited known fisher den trees in the Chilcotin and Williston areas. Each tree was assessed to determine if it was still functional for fisher reproductive use (i.e. standing and cavity integrity appeared intact). A Wildlife Tree Assessment form was completed for each tree still standing (BC Ministry of Environment Lands and Parks 1998). Additional data on den tree longevity from the Peace region of BC was provided by Inge-Jean Hansen (BC Ministry of Forest Lands Natural Resource Operations, Senior Wildlife Biologist, North Area). The data was analyzed using package Survival in R (Therneau 2020) to determine the longevity of den trees and aid in projecting the habitat supply for this critical habitat element (R script – Appendix 3).

Results and Outcomes

The analysis of hair samples from the 2018 late winter and reproductive denning seasons identified 21 fisher samples out of the 21 samples submitted. It is important to note that during this final monitoring season, we assessed each sample for probability of being a fisher and did not include any samples with a high probability of being from other species. Over the 5-year project, marten (*Martes americana*), red squirrel (*Tamiasciurus hudsonicus*), and northern flying squirrel (*Glaucomys sabrinus*) were the other species most frequently detected at den boxes (Table 1). In 2018, I also identified 9 occasions where fishers were detected by trail cameras and no DNA was found. Using the total of 30 detections in 2018, fisher detection rates varied from 0.08 – 0.21 detections/sample session/den box and this range of detection rates was relatively consistent over the 5 year project life (mean = 0.11, SE = 0.01, n = 28, range: 0.03 – 0.21 detections/sample session/den box). Out of the 30 fisher detections in 2018, eleven different individuals left DNA at the den boxes. Similar to the first four years of the study, the den boxes were selective by sex, with all 11 being identified as female. Out of the 11 fishers in 2018, only 3 are individuals not previously identified. The total number of fishers identified to individual identity using DNA over 5 years is 34 (28 female and 6 male) (Table 1) and the total number of den boxes with a fisher detection (either DNA or video evidence) over the projects 5-year lifespan is also 34 (Appendix 1 and 2).

Table 1. Species detected at fisher den boxes using DNA between 2014 – 2018 (Sample sessions = # den boxes x # sampling occasions). Results include the previous winter monitoring and subsequent reproductive denning season. Only fishers were analyzed for individual identity and sex (Females = F, Males = M).

Year	# Sample sessions/ samples submitted	Species detected	Number detections	Individuals identified / Sex
2014	175 / 5	Fisher (*Pekania pennant*)	2	2 / 2 F
		Woodrat (*Neotoma cinereal*)	1	
2015	378 / 75	Fisher	43	14 / 12 F, 2 M
		Marten (*Martes americana*)	9	
		Flying squirrel (*Glaucomys sabrinus*)	9	
		Red squirrel (*Tamiasciurus hudsonicus*)	4	
		Black bear (*Ursus americana*)	1	
2016	318 / 66	Fisher	28	12 / 9 F, 3M
		Marten	8	
		Flying squirrel	3	
		Red squirrel	21	
		Black bear	1	
2017	265 / 39	Fisher	26	10 / 8F, 2M
		Marten	4	
		Red squirrel	8	
		Black bear	1	
2018	265 / 21	Fisher	21	11 / 11F, 0M
Totals	1401 / 206	Fisher	120	34 / 28F, 6M

During the 2018 reproductive season (April – June), I identified 8 female fishers that had the potential to be or were known to be reproductive (i.e. ≥2 years old and known to be alive during the denning season or had kits born in the denning season; Table 2). Out of the 8 females, 4 made short or undetermined duration use of a den box (1-2 detections by DNA and/or camera). Four other females appeared to make a reproductive denning attempt (>2 detections on consecutive days or multiple observations at the same den box) and 2 of these individuals were observed with kits (Figure 1 – 2). Two other females that were not verified as being reproductive also made short term use of den boxes during the reproductive season.

Table 2. Female visits at den boxes during the 2018 reproductive denning seasons (April – June) in the Bridge River and Cariboo-Chilcotin areas of British Columbia. Denning behavior is rated by level of activity and presence of kits (1: 1-2 detections based on DNA and/or single video; 2: >2 detections based on DNA and videos of female entering den; 3: kits observed at den). Breeding interactions indicated where a larger fisher was observed on video at box interacting with a female inside.

Female	Den box	Denning behavior	# kits seen	Breeding interactions observed	Comments
F03	DB18	1		No	DNA collected April 4.
F03	DB19	1		No	DNA collected April 4.
F05	DB22	1		No	DNA collected April 3
F14	CB7	3	1	No	DNA collected April 12 and June 20. Video of female and kit entering box April 27. Female and kit leave May 12.
F17	DB24	2		No	DNA + Video female entering box April 17, 29, May 4, 12, June 4.
F20	CB4	2		Yes	DNA collected May 15. Multiple videos female in den March 29 – April 13. Male and female interacting outside den April 4.
F22	CB5	1		No	DNA collected April 12
F23	CB291	1		No	DNA + video May 16
F24	CB286	3	2	No	DNA + Video of female and kits May 20 – June 2; June 13-16.

Two females (F17 and F20) made multiple visits (>2) to den boxes (Table 2). Female F20 was observed at a den box that had been used in 2017 to raise a kit and had video evidence of sustained use at the same den box between March 29th to April 11th, 2018. Female F20 was observed entering and leaving multiple times over this period and having an interaction with another larger fisher on April 4th. The interaction started on top of the box and continued on the ground based on audio from the camera. After 25s the female was observed back on camera peering back at the ground while vocalizations continued. On April 11th, a fisher was observed leaving the box; however, I could not identify if she had a kit due to the camera angle.

Figure 1. Photograph of female bringing the first of two kits to CB286 on May 20th, 2018.

Figure 2. Photograph of two kits and female outside CB286 on June 15th, 2018.

A monitoring visit that included video of the box interior on April 12th did not show any kits. The female returned to use the box for April 12th – 13th and no kits were observed on video during that period. There were no other detections of F20 during the remainder of the reproductive season. Similarly, Female F17 used den box D24 multiple times over the breeding season but no kits were observed on video.

Out of the two den boxes verified as being successfully used as a reproductive den in 2018, one had been used in a previous year. Female F14 was observed bringing one kit to den box CB7 on April 27th and leaving with the kit May 12th, 2018. The den box was not used after that time interval and F14 did not leave DNA at any other den boxes in 2018 (Table 2). However, the same female had used den box CB7 in 2015 as a natal den for 2 kits and then returned to use the box as a maternal den in the same year (Table 3). Female F24 and two kits used a den box in the Chilcotin as a maternal den for two periods (May 20 – 24 and May 26 – June 14th) (Table 2) (Photographs 1 and 2). That den box had not been previously been used for reproduction; however, the same female was detected there in June 2017 making short term use of the structure.

Over the 5 denning seasons, 6 different reproductive females made short duration use of den boxes (Denning behavior = 1; Tables 2 and 3) while 3 females showed evidence of more sustained use of den boxes where no video evidence of kits was observed (Denning behavior = 2). Eight females made reproductive use of 9 den boxes that was verified by kit observations; however, individual identity was available for only 7 individuals. In 2017, one female at den box DB4 and 2 kits were observed in April but did not leave DNA due to chewing damage on the entrance and the hair snagger by an infanticidal male fisher. Female F03 used two different den boxes in the 2016 reproductive season and one of the same den boxes again in 2017. Two other females had 2 reproductive uses, with F06 using two different den boxes in 2016 and 2017 while F14 used the same den box in two reproductive denning seasons (2015 and 2018). By den box, 9 den boxes had 12 reproductive uses that were verified by kit observations. There was a total of 18 kits observed over the five reproductive seasons and the average number of fisher kits/year/ female observed is 1.6 (n = 11, SE = 0.20, Tables 2 and 3).

The number of reproductive fishers and attempted denning each year is shown in Table 4. Over the 5 reproductive seasons, between 1 – 8 different females where classified as reproductive and between 0 – 4 denning attempts were made. Based on these results, the proportion of reproductive females attempting denning using a den box is 54% and the proportion of reproductive females successfully reproducing is 42%. Of the reproductive denning attempts in den boxes, 76% were successful and only one documented a reproductive failure over the 5 denning seasons (kits known to be present but killed by a male fisher).

The infanticide event at den box DB4 in 2017 helped identify a flaw in the original design that was addressed by installing a solid wood molding around the door of all den boxes. Squirrel chewing damage had enlarged the entrance at 21% of structures, facilitating the entry of larger animals which can include male fishers. An assessment of the den boxes in June 2018 found that none of the solid wood door frames had sustained any chewing damage.

Table 3. Female visits at den boxes over the 2014 – 2017 reproductive denning seasons (April – June). Denning behavior is rated by level of activity and presence of kits (0 – no detections during breeding season but ≥2 years old and known to be alive; 1 – presence of DNA and/or single video; 2 – DNA and multiple videos of female entering den; 3 – kits observed at den). Denning behavior is only noted for females known to be ≥2 years old based on capture history or successful reproduction. Breeding interactions indicated where a larger fisher was observed on video at box interacting with a female at a den box. Den boxes with a "CB" are in the Cariboo-Chilcotin and those with a "DB" are in the Bridge Watershed areas of British Columbia.

Year	Female	Den box	Denning behavior	# kits seen	Breeding interactions observed	Comments
2015	F03	DB10	2		No	DNA + Fisher on video April 15, back on May 12, 17 and enters den box May 21
	F04	DB23	3	1	Yes	DNA + Fisher on video March 21 – April 8 and leaves with kit. Male arrives on March 29 and spends approximately 18 hours interacting with female. Female returns with kit on April 19, leaves April 20. Female brings kit back May 31 - June 2.
	F05	DB24	1		No	DNA + Fisher enters box on video May 8
	F06		0			Denning opportunity but no detections.
	F14	CB7	3	2	No	DNA + Female first observed on video March 31. Kits seen inside box 14 April. Returns with kits June 1 – 8.
2016	F03	DB20	3	1	No	DNA + Female and kit enter on April 27. Female last observed on video May 4
	F03	DB10	3	1		DNA + Female arrives with kit May 30.
	F05		0			Denning opportunity but no detections.
	F06	DB24	3	2	No	DNA + Female and 2 kits in box on May 21 - 25
	F13	CB289	3	3	No	DNA + Female observed on video between April 28 – May 11. Gopro footage shows 3 kits inside box on May 19.
2017	F03	DB10	3	1		DNA + Fisher and kit May 7-9
	N/A	DB4	3	2	No	Video of female arriving April 18. Female leaves den April 25, male arrives and chews open box door, kills 2 kits. Female stays at den till May 2. GoPro footage May 3 shows no remaining kits inside den.
	F05					Denning opportunity but no detections.
	F06	DB23	3	2	No	DNA + video female and kits May 31 – June 2
	F14		0			Denning opportunity but no detections.
	F17		0			Denning opportunity but no detections.
	F20	CB4	3	1	Yes	DNA + Female and 1 kit at box April 1-12. Male interacting with female April 10-11. Female on video entering box April 22.

Table 4. Number of reproductive aged fishers, denning attempts, and successful dens using den boxes in the Bridge River and Cariboo-Chilcotin areas of British Columbia between 2014 - 2018.

Year	# Known reproductive females	# Denning attempts	# Successful dens
2014	1	0	0
2015	5	3	2
2016	5	3	3
2017	7	4	3
2018	8	4	2
Average (SE)	6.0 (0.6)	3.3 (0.2)	2.5 (0.3)

The site characteristics of den boxes used for reproduction are shown in Table 5. Six out of 9 of the den boxes were in the Interior Douglas-fir biogeoclimatic zone, and three boxes were located in the Sub Boreal Pine Spruce zone. In general, den boxes used for reproduction were on gentle slopes (<15%), at lower mesoslope positions, and all were in structural stage 6 and 7 stands. Comparisons of site characteristics at reproductive den boxes versus boxes not used for reproduction did not identify any significant (α=0.10) predictive variables for den boxes where there was reproductive use (Tables 5 – 11).

I assessed the status of 26 natural fisher den trees from previous fisher studies in BC (Davis 2009, Weir 2000, personal communication with I. Hansen, Senior Wildlife Biologist, North Area) (Appendix 4). The majority of trees examined were cottonwood (11) (Populus balsamifera ssp. trichocarpa), followed by trembling aspen (7) (Populus tremuloides), lodgepole pine (4) (Pinus contorta), balsam poplar (3) (Populus balsamifera) and Douglas-fir (1) (Pseudotsuga menziesii). Of the trees, only 13 appear to be in a state still usable by fishers for reproduction (i.e. still standing and den cavity integrity appears intact). Out of the trees no longer suitable for a reproductive den, 8 had fallen (62%), 3 had den cavities that were compromised (23%), and two had burned and fallen during wildfires (15%). Overall, den trees appeared viable for an average of >13 years (n = 26, SE = 1.1) after being first discovered. Table 12 provides a breakdown of average survival time by tree species.

Due to low sample sizes of den trees by species, all 21 Populus genus den trees were grouped for survival analysis. Out of this group, 8 of the trees had fallen and 2 had compromised den cavities. The mean survival time was estimated at 16 years (n = 21, SE = 1.4) while the median survival time was estimated at 20 years (Figure 1).

Table 5. Site characteristics and number of years used for eight den box sites in the central interior of British Columbia used by fishers for reproduction up to 2016. Site descriptions based on Describing Ecosystems in the Field (Province of BC 1998).

Denbox	# Years used	Elevation (m)	Aspect	% Slope	Biogeoclimatic zone	Mesoslope	Structural Stage	% Tree cover	% Shrub Cover	Dominant tree species
CB7	1	986	E	12	IDFdk4	Mid	7	30	20	Douglas-fir, lodgepole pine
CB4	1	1191	S	0	SBPSxc	Toe	6	60	15	White spruce, Trembling aspen, lodgepole pine
CB289	1	1138	W	5	SBPSxc	Toe	6	25	30	Salix spp., Betugla glandulosa
DB23	2	996	SE	10	IDFdc	Toe	6	60	50	Douglas-fir, paper birch
DB10	2	1145	Flat	0	IDFdc	Toe	7	40	40	Shepherdia canadensis, Salix spp.
DB4	1	857	Flat	0	IDFdc	Depression	6	60	60	Trembling aspen, paper birch
DB20	1	1149	SW	4	IDFdc	Lower	6	50	20	Shepherdia canadensis, Rosa spp.
DB24	2	1052	E	15	IDFdc	Lower	7	60	50	Acer glabrum, Cornus stolonifera
CB286	1	1105	W	8	SBPSmk	Toe	6	25	20	White spruce, Trembling aspen, lodgepole pine

Table 6. Comparison of continuous site variables at fisher den boxes used for reproduction.

	Reproductive dens			Other dens		
	Mean	Count	SE	Mean	Count	SE
Shrub cover (%)	36.7	9	5.5	31.3	44	2.8
Tree cover (%)	44.4	9	5.0	36.9	44	2.1
Slope (%)	6.3	9	1.8	8.6	44	1.4
Elevation (m)	1014	9	46.9	1076	44	21.0

Table 7. Reproductive use of fisher den boxes in different aspect classes (Flat: <5% slope; North: 134 - 271°; Southwest: 135 - 270°).

	Reproductive	Others	Total
Flat	5	19	24
North	2	8	10
South-west	2	17	19
Total	**9**	**44**	**53**

Table 8. Reproductive use of fisher den boxes in different biogeoclimatic zones (IDF: Interior Douglas-fir; MS: Montane Spruce; SBPS: Sub Boreal Pine Spruce).

	Reproductive	Other	Total
SBS	0	6	6
IDF	6	23	29
MS	0	4	4
SBPS	3	11	14
Total	9	44	53

Table 9. Reproductive use of fisher den boxes at different mesoslope positions (Low: depression, flat, and toe; Mid: lower slope; Upper: mid, upper, and crest).

	Reproductive	Other	Total
Low	5	19	24
Mid	2	10	12
Up	2	15	17
Total	9	44	53

Table 10. Reproductive use of fisher den boxes in different structural stages (4: pole/sapling; 5: young forest; 6: mature; 7: old).

Seral stage	Reproductive	Other	Total
4 + 5	0	5	5
6 + 7	9	39	48
Total	**9**	**44**	**53**

Table 11. Reproductive use of fisher den boxes in different stand types (Coniferous: <20% deciduous; Mixed: ≥20% deciduous component).

	Reproductive	Other	Total
Coniferous	4	29	33
Mixed	5	15	20
Total	9	44	53

Table 12. Average time for den trees to fall or have compromised cavities.

Tree species	Mean (years)	n	SE	Number fallen or compromised
Cottonwood	>16	11	2.1	6
Trembling aspen	>10	7	0.9	1
Lodgepole pine	>10	4	0.8	3
Balsam poplar	9	3	1.5	3
Douglas-fir	>12	1	na	0

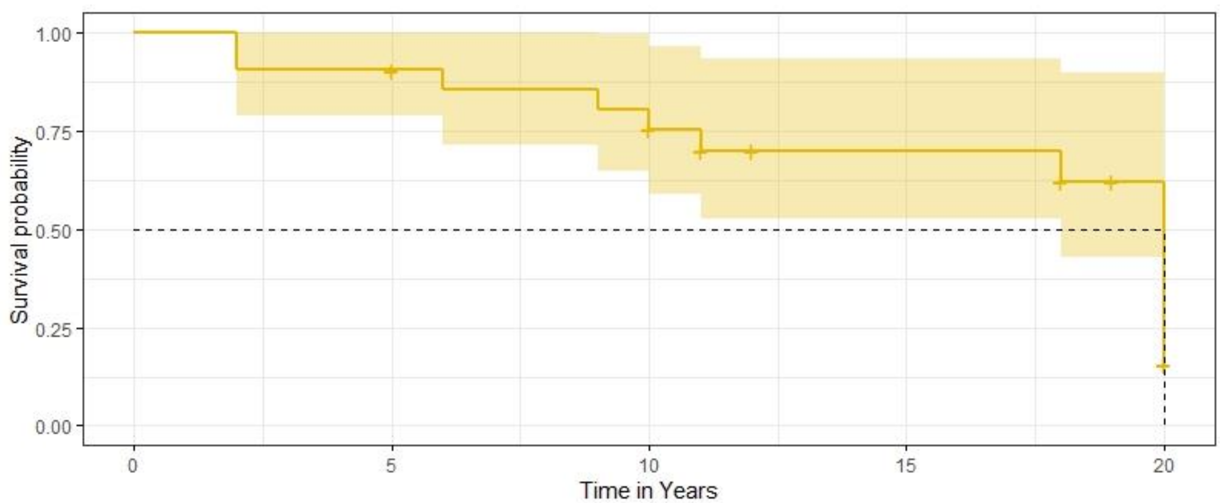

Figure 3. Survival curve for Populus species in British Columbia with individual confidence intervals (yellow shaded region). The dashed line indicates the median number of years that the den trees remain viable.

Discussion

Fishers are among the largest obligate tree-cavity users in North America, requiring trees that have cavities large enough to fit the female and up to 3 kits (Wier et al. 2012, Weir and Corbould 2008). The den must also have suitable entrance dimensions to prevent larger predators from entering and microclimatic conditions that help sustain the kits when the female is away foraging and breeding (Mathews et al. 2019). The den boxes used in this project were designed to replicate these crucial attributes of natural dens. The boxes have a relatively large internal diameter, are insulated to buffer extremes in temperature, and have entrance dimensions observed from natural dens in British Columbia (Davis 2009, Weir and Corbould 2008, Weir et al. 2012). Using 54 artificial den boxes in south-central British Columbia, this project has successfully documented female fishers using the structures to birth and raise kits over the last four out of five denning seasons. When all years are included, an average of 6 reproductive aged fishers in the project area had 2.5 successful reproductive dens per year and raising 1.6 kits per litter using the artificial den boxes. Females have been documented using the structures for both natal and maternal dens, with several females reusing den boxes both within a year and in different years.

I am aware of no other researchers documenting fishers using artificial den boxes for reproduction; however, den boxes have been used successfully by marten (Martes martes) in the United Kingdom (UK) (Messenger et al. 2006). Over 12 years of monitoring, Croose et al. (2016) documented between 0 – 20% of the den boxes in the UK being used by marten for reproduction on a yearly basis. In comparison, this project found that between 0 – 11% of den boxes were used for reproduction on a yearly basis when all 5 denning seasons are included. It is likely that the higher proportion of den boxes used by marten in the UK reflects, at least in part, a much lower availability of arboreal den cavities in the managed forests of the UK (Croose et al. 2016) compared to British Columbia. While there are still remnants stands of old forest in British Columbia, the supply of low to mid elevation old forest stands has decreased substantially across British Columbia due to the combined impacts of bark beetle infestations, forest harvesting, and wildfire (Price et al. 2020). Younger stands have a much lower density of potential den trees (Davis 2012, Calabrese and Davis 2010) and deploying fisher den boxes in areas that are deficient in natural den trees may result in a greater proportion of the structures being used. Such a deployment would also provide a test of the utility of den boxes as a conservation tool for fishers.

In other studies of fisher reproductive parameters, the proportion of breeding aged females that had successful reproduction is approximately 71% (Green et al. 2018). The proportion of breeding aged females using den boxes in this study is relatively low in comparison at 42%. There are several potential explanations for this difference including an inability to follow all reproductive females present throughout the denning season, the availability of suitable natural den trees in the landscape, and a naturally lower reproductive rate for fishers in the study area. This study relied on passive methods to document reproduction, such as DNA through hair samples and video evidence, whereas

Green et al. (2018) included a wider variety of sources in their study including monitoring known dens in the wild, observing females in captivity, analysis of reproductive tracts, and assessing teat condition in live animals. Having the ability to follow radio tagged animals would have provided greater certainty in determining the proportion of successful reproductive attempts in this study since some reproductive individuals may have successfully used trees for dens.

Surveys of potential den trees in the project areas estimated 0.5 trees/ha with characteristics of natural fisher den trees (e.g. tree species conducive to heart rot, large diameter, presence of heart rot cavities, and suitably sized entrances for fishers) (Davis 2012, Calabrese and Davis 2010) and the density of these stands may not be limiting for reproductive habitat in the study area at this time. Fishers in the project area may also have lower reproductive potential due to habitat constraints. Research on the fisher populations in British Columbia found that the proportion of fishers reproducing in the Columbian population was 0.54 and litter sizes averaged 1.7 kits/litter (Lofroth et al. 2018). In contrast, the Green et al. (2018) review of reproductive parameters found that the proportion of females reproducing was 0.71 and an average of 2.3 kits per litter were produced in wild populations Given these factors, the successful reproductive rate in this study may not be out of the ordinary for this population and the den boxes appear to provide acceptable reproductive habitat for female fishers.

Den Box Use across Project Years

When fisher use of den boxes across all reproductive seasons are compared, the only year without reproduction was during the first year of monitoring when the den boxes were newly installed. The monitoring protocols were changed over the 5 years largely in response to the number of den boxes where fishers were being detected. These changes include no bait being used in the first year (2014), bait being added to every box in 2015 in an effort to increase fisher detections, then decreasing numbers of boxes having bait attached inside the structures after 2015 (i.e. bait only used in boxes without a fisher detection), and finally no bait being used in any box during 2018. Over the same period, the number of monitoring visits during the winter decreased from 4 to 2 while 3 visits at 1-month intervals were conducted during all denning seasons (April – June). Despite these changes, average yearly detection rates remained very consistent between 2015 – 2018. Given this, time for fishers to discover den boxes may be more important in fostering fisher use of the structures than baiting the structures. Further, monitoring with just trail cameras and hair snaggers may be a cost-effective method of assessing the use of den boxes by fishers since it would not require frequent visits to the structures for baiting.

While we detected fishers at 63% of den boxes overall, some areas showed much greater success in both the number of detections and reproductive events. The Bridge Watershed and Chilcotin study areas had had much greater numbers of fisher detections and reproductive events than the Cariboo. Both locations had previous inventories or research on fishers (Davis 2003, Davis 2009, Davis and Weir 2020). In contrast, den boxes in the Cariboo had only 2 fisher detections over the five years den boxes were deployed in those areas. The placement of den boxes in locations east of the Fraser River depended on anecdotal information from local trappers on fisher presence. Given this, project areas that used recent inventory data on fisher presence likely benefited from this information, and the success of future deployments of den boxes would also benefit from first conducting fisher inventories in those locations.

Site Factors Influencing Fisher Use of Den Boxes

On an individual den box site basis, no variables had a significant relationship with reproductive use of a den box. The lack of significance for the variables in predicting reproductive use of den boxes likely stems from the deliberate placement of den boxes by an experienced researcher in locations more likely to be used by fishers (i.e. very limited testing of locations that did not appear to provide high quality fisher habitat). Further, den box placement was also constrained by the requirement of gentle terrain for installing den boxes (due to safety concerns during installation) and the avoidance of areas likely to be logged. Thus, most den boxes in this project have been placed in riparian forests with gentle terrain and where British Columbia has legislated requirements for forested reserves. Fishers have an affinity for riparian stands (Davis 2009, Weir 1995; Jones and Garton 1994; Jones 1991; Buck et al. 1983) making these locations good candidates for den box deployment. However, as stated previously, placing the structures in locations where recent inventories indicate female fishers are found is likely to be the most important factor influencing the likelihood of reproductive use.

Fisher Den Box Project Challenges and Lessons Learned

The 2017 cannibalism event in the Bridge Watershed helped to identify a shortcoming in the den box design. Squirrel chewing damage to the structures was documented over the course of the project and this damage caused the den box entrance dimensions to increase on a proportion of structures. Female fishers appear to select natural cavities with entrances that are just large enough for them to fit, which has been theorized as helping to prevent infanticide by male fishers (Powell 1993, Paragi et al. 1996, Mathews et al. 2019). The door molding added to the boxes in June 2017 appears to have addressed this problem with no boxes showing signs of squirrel damage on the moldings over the following year and no other instances of infanticide observed. Based on video and DNA evidence, the moldings do not appear to affect female fishers trying to enter the structures.

In 2017, the entrance to the structure was redesigned to include a solid wood jamb and molding as an upgrade to the original plan which increases the thickness of wood at the entrance and is replaceable if the entrance were damaged (Davis 2016). This upgrade to the design has been used on new den boxes installed to address habitat loss near the Site C dam in British Columbia and at a recent fisher den box research project in Minnesota (Personal communication with Michael Joyce, Natural Resources Research Institute, Minnesota, USA).

In addition to the 2017 cannibalism event, I documented male visits at 3 other den boxes where kits were known to be present. The 3 events occurred in late March – April 11th and involved male fishers spending 1 – 2 days interacting with females. The interactions were observed on video and varied from just vocalizations to physical interactions between the fishers. No video of copulations were recorded but much of the activity occurred off camera based on the vocalizations recorded. These interactions appear to be breeding attempts with both the timing and duration of the interactions consistent with the findings of recent research (Smith et al. 2020). Smith et al. (2020) found that the mean date of copulation for fishers was March 24th with 95% of male visits occurred before April 17th and breeding observed within an average of 3.1 days of the male locating the den. Ninety-six percent of male visits were documented at natal dens and males were much less likely to be observed at dens as the breeding season progressed (Smith et al. 2020). That study did not find any evidence of infanticide by males.

The infanticide event seen in this project during 2017 occurred on April 25th at a maternal den. Smith et al. (2020) did not document any breeding interactions at maternal dens and the April 25th date is also outside the period when 95% of male visits to reproductive dens were recorded. Infanticide committed by males is generally thought to support a *sexual selection* hypothesis (Agrell et al. 1998). Under this theory, the killing of an offspring results in the female stopping lactation and coming into estrus sooner than if she continued to nurse the young. However, this hypothesis is generally only thought to work in species that breed aseasonally, have long breeding seasons, or very short breeding cycles (Agrell et al. 1998). Fishers breed within 7 – 10 days of giving birth followed by delayed implantation, where the blastocyst does not implant in the uterus and development of the embryo is delayed to the following February. Given this, the killing of kits would not induce female fishers to come into estrus any sooner than dictated by the natural cycle.

Two other potential hypotheses for infanticide are the *exploitation* and *resource competition* hypotheses (Agrell et al. 1998). Infanticide that includes cannibalism, as seen here, is also seen in other species such as bears (Davis and Harestad 1996) and the exploitation hypothesis would attribute the behavior to the male gaining nutritional benefits from eating the kit. In this case, the male fisher killed the kits in early spring and prey at this time year may be more difficult to find, making the kits an attractive resource. Under the resource competition hypothesis, unrelated young are killed to increase resources available for the perpetrator or their offspring (Agrell et al. 1998). Smith et al. (2020) argued that for these last two hypothesis to be true, there should be evidence for male fishers attending dens later in the denning season after they return to pre-breeding condition (i.e. mid-May, Frost et al. 1997). This pattern of male attendance was not seen in a reintroduced fisher population in northern California, with male visitations tapering off sharply after April 4th and only one visit seen after mid-May (Smith et al. 2020). Based on this, the authors suggest that when infanticide occurs in fisher populations, it is likely pathological or maladaptive and difficult to predict (Smith et al. 2020). However, fishers in an introduced population may not be at densities that promote resource competition and by late May – June, many prey species have young that provide an abundant nutritional resource for fishers decreasing the attractiveness of a scarce resource like fisher kits. This study was conducted on an existing natural population that may be near the areas carrying capacity making the exploitation and resource competition hypotheses both possible and not mutually exclusive explanations for the behavior observed.

Fisher Den Tree Longevity

Half the natural den trees I examined in British Columbia had become no longer usable by fishers for reproductive dens due to tree fall or structural defects to the den cavity. Most of the den trees that were no longer useable had fallen (62%) or had compromised cavities (23%), similar to the results found by Edworthy and Martin (2013) who found that 90% of cavities were lost when the tree had fallen or the bowl had cracked in a study near Williams Lake, BC. Edworthy and Martin (2013) had sufficient trembling aspens with cavities to calculate Kaplan-Meier survival estimates for this species with the median survival time for live aspen estimated at >15 years. Due to small sample sizes of deciduous species in my study, I analyzed the combined *Populus* species used by fishers and estimated a median survival of >20 years after the tree was first discovered using the Kaplan-Meier estimator (Package Survival in R, Therneau 2020, Appendix 3). There are several potential reasons why the longevity estimate found here differs from that of Edworthy and Martin but the inclusion of cottonwood and balsam poplar with trembling aspen in the data is likely the greatest factor. Cottonwood trees can continue to grow well for up to 200 years and older (DeBell and Dean 1990) while trembling aspen usually do not live more than 150 years (USDA 2002). Further, Hiratsuka and Loman's (1984) comparison of age-decay relationships for aspen and balsam poplar found that aspen has a much more rapid decay relationship with age than balsam poplar. The larger number of cottonwood and inclusion of balsam poplar in my sample likely increased the longevity estimate for *Populus* fisher den trees.

It is important to note that Edworthy and Martin's estimate was based on finding and tracking newly excavated cavities whereas the fisher dens I analyzed were discovered by tracking female fishers to their den and the age of the cavity at that point was unknown. Assumptions can be made about when the dens were discovered relative to its lifespan to aid in estimating the longevity of viable cavities. If we assume that fisher den trees are discovered at the midpoint in their usable lifespan, these results suggest that a component of deciduous den trees may continue to be viable as reproductive dens for up to a 40-year period.

Maintaining a supply of cavity trees for fisher dens will require preserving sufficient trees over time that are spatially distributed to reflect the territorial nature of female fishers and their distribution in British Columbia. The BC Fisher Working Group has identified the proportion of female home ranges that should be retained in high value denning habitat at between 5% in the Sub-boreal Zone, 8% in the Dry Forest Zone, and 36% in the Boreal Zone based on the 75th percentile of fisher denning habitat in known home ranges from

British Columbia[1] (Figure 4). This project is in the Dry Forest Zone and female fisher home ranges require 232 ha of high-quality denning habitat out of a 3000-ha home range to meet the 75th percentile target. An analysis of the remaining high value denning habitat in the Dry Forest Zone found that the proportion of the zone meeting this target was only 6% of the total area[2]. Further, more than 75% of Dry Zone only meets the 25th percentile for denning habitat based on an analysis of 2020 GIS data. The other fisher habitat zones in the province have experienced similar declines in habitat[2].

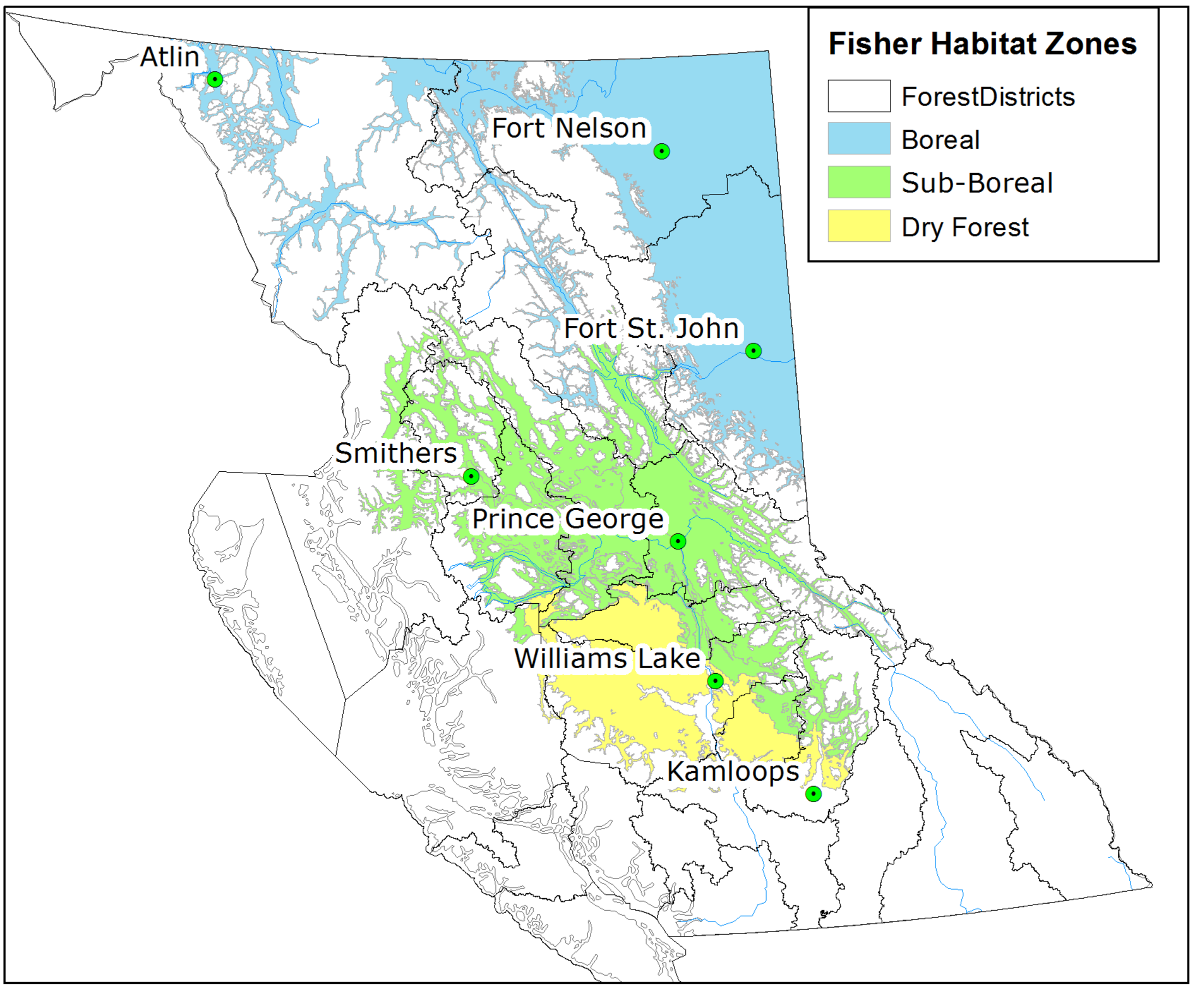

Figure 4. Fisher Habitat Zones in British Columbia. Image provided by the BC Fisher Working group. Accessed June 2020 [https://www.bcfisherhabitat.ca/habitat-tools/].

[1] BC Fisher Habitat – British Columbia Fisher Habitat and Forestry Web Module. Accessed June 2020 [https://www.bcfisherhabitat.ca/].

[2] Personal communication June 2020. Richard Weir, MSc, RPBio. Carnivore Conservation Specialist, BC Ecosystems Branch, Ministry of Environment and Climate Change Strategy.

Given the state of fisher habitat in British Columbia, landscape level modeling tools are required to ensure that denning habitat is present in sufficient fisher home ranges to help maintain viable fisher populations. Data driven models, such as MARXAN, that improve our ability to identify remaining critical denning habitat would be valuable in prioritizing fisher habitat for retention. Ideally, the models should include a spatially explicit component and incorporate the information derived here on den tree longevity to project den tree supply over time. Identifying and retaining areas with remaining high-quality denning habitat for retention may help meet current needs; however, planning for recruitment is also needed. Lastly, only half the den trees I surveyed had fallen at the time of the assessment. Increasing the number of known den trees and assessing known fisher den trees on a regular basis over a longer time period (e.g. assess every 5 years until at least 75% of the trees had fallen) would help provide additional data for modeling fisher den tree supply.

Communication and Outreach

In this final year of the project, dissemination of project information has taken place primarily through presentations at Fisher Habitat Workshops in 100 Mile House (February 2020), Williams Lake (December 10, 2019), Quesnel (February 28, 2019), and Williams Lake (June 28, 2018). In May 2019, I also presented the results of the den box project to wildlife researchers at the BC Mesocarnivore Conference on Vancouver Island (May 24, 2019). All presentations included recognition of my funding sources. The Youtube video series on the Fisher Denbox Study also explicitly recognizes the support of all project sponsors and includes a new summary video (Available at: https://www.youtube.com/watch?v=mwwRdVkQe9Y&t=31s). Currently the video series has almost 35,000 views. These videos have also precipitated a large-scale trial on the use of den boxes to augment fisher habitat in Minnesota, USA[3]. I have requested that anyone using this information reference the work on den boxes completed here in any extension they produce.

Within British Columbia, data from this project has been used to provide information on fisher whelping rates for population assessments and den boxes are being used as a strategy to offset habitat losses due to flooding for a hydroelectric dam. Fisher populations west of the Rocky Mountains in British Columbia are thought to be declining in abundance (BC Conservation Data Centre 2020) and the information on kit numbers observed at den boxes is being used in a research paper on fisher vital rates to inform management decisions (Lofroth et al. 2018). Fisher den boxes have also been deployed near Fort St. John to offset habitat losses at the Site C dam. The den boxes will supply valuable reproductive habitat and monitoring of the structures will test how well the technique works in the Boreal Fisher Habitat Zone. Finally, a manuscript on reproductive

[3] Personal communication with Micheal Joyce, Wildlife Biologist, University of Minnesota – Duluth. Information on the project can be found at: https://www.nrri.umn.edu/natural-resources-research-institute/news/fisher-boxes

den boxes for fishers is being prepared and will be submitted to a journal for publishing.

Recommendations

The fisher population in the interior of BC (Population 5: Columbian) have been recently downgraded to the provincial red-list (S2) due to the effects of habitat loss, low reproductive output, and low survival of offspring (BC Conservation Data Centre 2020). Determining if den boxes could reduce the effects of habitat loss may help in the recovery of this species in some areas of its range. Salvage harvesting after the mountain pine beetle epidemic and the impacts of large-scale fires has negatively impacted large areas of fisher habitat in the province. Recent research from the Chilcotin area of British Columbia has found that fisher presence was negatively associated with areas that were burned and that severe burns had the greatest impact[4]; however, the researcher also found that fishers still made some use of areas that were burned. This is supported by a study in the Sierra Nevada area of California, USA, which found that female fishers in that area did not avoid high severity fire patches and theorized that the animals were using the habitat for foraging, while denning and resting habitat was being used in adjacent unburned forest (Hanson 2015). That fire was relatively small (5422 ha) compared to the areas burned in British Columbia in 2017 (1.2 million ha) and 2018 (1.3 million ha)[5], and fishers are not likely to have persisted in severely burned areas that are very large and lack significant patches of residual forest. Although severe fire was characteristic of many locations that were burned in BC, there are also many areas of light to moderate burn where residual forest is still present, and fishers may be able to persist if critical resources are present. Likewise, some areas with extensive salvage harvesting may also retain fisher populations if critical resources, such as reproductive habitat, is present.

Testing the utility of den boxes as a conservation tool will require deploying the structures in areas that are known to be deficient in den trees such as those that have been impacted by salvage harvesting and large-scale fires. The Nazko area is one such location where two local trappers made complaints about forestry practices negatively impacting fisher habitat which the Forest Practices Board investigated and upheld (Forest Practices Board 2018). Much of the Nazko area was also subsequently burned in 2017. Historically the traplines consistently produced fisher; however, the trappers currently do not use these traplines due to the combined impacts of fire and forest harvesting on furbearer populations[6]. This project had 5 den boxes in areas adjacent to those traplines that collectively had low numbers of fisher visits over the project life and where one box was burned in the 2017 fires. However, one of the remaining den boxes (CB286 – Appendix 2) in the area was used in 2018 for reproductive denning and I theorize that this recent use

[4] Personal communication with Rory Fogarty, RPBio, MSc Candidate, Thompson Rivers University, Kamploops, BC.
[5] British Columbia Forest Fires Environmental Fact Sheets. Accessed June 2020 [https://www150.statcan.gc.ca/n1/pub/16-508-x/16-508-x2019002-eng.htm]
[6] Personal communication with Wayne and Leilah Kirsh.

was due to the fire decreasing denning opportunities in this area. If this is theory is correct, expanding the number of den boxes in fire and salvage harvesting impacted areas may allow fisher populations to persist and provide a test of the utility of this conservation technique.

Any study area chosen to assess the utility of den boxes as a conservation tool should be focused on low – moderate severity burns and/or harvested areas with moderate cut levels that retain a range of unburned and/or unharvested residual forest cover. I also recommend that two activities be completed prior to deploying den boxes. The first is conducting den tree surveys stratified by burn/harvesting intensity in the proposed area to verify that den trees are limited in abundance. Secondly, a DNA-based inventory should be completed to identify the locations that female fishers are currently occupying. Den boxes could then be installed in patches of residual forest across the entire area using a fisher home range size grid approach (30 km^2) with several boxes being placed in each cell. Monitoring for reproductive use of den boxes by females and whether den box presence results in expanded detections of females would form the basis of testing the technique as a conservation tool. Such an approach may also help answer the question of how much residual forest habitat is required to maintain viable fisher habitat.

Finally, gaining a greater understanding of how long artificial den boxes will last in the field and how long natural den trees remain viable would be valuable information for fisher conservation efforts. The den boxes installed as part of this project have now been in the field for 6-7 years and I recommend periodic follow up surveys to help determine the longevity of the structures. A survey of the existing den boxes at the 10-year point and every 5 years after would provide feedback for planning conservation efforts involving den boxes. Similarly, the information found here suggests that natural den trees could be viable for >40 years; however, half the trees I monitored were still standing and continued monitoring on the longevity of the trees would help improve the accuracy of the data for projecting the den tree supply. Similar to the den boxes, I suggest that monitoring the remaining den trees at 5-year intervals would provide the data needed to increase the precision of the longevity estimate.

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References

Agrell, J. Wolff, J., and H. Ylonen. 1998. Counter-strategies to infanticide in mammals: costs and consequences. Oikos 83: 507-517.

Aitken, K., and K. Martin. 2012. Experimental test of nest-site limitation in mature mixed forest of central British Columbia. J. Wildlife Management 76(3): 557-565.

Buck, S.G., C. Mullis, and A.S. Mossman. 1983. Final report: Corral Bottom-Hayfork Bally fisher study. Arcata (CA): Humboldt State University and USDA Forest Service.

B.C. Conservation Data Centre. 2020. Conservation Status Report: *Pekania pennanti* pop. 5. B.C. Minist. of Environment. Available: http://a100.gov.bc.ca/pub/eswp/ (accessed May 11, 2020).

BC Ministry of Environment, Lands and Parks. 1998. Species Inventory Fundamentals – Standards for Components of British Columbia's Biodiversity No. 1. V2. Available at: http://www.for.gov.bc.ca/hts/risc/pubs/tebiodiv/sif/assets/spifml20.pdf.

Calabrese, M. and R.L. Davis. 2010. Occurrence of den trees for Fisher (Martes pennanti) in the Sub Boreal Pine-Spruce Biogeoclimatic Zone in the Chilcotin area of British Columbia. Unpublished report prepared for West Fraser Mills, Williams Lake and BC Timber Sales – Cariboo Chilcotin Business Unit.

Croose, E. J. Birks, and J. Martin. 2016. Den boxes as a tool for pine marten Martes martes conservation and population monitoring in a commercial forest in Scotland. Conservation Evidence 13: 57-61.

Davis, H. and A. Harestad. 1996. Cannibalism by black bears in the Nimpkish Valley, British Columbia. Northwest Science. 1996; 70(2): 88-92.

Davis, R.L. 2016. Fisher (Pekania pennanti) artificial reproductive den box study; with 2018 addendum. Unpublished report prepared for Fish and Wildlife Compensation Program and the Habitat Conservation Trust Foundation.

Davis, R.L. 2013. Inventory of Fisher Populations and Reproductive Dens in the Bridge River Watershed – FWCP-Coastal Project # 12W BRG 01. Unpublished report for FWCP-Coastal, Burnaby, BC.

Davis, R.L. 2012. Inventory of Fisher Populations and Reproductive Dens in the Bridge River Watershed – FWCP-Coastal Project # 10W BRG 01. Unpublished report for FWCP-Coastal, Burnaby, BC.

Davis, R.L. and R.D. Weir. 2011. Inventory of Fisher Populations and Reproductive Dens in the Bridge River Watershed - FWCP-Coastal Project # 11W.BRG.01. Unpublished report for FWCP-Coastal, Burnaby, BC.

Davis, R.L. 2009. Denning ecology and habitat use by fisher (*Martes pennanti*) in pine dominated ecosystems of the Chilcotin Plateau. Thesis, Simon Fraser University, Burnaby, British Columbia, Canada.

DeBell, and S. Dean. 1990. Populus trichocarpa Torr. & Gray: black cottonwood. In: Burns, Russell M.; Honkala, Barbara H., tech. coords. Silvics of North America: Volume 2, hardwoods. Agric. Handb. 654. Washington, DC: Forest Service, U.S. Department of Agriculture: 570-576.

Edworthy, A., Wiebe, K., and K. Martin. 2012. Survival analysis of a critical resource for cavity-nesting communities: patterns of tree cavity longevity. Ecological Applications 22(6): 1733-1742.

Forest Practices Board. 2018. Timber Salvage Harvesting and Fisher Management in the Nazko Area. Complaint Investigation #16037. FPB/IRC/217. 11pp.

Frost, H.C., and Krohn, W.B. 2004. Postnatal growth and development in fishers. *In* Martens and fishers (Martes) in human-altered environments: an international perspective. *Edited by* D.J. Harrison, A.K. Fuller, and G. Proulx. Springer-Verlag, New York. pp. 253–263.

Green, R.E., Purcell, K.L., Thompson, C.M., Kelt, D.A., and Wittmer, H.U. 2018. Reproductive parameters of the fisher (*Pekania pennanti*) in the southern Sierra Nevada, California. J. Mammal. 99(3): 537–553. doi:10.1093/jmammal/gyy040.

Hanson, C.T. 2015. Use of Higher Severity Fire Areas by Female Pacific Fishers on the Kern Plateau, Sierra Nevada, California, USA. Wildlife Society Bulletin 39 (3): 497-502.

Hiratsuka, Y. and A. Loman. 1984. Decay of aspen and balsam poplar in Alberta. Information report NOR-X-262. Northern Forest Research Centre Canadian Forestry Service, Environment Canada. 19pp.

Jones, J.L. 1991. Habitat use of fisher in northcentral Idaho. Thesis, University of Idaho, Moscow, Idaho, USA.

Jones, J.L., and E.O. Garton. 1994. Selection of successional stages by fishers in north-central Idaho. Pages 377-388 in S.W. Buskirk, A.S. Harestad, M.G. Raphael, and R.A. Powell, editors. Martens, sables and fishers: biology and conservation. Ithaca (NY): Cornell University Press.

Kilpatrick, H. and P. Rego. 1994. Influence of season, sex, and site availability on fisher (Martes pennanti) rest-site selection in central hardwood forest. Can. J. Zool. 72: 1416-1419.

Lima, C. and C. Garcia. 2016. Pre- and post-experimental manipulation assessments confirm the increase in number of birds due to the addition of nest boxes. PeerJ 4:e1806; DOI 10.7717/peerj.1806.

Lofroth, E., R. Weir, L. Davis, and I.J. Hansen. 2018. Population vital rates of fishers in British Columbia, Canada. Manuscript in preparation.

Matthews, S.M., Green, D.S., Higley, J.M., Rennie, K.M., Kelsey, C.M., and Green, R. 2019. Reproductive den selection and its consequences for fisher neonates, a cavity-obligate mustelid. J. Mammal. **100**: 1305–1316. doi:10.1093/jmammal/gyz069.

Meidinger, M.L., and J. Pojar. 1991. Ecosystems of British Columbia. B.C. Min. For., Res. Br., Victoria, B.C. Special Report Series No. 6.

Messenger, J.E., J.D. Birks, and T. Braithwaite. 2006. An artificial natal den box for pine martens (*Martes martes*). In Martes in Carnivore Communities, pages 89-98. M. Santos, J. Birks, E. O'Doherty, and B. Proulx, editors.

Paragi, T. F., S. M. Arthur, and W. B. Krohn. 1996. Importance of tree cavities as natal dens for fishers. Northern Journal of Applied Forestry 13:79-83.

Powell, R.A. 1993. The fisher: Life history, ecology and behavior. Second ed. Univ. of Minnesota Press, Minneapolis. 237 pp.

Price, K., R. Holt, and D. Daust. 2020. BC's Old Growth Forest: A Last Stand for Biodiversity. Available at [https://veridianecological.files.wordpress.com/2020/05/bcs-old-growth-forest-report-web.pdf].

Resources Information Standards Committee. 1999. Inventory methods for medium-sized territorial carnivores: Coyote, red fox, lynx, bobcat, wolverine, fisher and badger. Standards for components of British Columbia's biodiversity number 25. Victoria, BC.

Smith, K.P., A.N. Facka, and R.A. Powell. Using reintroduction to elucidate breeding system, breeding phenology, and infanticide for a solitary carnivore (fisher, Pekania pennanti). Can. J. Zoology 98: 433-447.

Therneau T (2020). A Package for Survival Analysis in R. R package version 3.2-3, https://CRAN.R-project.org/package=survival.

USDA. 2002. NRCS Plant Guide Quaking Aspen Populus tremuloides. Accessed June 2020 [https://plants.usda.gov/plantguide/pdf/cs_potr5.pdf].

Wier, R.D. 1995. Diet, spatial organization and habitat relationships of fishers in south-central British Columbia. M.Sc. Thesis. Simon Fraser University. Burnaby, BC.

Weir, R.D. 2000. Ecology of fishers in the sub-borealforests of north-central British Columbia: Year IV (1999/2000) - Radiotelemetry monitoring and habitat sampling. Peace/Williston Fish and Wildl. Compensation Prog., Prince George, B.C. Rep. No.222. 38 p.

Weir, R. D. 2009. Ecology of fishers in the Kiskatinaw Plateau ecosection: Year-end report. Unpublished report. Artemis Wildlife Consultants. Armstrong, BC.

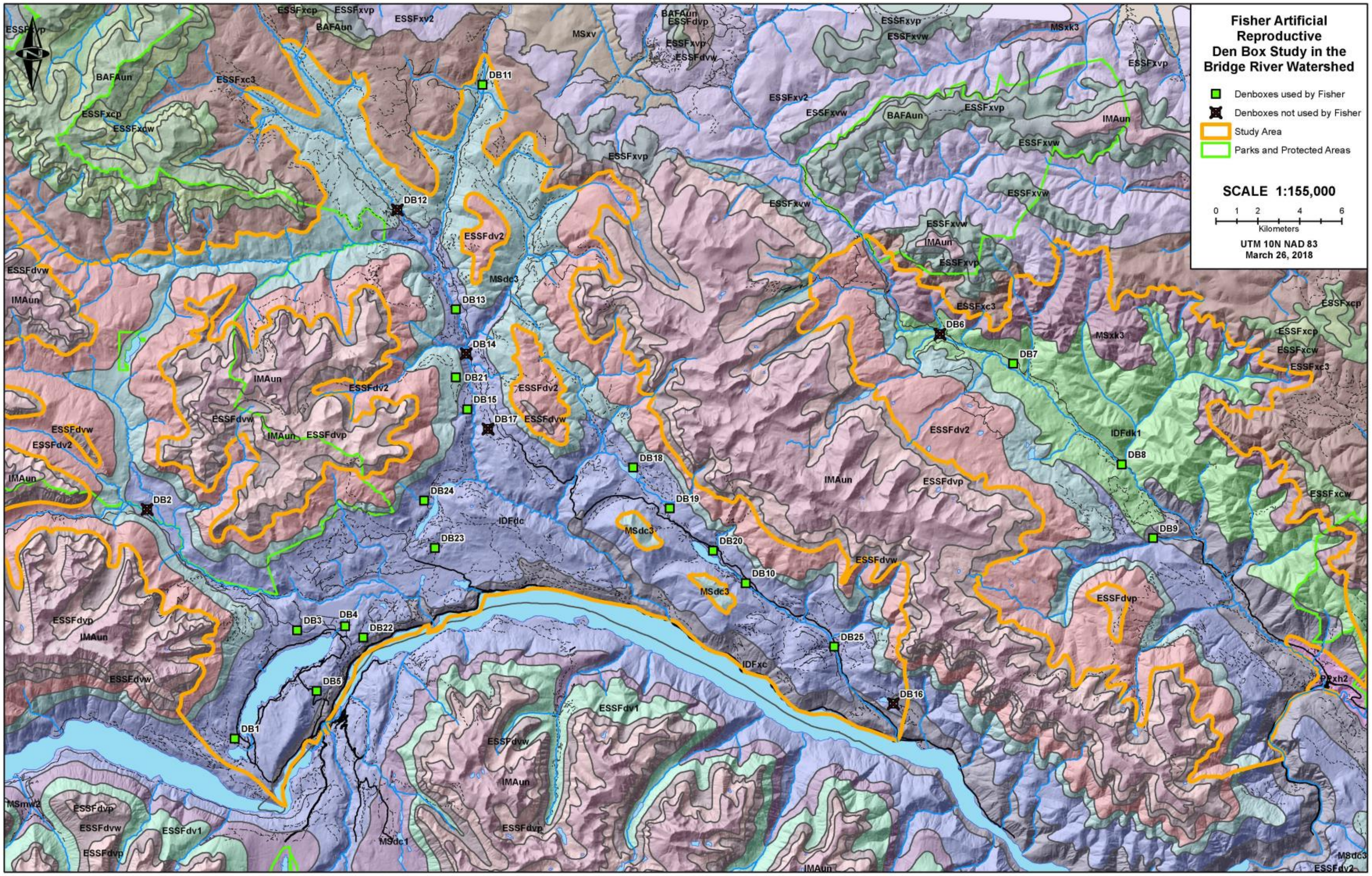
Weir, R.D., A.S. Harestad, and F. B. Corbould. 2009. Home ranges and spatial organization of fishers, Martes pennanti, in central British Columbia. Canadian Field Naturalist, 123: 126-132.

Weir, R. D., and F. B. Corbould. 2008. Ecology of fishers in the sub-boreal forests of north-central British Columbia. Final Report. Peace/Williston Fish and Wildlife Compensation Program. Report No 315. Prince George, BC.

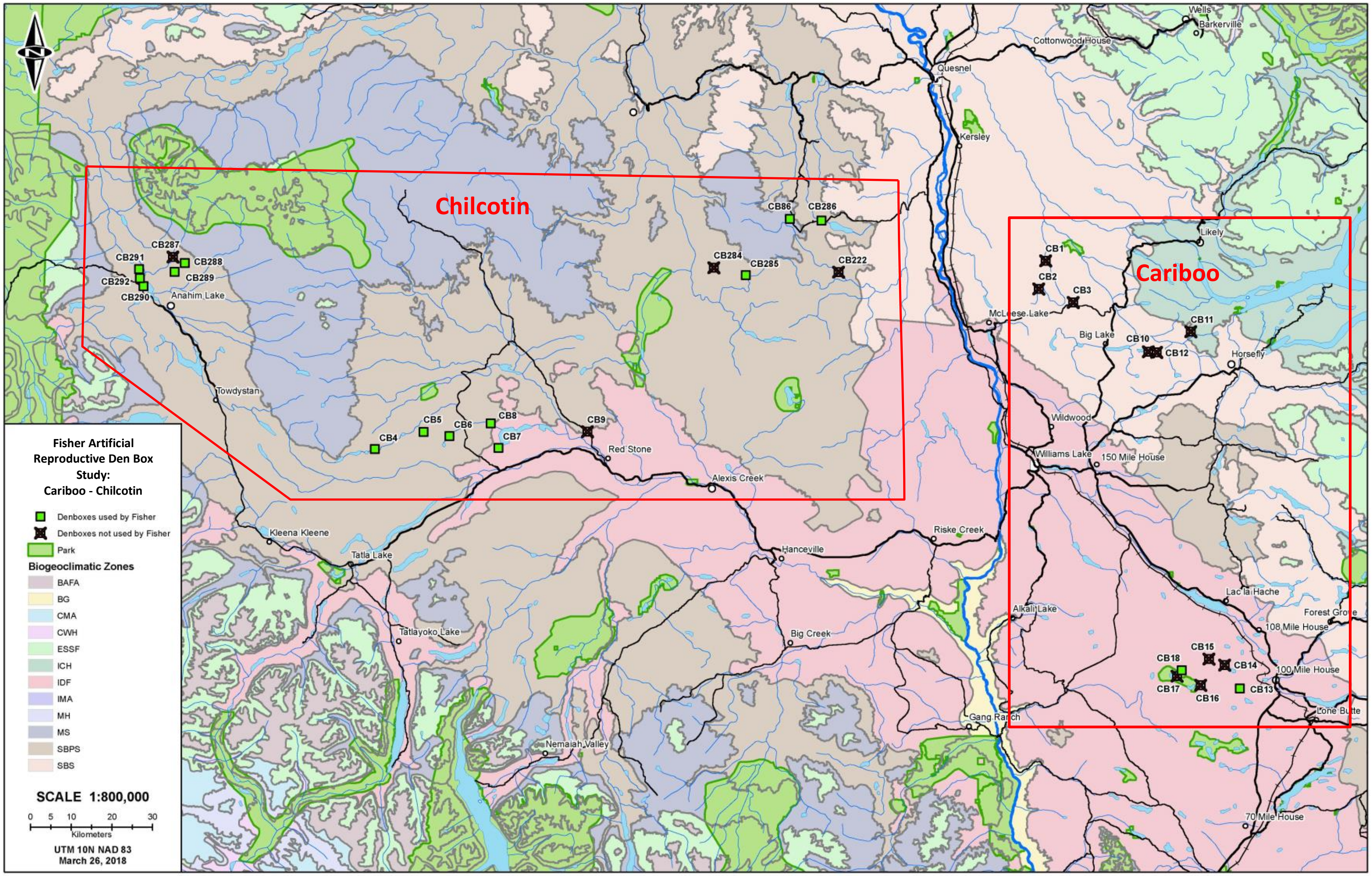
Weir, R.D., M. Phinney, and E.C. Lofroth. 2012. Big, sick, and rotting: why tree size, damage, and decay are important to fisher reproductive habitat. Forest Ecology and Management 265: 230-240.

Zielinski, W.J., R.L. Truex, G.A. Schmidt, F.V. Schlexer, K.N. Schmidt, and R.H. Barrett. 2004. Resting habitat selection by fishers in California. Journal of Wildlife Management 68: 475-492.

Appendix 1. 2014-18 Fisher den box locations and use in the Bridge River Watershed.



Appendix 2. 2016-17 Fisher den boxes and use in the Cariboo–Chilcotin



Appendix 3. R code used for den tree survival analysis

```
Survival of Deciduous Den trees R Code

# load required libraries

library("survminer")

install.packages("readxl")

library("readxl")

my_data2 <- read_excel(file.choose())

head(my_data2)

# Fit survival curves

require("survival")

fit <- survfit(Surv(time, status) ~ 1, data = my_data2)

print(fit)

# Summary of survival curves

summary(fit)

d <- data.frame(time = fit$time,

                n.risk = fit$n.risk,

                n.event = fit$n.event,

                n.censor = fit$n.censor,

                surv = fit$surv,

                upper = fit$upper,

                lower = fit$lower

)

head(d)

ggsurvplot(fit,

           title = "Plot of Deciduous Den Tree Survival",
```

```
            xlab = "Time in Years",
            risk.table = TRUE, # Add risk table
            risk.table.col = "strata", # Change risk table color by
groups
            linetype = "strata", # Change line type by groups
            surv.median.line = "hv", # Specify median survival
            ggtheme = theme_bw(), # Change ggplot2 theme
            palette = c("#E7B800", "#2E9FDF"))

summary(fit)$table
```

Appendix 4. Den trees assessed for longevity.

Fisher ID	Time (years)	Status*	Year used	Tree species**	Year assessed	Comment
Pouce	6	2	2007	Acb	2013	Tree fallen
Amy	10	2	2007	Acb	2017	Tree fallen
Flora	20	2	2006	Acb	2017	Tree fallen
F04	20	2	1997	Act	2017	Tree fallen
F07	20	2	1997	Act	2017	Cavity compromised
F09	20	2	1997	Act	2017	Cavity compromised
F02	20	1	1997	Act	2017	
F09	19	1	1998	Act	2017	
F04	19	1	1998	Act	2017	
F02	19	1	1998	Act	2017	
F09	18	2	1999	Act	2017	Tree fallen
F04	18	1	1999	Act	2017	
F07	2	2	1997	Act	1999	Tree fallen
F02	2	2	1998	Act	2000	Tree fallen
A4	12	1	2006	At	2018	
Amy	9	2	2008	At	2017	Tree fallen
Jackie	11	1	2007	At	2018	
Patrona	12	1	2006	At	2018	
Bessy	5	1	2008	At	2013	
Tinaw	12	1	2006	At	2018	
Arras	10	1	2008	At	2018	
P7	12	1	2006	Fd	2018	
P9	11	2	2007	Pl	2018	Tree burned
P10	9	2	2006	Pl	2015	Tree burned
P2	9	2	2006	Pl	2015	Cavity compromised
P3	12	1	2006	Pl	2018	

*Status: tree and cavity functional = 1; tree fallen or cavity compromised = 2.

**Tree species: Acb = balsam poplar (*Populus balsamifera*); Act = cottonwood (*Populus balsamifera ssp. trichocarpa*); At = trembling aspen (*Populus tremuloides*); Fd = Douglas-fir (*Pseudotsuga menziesii*); and lodgepole pine (*Pinus contorta*).