Wolverine Distribution and Ecology in the North Cascades Ecosystem

Final Progress Report (February 9, 2016)

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Frontispiece. Male wolverine being released from a livetrap at Easy Pass, Washington.

I. Introduction

The wolverine (*Gulo gulo*) is one of the rarest mammals in North America and the least known of the large carnivores (Banci 1994). The wolverine is considered a sensitive species in the Pacific Northwest Region by the U.S. Forest Service, and a candidate species for listing as threatened or endangered by the state of Washington. On 13 August 2014, the U.S. Fish and Wildlife Service (USFWS) withdrew their 2013 proposed rule to list wolverine populations in the contiguous U.S. as "Threatened" under the Endangered Species Act (ESA; U.S. Fish and Wildlife Service 2013, 2014). The USFWS stated that "while there is significant evidence that the climate within the larger range of the wolverine is changing, affecting snow patterns and associated wolverine habitat, the specific response or sensitivity of wolverines to these forecasted changes involves considerable uncertainty at this time" (U.S. Fish and Wildlife Service 2014). On 14 October 2014, a coalition of 8 conservation groups filed a lawsuit challenging the USFWS's decision to withdraw their proposed rule to list the wolverine in the contiguous U.S. under the ESA.

The northern Cascade Range in Washington represents the southernmost extent of current wolverine range along the Pacific coast of North America (Aubry et al. 2007). Prior to our research, wolverines had never been studied in the field in this region, due partly to their low densities and extremely limited access into the unroaded wilderness areas where they occur during all periods of the year. Recent telemetry studies of wolverines in the Rocky Mountains of British Columbia (Krebs et al. 2007) and the United States (Copeland 1996, Copeland et al. 2007, Squires et al. 2007) indicate that wolverines are wide-ranging, inhabit remote areas near timberline, give birth to young during winter in subnivean dens, and may be sensitive to human disturbance at natal and maternal den sites. Winter recreation activities are widespread in the northern Cascade Range and often occur in suitable wolverine denning habitat. Such activities may affect wolverines or their use of preferred habitat.

Snowtracking and remote-camera surveys conducted from 1995 to 2005, coupled with a review of historical occurrence records in Forest Service files, resulted in a number of highly credible wolverine observations (many verifiable) from areas near the Cascade Crest on the Methow Valley Ranger District of the Okanogan-Wenatchee National Forest. Consequently, we chose this area to evaluate the feasibility of trapping wolverines during winter in the northern Cascade Range. The first year of the study (2005/06) was successful, so we continued to use the Methow Valley Ranger District as the center of a greatly expanded study area in which to monitor wolverine movements with satellite telemetry, estimate home ranges, and investigate patterns of habitat use.

Although all verifiable records of wolverine occurrence in Washington obtained prior to 2005 were from areas near the Cascade Crest, DNA analysis confirmed that a sample of hair collected in 2005 in the Kettle Range near Danville in Ferry Co. was from a wolverine (C. Loggers, U.S. Forest Service, personal communication). This record suggested that wolverines may be more broadly distributed in Washington than we thought. Thus, an additional objective of our study was to expand our trapping area and establish trap sites as far east of the Cascade Crest as feasible, in hopes of capturing individuals or family groups that occur outside the Pasayten Wilderness. Also, findings from the first few years of our research indicated that wolverines in the northern Cascades of Washington appeared to be part of a larger population that included portions of British Columbia and, possibly, Alberta.

As in Washington, however, relatively little is known about the population status or ecology of wolverines in southwestern Canada. Consequently, in year 4 (winter 2008/09), we expanded the geographic scope of our study by establishing a collaborative relationship with forest carnivore biologists at the B.C. Ministry of Environment (Eric Lofroth and Rich Weir) and at the B.C. Ministry of Forests, Lands and Natural Resource Operations (Cliff Nietvelt). Field crews in British Columbia followed our study protocols, and all data were sent to the Pacific Northwest Research Station to be integrated with data collected in Washington.

This progress report is cumulative, and includes preliminary results from 10 years of research (winters of 2005/06 thru 2014/15) on wolverine distribution and ecology in the North Cascades Ecosystem.

II. Methods

Study Area**—**Our study area is located in the northern Cascade Range, primarily on the Methow Valley Ranger District of the Okanogan-Wenatchee National Forest in Washington (Figure 1). The Methow Valley Ranger District encompasses portions of the Pasayten and Lake Chelan-Sawtooth wildernesses, and extends approximately 80 km along the Cascade Crest. Vegetation cover types include bitterbrush/bluebunch wheatgrass at lower elevations, mixed-conifer forests at mid- to high elevations, and alpine meadows, rocky ridges, peaks, and small glaciers at the highest elevations. In 2008/09, we expanded the study area northward into the Silver Skagit, Skagit, and Similkameen watersheds of British Columbia. This area encompasses multiple land ownerships including portions of Skagit Valley and Manning Provincial Parks.

Live-trapping Wolverines for Satellite Telemetry**—**We constructed 12 wolverine livetraps in Washington (Figure 2 and Table 1) and 15 in British Columbia (Figure 2). In Washington, we located all traps near the Cascade Crest or adjacent to the Pasayten and Lake Chelan/Sawtooth Wildernesses. For several years, we monitored or operated 2 traps (Baldy Pass and Thirtymile) in the eastern portion of our study area in Washington but did not detect any

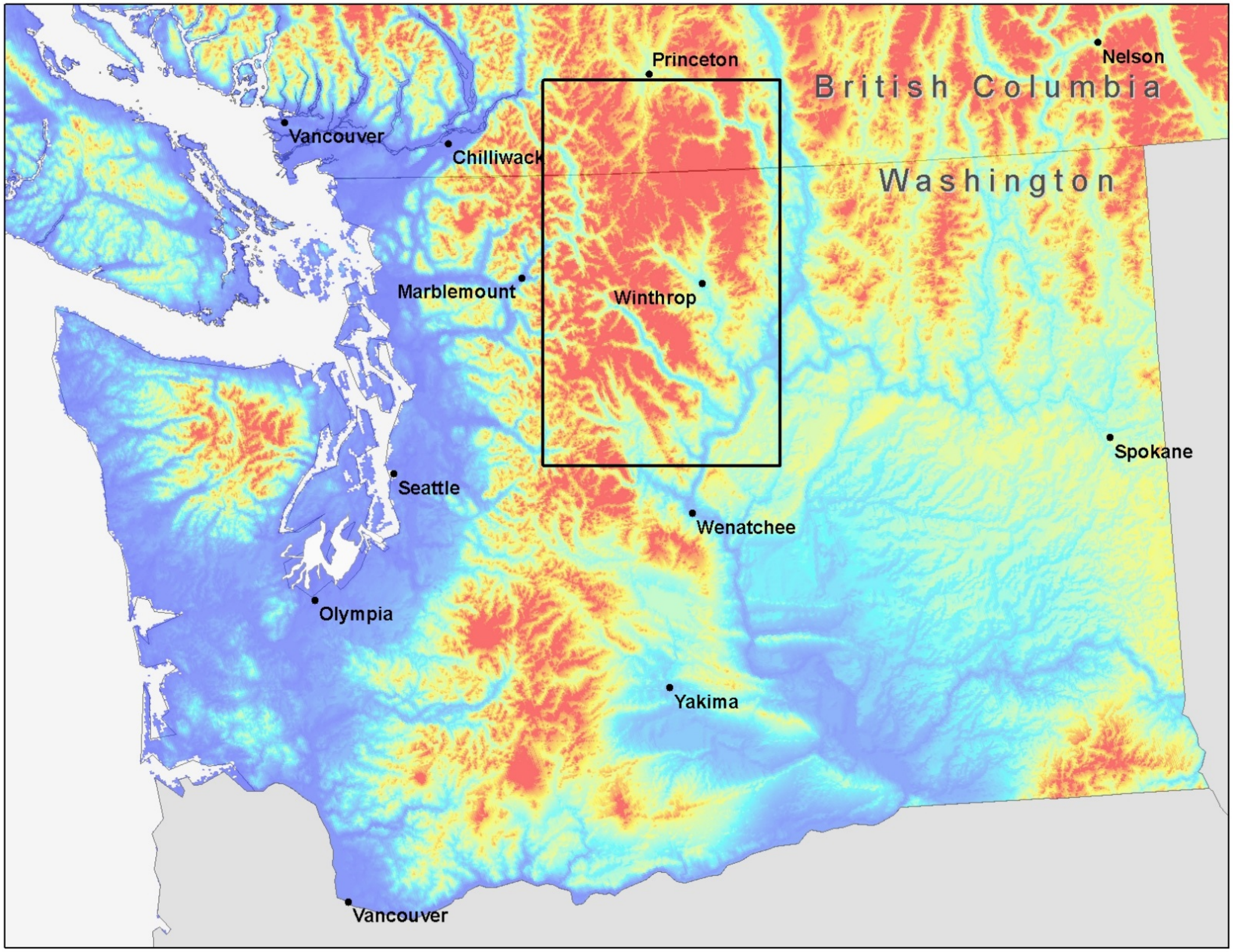

Figure 1. Primary area of research activities for the North Cascades Wolverine Study. Colors show the topographic gradient based on a digital elevation model; "cool" colors are lower in elevation that "warm" colors.

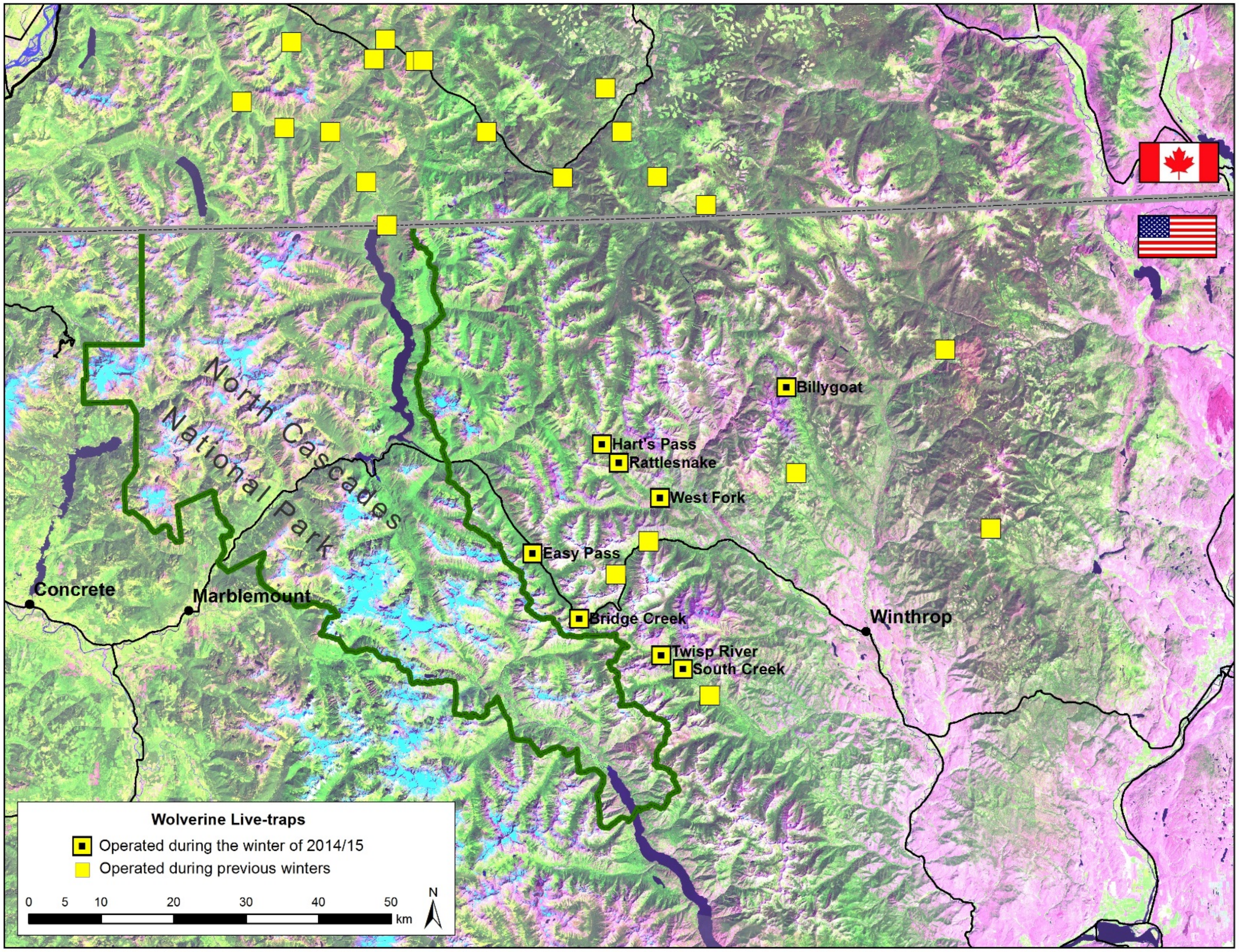

Figure 2. Locations of wolverine livetraps operated during the winter of 2014/15 by field crews in the North Cascades Ecosystem in Washington. In British Columbia, live-trapping efforts have not been conducted since the winter of 2011/12.

Table 1. General site characteristics at wolverine livetraps in the North Cascades Ecosystem in Washington. For traps that were built but not operated immediately (i.e., traps were not set to live-capture wolverines), we baited and monitored the site for wolverine activity.

Trap site	Winter built	Winters operated	Elevation (m)	Vegetation type
Cutthroat	2005/06	2005/06 thru 2010/11; 2012/13	1,341	Subalpine mixed-conifer
Hart's Pass	2005/06	2005/06 thru 2014/15	1,890	Subalpine mixed-conifer
Twisp River	2005/06	2006/07 thru 2014/15	1,097	Montane mixed-conifer
Baldy Pass[a]	2006/07	2006/07 thru 2008/09; 2010/11	1,951	Subalpine mixed-conifer
Billygoat	2007/08	2007/08 thru 2010/11; 2013/14 thru 2014/15	1,463	Subalpine mixed-conifer
Thirtymile[b]	2007/08	Monitored 2007/08 thru 2009/10	1,036	Montane mixed-conifer
Reynolds	2008/09	2008/09 thru 2011/12	884	Montane mixed conifer
South Creek	2008/09	2008/09 thru 2014/15	975	Montane mixed conifer
Rattlesnake	2008/09	2008/09 thru 2014/15	1,646	Subalpine mixed-conifer
West Fork	2008/09	2008/09 thru 2014/15	823	Montane mixed conifer
Silverstar Creek	2008/09	2008/09 thru 2011/12	1,036	Montane mixed conifer
Sweetgrass Butte	2008/09	2008/09 thru 2011/12; 2013/14	1,829	Subalpine mixed-conifer
Easy Pass	2010/11	2010/11[c] thru 2014/15	1,128	Montane mixed conifer
Bridge Creek	2011/12	2011/12 thru 2014/15	1,372	Subalpine mixed-conifer

[a]The Baldy trap was removed after the winter of 2010/11 and moved to Bridge Creek

[b]The Thirtymile trap was removed after the winter of 2009/10 and moved to Easy Pass

[c]The Easy Pass trap was only open for a few days during the winter of 2010/11

wolverine activity; thus, we moved those 2 traps to more productive locations near the Cascade Crest (Bridge Creek and Easy Pass; see Figure 2 and Table 1). In British Columbia, livetraps were operated for 4 winters (2008/09 thru 2011/12; Figure 2); however, 5 livetraps in the Skagit Valley north of Ross Lake were not operated during the winters of 2010/11 or 2011/12, due to limited access. Our collaborators in British Columbia have not been able to acquire funding for live-trapping efforts since 2011/12.

In Washington, we built traps *in situ* in areas where wolverine occurrences had been documented recently and, for reliable access during winter, located them within ~150 m of roads that were regularly used by snowmobilers. We constructed traps using logs cut from trees at the site based on the design recommended by Copeland et al. (1995), which is being used for wolverine studies in the northern Rocky Mountains and elsewhere in North America (Appendix, Photo 1).

In British Columbia, our collaborators constructed 10 livetraps during the winter of 2008/09, 2 additional traps during the winter of 2009/10, and 3 during the winter of 2010/11; all were located in Interior Douglas-fir, Coastal Western Hemlock, and Montane Spruce biogeoclimatic zones. In British Columbia, field crews prefabricated traps with milled lumber, and then transported them to the trap site for re-assembly and installation (Lofroth et al. 2008; Appendix, Photo 1).

We baited traps with parts of road-killed mule deer, beaver carcasses, or salmon carcasses, and monitored them daily via a trap-site transmitter that indicated whether the trap lid had closed. We visited all operating traps twice per week to ensure that they were functioning properly. We immobilized captured wolverines with a mixture of ketamine and medetomidine (Washington) or Telazol (British Columbia) administered via a jab stick. We took tissue samples from all captured wolverines for genetic profiling, and gathered data on the sex, age, and condition of captured animals. We attached a small, colored plastic tag to each ear, and outfitted each study animal with Sirtrack telemetry collars containing both Argos satellite transmitters and standard VHF transmitters. Satellite transmitters provide general location and movement data collected remotely via an internet-based connection to the Argos Data Collection System. When possible, the VHF transmitters enable us to obtain fine-scale occurrence data to facilitate locating natal and maternal dens of reproductive females, and to recover telemetry collars that are removed prematurely by the study animal or if the animal dies during the lifespan of the satellite transmitter. In year 3 (2007/08), we began taking standardized photographs of throat and chest markings of all captured wolverines; such markings can be used to distinguish individuals. In year 4 (2008/09), we modified our capture/handling protocol to include a passive integrated transponder (PIT) tag injected subcutaneously on the back of captured wolverines to enable individual identification of previously captured animals if they are no longer wearing a collar or ear tags.

During the first year of our study, we programmed satellite transmitters to be on for only 5 hr each day so that the transmitters would gather location data for >1 yr. However, this duty cycle resulted in very few satellite locations from collared wolverines, indicating that a longer duty cycle was needed to obtain a sufficient number of high-quality locations to investigate broad-scale habitat use by wolverines. To correct these problems, during years 2 and 3 (winters 2006/07 and 2007/08), we programmed satellite transmitters to be "on" for 48 hr and "off" for 24 hr and to transmit a signal every 60 sec while on. We programmed the VHF transmitters to be on continuously. Using these duty cycles, the satellite and VHF transmitters had a battery life of 4 and 12 months, respectively. These duty cycles proved successful and we were able to collect

>80 high-quality satellite locations on each collared wolverine during years 2 and 3 of the study. However, analyses of our satellite location data for those years revealed that most of the high-quality locations were acquired between the hours of 0600 and 1800. This pattern may result from both limitations of satellite coverage in our study area as well as wolverine behavior patterns (e.g., wolverines may be less active during the night and in a position that obstructs the ability of the satellite to pick up transmission signals). Consequently, in year 4 (2008/09), we reprogrammed all of the satellite transmitters to be "on" for 14 hr between 0500 and 1900 hrs PST and then "off" for 34 hr. This new duty cycle extended the life of our satellite transmitters from 4 to about 8 months and is the standard duty cycle we have been using for all wolverines collared since 2008/09. In year 9 (2013/14), we began using KiwiSat 303 telemetry collars; an upgraded design of the original KiwiSat 101 that we had been using since the beginning of our study in 2005/06. The KiwiSat 303 collars weigh about 24% less than the previous 101 collars (160 g vs. 210 g) and, because of improved technology, the satellite transmitter battery lasts almost twice as long (15 months vs. 8 months when programmed with our standard duty cycle of 14 hr "on" and 34 hr "off").

Unlike satellite collars, GPS collars that have been used successfully on wolverines by other researchers are store-on-board systems that require recapturing animals to retrieve location data. GPS collars typically provide more accurate location data (calculated using triangulation methods) than satellite collars (calculated using the Doppler shift). Based on our recapture rate in year 2 (1 female captured twice, and 1 male captured 3 times), we experimented with 1 GPS collar in year 3 to determine if we could successfully augment our current research program with this technology. In March 2008, after one of the satellite collars on a male wolverine had been collecting location data for 2 months, we recaptured the male and replaced his collar with a

Lotek store-on-board GPS/VHF telemetry collar. We programmed the GPS locator to "fix" a location once per hour, giving it a projected battery life of 45 days. Unfortunately, we were not able to recapture the male before he slipped his GPS collar with stored location data, nor were we able to locate the collar's VHF signal during an extensive search from a fixed-wing aircraft. Therefore, we determined that satellite collars are the best option for collecting wolverine movement data in our study area, and did not use store-on-board GPS collars during the remainder of our study.

***Camera Stations*—**In year 5 (2009/10), we installed 8 run-pole remote-camera stations in Washington and 9 in British Columbia using the design recommended by Magoun et al. (2011, 2008) to obtain clear photographs of the light-colored throat and chest blazes of wolverines, which can be used for individual identification. During each winter since 2009/10, we have continued to operate run-pole remote-camera stations (Figure 3) altering the number and locations of stations to meet project objectives including monitoring our existing study population and surveying new locations within the study area where wolverines have not yet been detected.

***Scat-detection Dogs*—**During the summer of 2015 (the final year of our study), we employed scat-detection dog teams (Conservation Canines; http://conservationbiology.uw.edu/conservation-canines/) to search 3 separate sites that had been visited by wolverines during late-winter or early-spring of the same year: a remote camera station, a potential wolverine reproductive den site, and an area visited repeatedly over a period of about 7 weeks by one of our collared males. To our knowledge, scat-detection dogs have not been used previously to augment data collection during field studies of wolverines. Although the dogs had been trained to detect wolverine scat, as well as the scat of several other species of

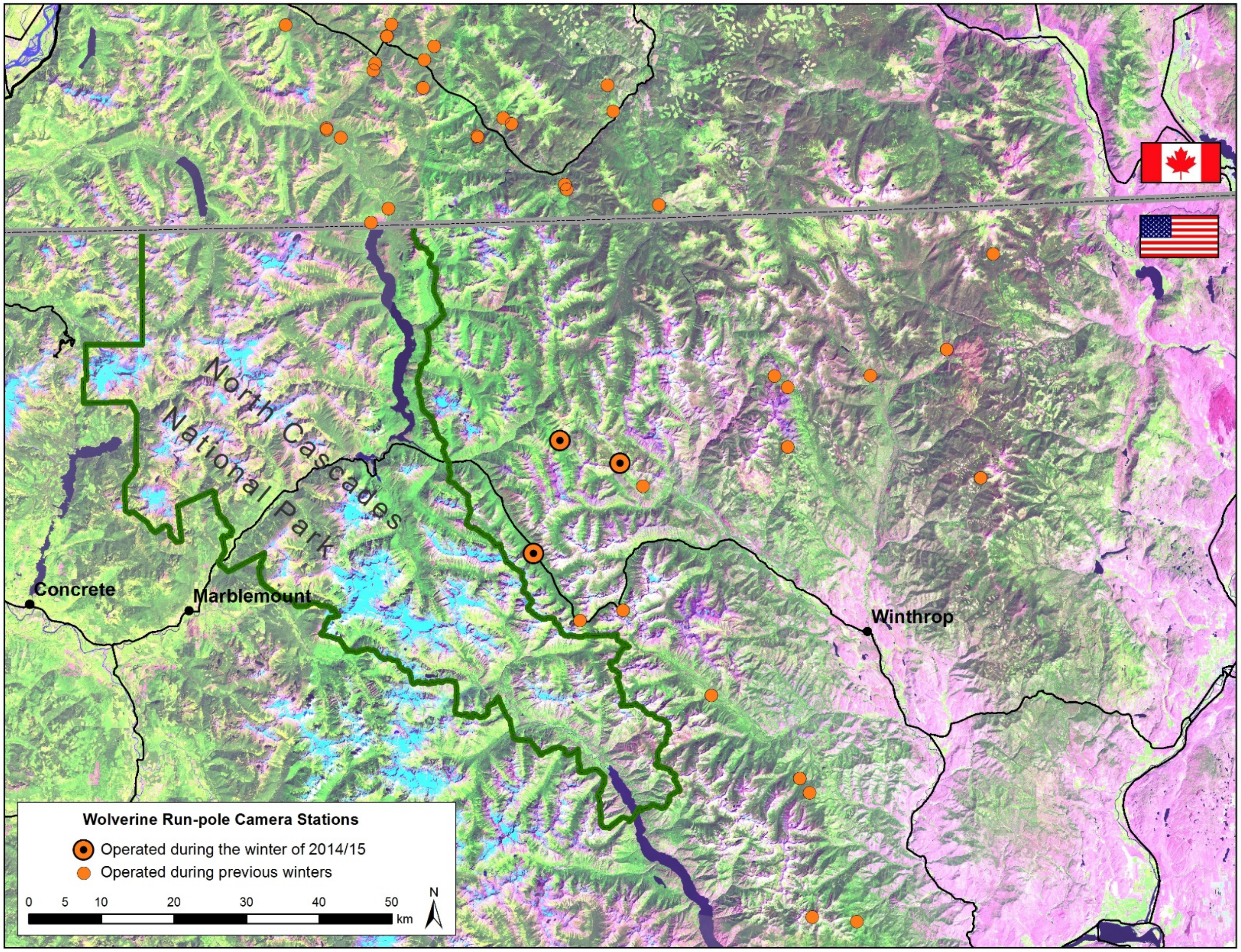

Figure 3. Locations of run-pole camera stations operated during the winter of 2014/15 by field crews in the North Cascades Ecosystem in Washington. In British Columbia, run-pole camera stations have not been operated since the winter of 2012/13.

forest carnivores, we supplied the handlers with scats from 4 of our study animals so they could refresh the dogs on wolverine scats prior to field searches in our study area. At each site, a single dog team (1 dog and 1 handler) searched the area of interest and collected any potential wolverine scats that the dog detected. We sent the scats to the National Genomics Center for Wildlife and Fish Conservation (Missoula, MT) for species identification based on mitochondrial DNA; if a scat was from a wolverine, the lab then conducted microsatellite analyses to obtain an individual genetic profile.

III. Results

Live-trapping—In Washington, we operated 2 to 5 traps during the first 3 years (Table 2). Since the 4th year of the study (winter 2008/09), we've operated 7-12 traps each winter depending on our project objectives and available resources (Table 2). In most years, the trapping season began in January and continued into late-March or early April; however, during the past 4 winters (2011/12 thru 2014/15), we began trapping in early December. Some trap sites take longer to open at the beginning of the season than others (i.e., it takes longer to establish a safe snowmobile route), and there are occasions when we periodically need to close traps due to high avalanche danger. Thus, in any given winter, the number of trap nights can be much lower for some traps than others (Table 2). To date in Washington, we have operated traps for a total of 4,781 trap nights during 10 winter field seasons, and have live-captured 13 different wolverines on 39 occasions (Table 2). Non-target species captured included Canada lynx, marten, and bobcat; all were released unharmed. Although we detected 5 different wolverines at our trap sites this past winter (2014/15), we only captured 1 male. An unusually warm winter with a corresponding low snowpack (the snowpack was 16% of normal for Washington;

Table 2. Capture results for wolverine livetraps in the North Cascades Ecosystem in Washington.

Winter	Cutthroat	Hart's Pass	Twisp River	Baldy Pass	Billygoat	Reynolds	South Creek	Rattlesnake	West Fork	Silverstar	Sweetgrass	Easy Pass	Bridge Creek	Total
	Trap site													
2005/06														
Trap nights	49	70												119
Wolverine captures	0	2												2
2006/07														
Trap nights	62	20	52	46										180
Wolverine captures	1	1	4	0										6
2007/08														
Trap nights	64	56	85	62	65									332
Wolverine captures	0	2	0	0	0									2
2008/09														
Trap nights	70	81	80	69	70	80	87	67	77	91	77			849
Wolverine captures	0	0	1	0	0	0	0	0	0	0	0			1
2009/10														
Trap nights	57	54	64		40	64	64	57	57	58	40			555
Wolverine captures	0	0	0		0	0	1	0	0	0	0			1
2010/11														
Trap nights	73	31	87	60	30	79	79	32	57	64	63	4		659
Wolverine captures	0	1	1	0	0	0	0	1	0	0	0	0		3

	Trap site													
Winter	Cutthroat	Hart’s Pass	Twisp River	Baldy Pass	Billygoat	Reynolds	South Creek	Rattlesnake	West Fork	Silverstar	Sweetgrass	Easy Pass	Bridge Creek	Total
2011/12														
Trap nights		52	129			125	129	86				55	58	634
Wolverine captures		0	1			0	1	0				2	1	5
2012/13														
Trap nights	91	27	91				98	41	34			53	48	483
Wolverine captures	0	0	2				1	1	1			2	1	8
2013/14														
Trap nights		46	98		39		84	48	59		41	65	67	547
Wolverine captures		0	2		0		0	0	0		0	3	0	5
2014/15														
Trap nights		54	77		48		30	60	35			59	60	423
Wolverine captures		0	1		0		0	0	0			3	2	6

http://earthobservatory.nasa.gov/IOTD/view.php?id=85887) may have been a contributing factor to the low capture rate we experienced.

Our collaborators in British Columbia operated most of their 10 livetraps for 17-20 days during the winter of 2008/09 (year 4), but did not capture any wolverines. During the winter of 2009/10 (year 5), they operated 12 livetraps from 7 January to March 22 for a total of 472 trap nights and captured 2 adult wolverines that had been captured previously in Washington. During the winter of 2010/11 (year 6), they operated livetraps for varying number of days from 12 January to 5 April, but did not capture any wolverines. During the winter of 2011/12 (year 7), they operated 9 livetraps for a total of 538 trap nights and captured 1 new female on 2 occasions. No livetraps have been operated in British Columbia since the winter of 2011/12. Thus, in British Columbia, we captured 3 individual wolverines during a 4-year period: 2 that were previously captured in Washington (Rocky and Melanie) and 1 that was new to the study (Kendyl). Incidental captures in British Columbia included marten, Canada lynx, and cougar.

Capture Histories, Spatial Use, and Movements of Wolverines—Five of our 14 study animals have been captured and monitored using satellite/VHF collars during multiple years (Table 3). Although the remaining wolverines have only been monitored during a single year, periodic detections at remote-camera stations have provided valuable information on the welfare and general location of those wolverines. To delineate wolverine activity areas (Table 4, Figure 4), we calculated 100% convex polygons using all location data in Argos accuracy-classes 1−3. Note that an activity area does not represent a home-range estimate; the estimation of home ranges requires careful data screening and more rigorous analytical procedures. Data on the areal extent of wolverine activity areas are presented here solely to provide a general idea of spatial use by our study animals.

Table 3. Capture data for 14 wolverines live-trapped in the North Cascades Ecosystem in Washington and British Columbia from 2006 thru 2015. We fitted wolverines with satellite/VHF collars and programmed the satellite transmitter as follows: "on" for 5 hr each day during year 1 (2005/06); "on" for 48 hr and "off" for 24 hr during years 2 and 3 (2006/07, 2007/08); and since year 4 (2008/09), "on" for 14 hr between 0500 and 1900 hours followed by 34 hr "off".

Wolverine name and sex	Capture date	Trap site	Estimated age	Weight (kg)
#1 – Melanie (F)	February 10, 2006	Hart's Pass, WA	1-2	8.6
	February 14, 2007	Hart's Pass, WA	2-3	9.6
	March 7, 2010	Memaloose, BC	5-6	10.1
#2 – Rocky (M)[a]	April 11, 2006	Hart's Pass, WA	2-3	14.7
	January 25, 2008	Hart's Pass, WA	3-4	14.2
	March 24, 2008	Hart's Pass, WA	3-4	13.8
	February 26, 2010	Memaloose, BC	5-6	15.0
	February 8, 2011	Twisp River, WA	6-7	13.2
	February 20, 2012	Easy Pass, WA	7-8	14.7
	March 14, 2012	South Creek, WA	7-8	13.4
#3 – Chewbacca (M)	January 24, 2007	Twisp River, WA	2-4	13.6
	March 17, 2007	Twisp River, WA	2-4	14.6
#4 – Xena (F)	February 11, 2007	Twisp River, WA	1-2	8.0
	March 26, 2007	Twisp River, WA	1-2	8.0
	February 18, 2012	Twisp River, WA	6-7	9.5
	February 20, 2013	Twisp River, WA	7-8	9.0
#5 – Sasha (F)	February 23, 2009	Twisp River, WA	1-2	8.1
#6 – Eowyn (F)	February 1, 2010	South Creek, WA	1-2	9.2
#7 – Mattie (F)[b]	January 29, 2011	Hart's Pass, WA	≥ 2	7.7
#8 – Mallory (F)	March 24, 2011	Rattlesnake, WA	≥ 3	8.3
	February 6, 2012	Easy Pass, WA	≥ 4	9.5
#9 – Special K (M)	February 5, 2012[c]	Bridge Creek, WA	unknown	unknown
	February 1, 2015	Easy Pass, WA	≥ 4	13.6
	February 15, 2015	Easy Pass, WA		
	February 27, 2015	Easy Pass, WA		
	February 28, 2015	Twisp River, WA		

Wolverine name and sex	Capture date	Trap site	Estimated age	Weight (kg)
Special K – *continued*	March 5, 2015	Bridge Creek, WA		
	March 12, 2015	Bridge Creek, WA		
#10 – Kendyl (F)	February 29, 2012	Memaloose, BC	1-2	9.9
#11 – Dasher (M)	December 24, 2012	South Creek, WA	1	11.6
	February 5, 2013	Twisp River, WA	1	11.6
#12 – Logan (M)	January 24, 2013	Easy Pass, WA	1-2	11.5
	January 26, 2013	Bridge Creek, WA		
	February 12, 2013	Rattlesnake, WA		
	February 16, 2013	Easy Pass, WA		
	December 19, 2013	Easy Pass, WA	2-3	11.8
	January 29, 2014	Easy Pass, WA		
	March 23, 2014	Twisp River, WA	2-3	12.8
#13 – Chance (M)	March 14, 2013	West Fork, WA	2-3	12.3
#14 – Hobbes (M)	January 7, 2014	Twisp River, WA	1-2	10.5

[a] Originally, this male was named 'Thor' but was renamed 'Rocky' in 2008

[b] Satellite transmitter programmed to operate continuously

[c] Released without taking measurements or attaching a satellite/VHF collar because we couldn't adequately sedate him for safe handling

Table 4. Activity areas calculated for wolverines monitored in the North Cascades Ecosystem in Washington and British Columbia from 2006 thru 2015. Activity areas are 100% convex polygons delineated using Argos satellite location data in accuracy-classes 3 (<250 m), 2 (250−500 m), and 1 (500−1,500 m). These are preliminary results for general information only.

Wolverine (gender)	Time period	# of satellite locations	Activity area (km^2)
#1 – Melanie (F)	Feb 2006	Not enough locations to calculate an activity area	
	Feb – Jul 2007	130	1,447
	Mar – Sep 2010	183	1,225
#2 – Rocky (M)	Apr 2006	Not enough locations to calculate an activity area	
	Jan – Mar 2008	99	1,162
	Feb – Nov 2010	317	2,992
	Feb – Jul 2011	114	1,149
	Feb – Sep 2012	96	1,429
#3 – Chewbacca (M)	Jan – Jul 2007	80	1,893
#4 – Xena (F)	Feb – Jul 2007	118	1,969
	Feb – Aug 2012	174	643[a]
	Feb – Sep 2013	235	1,296
#5 – Sasha (F)	Feb – Aug 2009	143	1,495
#6 – Eowyn (F)	Feb – Mar 2010	Made long-distance movements; did not have an activity area	
#7 – Mattie (F)	Jan – Apr 2011	174	965
#8 – Mallory (F)	Mar – Aug 2011	162	535
	Feb – Jun 2012	69	293[a]
#9 – Special K (M)	Mar – Dec 2015	340	2,590
#10 – Kendyl (F)	Mar – May 2012	121	571
#11 – Dasher (M)	Dec 2012 – Feb 2013	42	199
#12 – Logan (M)	Jan – Jun 2013	159	2,088
	Dec 2013 – Oct 2014	41	1,297
#13 – Chance (M)	Mar – Oct 2013	Made long-distance movements; did not have an activity area	
#14 – Hobbes (M)	Jan 2014	Died before we obtained enough data to calculate an activity area	

[a]Adult female was denning for the first 2 months of the tracking period (i.e., movements were very restricted) and then was travelling with young during the remainder of the tracking period

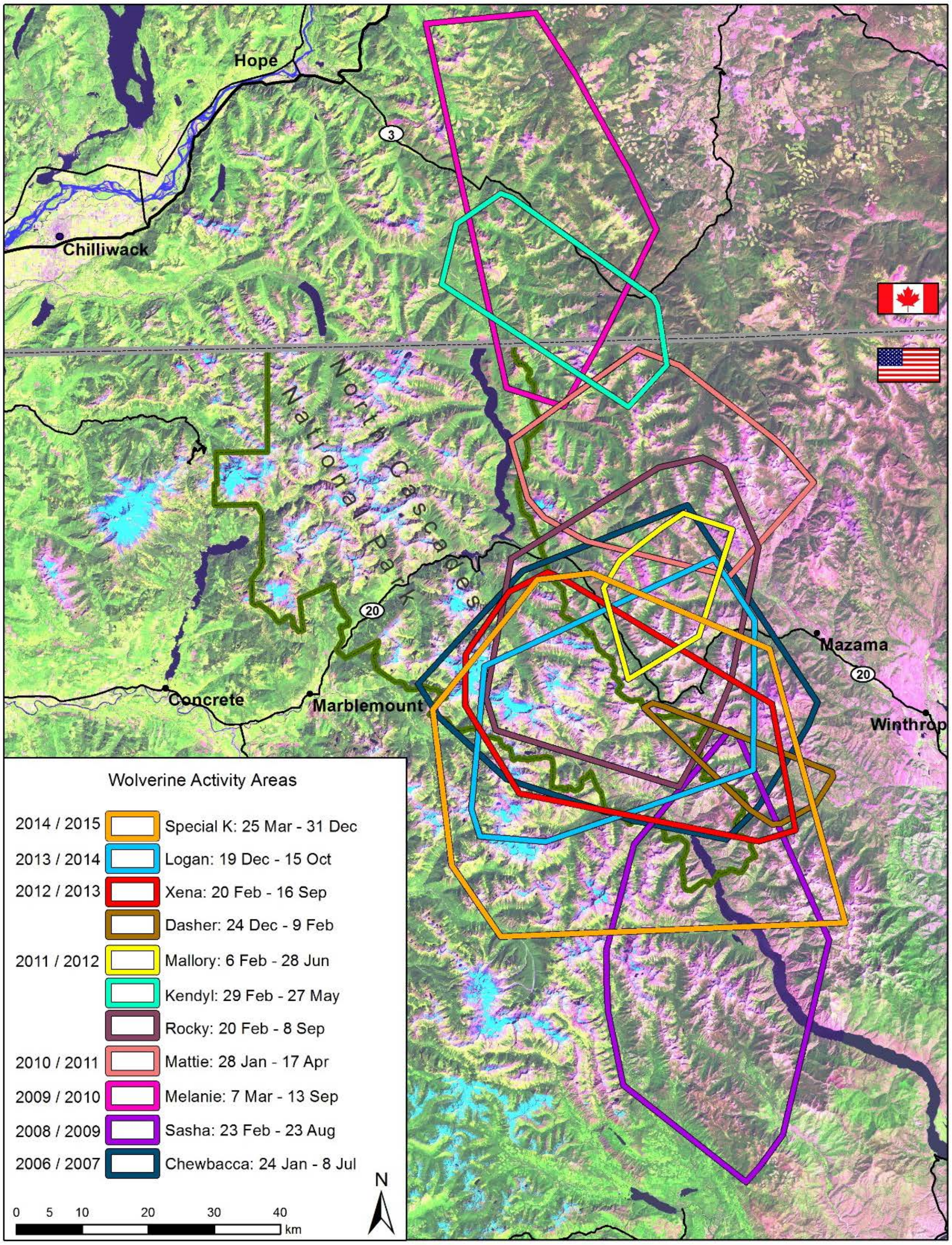

Figure 4. The most recent activity areas for 11 wolverines tracked with satellite telemetry in the North Cascades Ecosystem since the beginning of the study in 2005/06. Activity areas are 100% convex polygons delineated using Argos satellite locations data in accuracy-classes 3 (<250 m), 2 (250-500 m), and 3 (500-1,500 m) for the dates indicated.

<u>Wolverine #1 – Melanie</u>: Melanie was initially captured in 2006 at the Hart's Pass trap (Table 3). Approximately 1 week after her capture, the activity sensor data from her collar indicated that it was no longer moving. Upon retrieving the collar, we determined that the metal band used to attach the collar strap to the transmitter package had broken. The manufacturer corrected this design flaw on all remaining satellite collars before we deployed any additional collars on other wolverines. We recaptured Melanie in the Hart's Pass trap in 2007 and fitted her with a new satellite/VHF collar. We obtained 130 high-quality locations for her during a 5-month period in 2007, resulting in an activity area of approximately 1,447 km^2 (Table 4). Melanie's activity area was centered in the western half of the Pasayten Wilderness on the Okanogan-Wenatchee National Forest, and included portions of the North Cascades Scenic Highway Corridor and Manning Provincial Park in British Columbia, Canada. Our physical examination of her on February 14, 2007 also revealed that she was pregnant (distended nipples and at least 1 fetus felt during palpation). Over a 17-day period in late February and early March, we obtained 5 high-quality locations for Melanie in a localized area near Center Mountain (11 km NW of Hart's Pass), indicating that she may have established a natal den. However, soon after that time, she stopped frequenting that site and did not return. We conducted several helicopter flights during the spring of 2007 to determine whether Melanie had successfully given birth to kits by tracking the VHF signal for her collar and attempting to see her on the ground accompanied by kits; however, these flights were unsuccessful. Although our location data suggest that Melanie may have lost her kits, such data can be misleading (J. Copeland, U.S. Forest Service, personal communication). Consequently, the outcome of Melanie's reproductive effort in 2007 remains unknown. We did not recapture Melanie again

until the winter of 2009/10 when she was live-trapped at the Memaloose trap in British Columbia (Table 3). We fitted Melanie with a satellite/VHF collar and collected 183 high-quality locations over a 6-month period (Table 4). We determined that she was not reproductive in 2010, and her activity area had shifted from being primarily in Washington during 2007 to almost exclusively in southern British Columbia in 2010 (Figure 4). Although we have not recaptured Melanie since 2010, we detected her at the Memaloose run-pole camera station in British Columbia in April and May of 2012, indicating that she was at least 7 years of age and still a resident adult female in the northern portion of our study area.

Wolverine #2 – Rocky: Rocky (also known as 'Thor') was originally captured as a young male in the Hart's Pass trap in 2006 (Table 3). We have captured and monitored Rocky's movements during 5 different years (2006, 2008, 2010, 2011, and 2012), during which he appeared to be one of the primary resident adult males in our study population. In each of those years, we monitored Rocky's movements for 2–9 months; the size of his activity area varied from 1,149 to almost 3,000 km^2 (Table 4). Rocky's movements appeared to be influenced, in part, by the number and perhaps the reproductive status of available females. The largest activity area we documented for him was in 2010, when he extensively overlapped Melanie's 2010 activity area in British Columbia (Figure 4) and ranged well south of Rainy Pass along Highway 20 in Washington. We speculated that the areas he was using in Washington coincided with those of at least 1 adult female (we had detected Xena and another wolverine at the Easy Pass run-pole camera station along Highway 20). In 2011, his activity area was restricted to Washington where he overlapped 2 collared females extensively (Mattie and Mallory). In 2012, Rocky's movements were also restricted to Washington and completely encompassed those of 2 reproductive adult females (Mallory and Xena), suggesting that he was the father of the kits produced by those 2 females in 2012. Although we did not capture Rocky in 2013, we detected him on video at the Twisp River trap site on January 29, 2013. Rocky was travelling with a subadult male (Dasher) that we had captured a month previously – this association, in conjunction with genetic data from both males, indicate that Rocky was likely Dasher's father. It also indicates a degree of social tolerance in wolverines between a father and his male offspring that has not been described previously (but see Copeland et al. *in press*). We have not detected Rocky since 2013 and, if still alive, he would be at least 10 years of age. This, as well as the presence of other males (see narrative for Special K and that associated with Appendix, Photo 4) during the winter of 2014/15 in the area that Rocky used to occupy, suggests that Rocky is no longer alive or has been displaced by younger males.

<u>Wolverine #3 – Chewbacca</u>: In 2007, we captured a young male wolverine (Chewbacca) in the Twisp River trap (Table 3). We fitted Chewbacca with a satellite/VHF collar and obtained 80 high-quality locations, resulting in an activity area of approximately 1,893 km^2 (Table 4). This area included the southeast portion of North Cascades National Park and the adjacent Lake Chelan-Sawtooth Wilderness and North Cascades Scenic Highway Corridor of the Okanogan-Wenatchee National Forest (Figure 4). Although we never recaptured Chewbacca, we obtained photographs of him in February and May of 2008 at a remote-camera station we installed near the Twisp River trap.

Wolverine #4 – Xena: In 2007, we captured a young nulliparous female wolverine (Xena) in the Twisp River trap (Table 3). We fitted Xena with a satellite/VHF collar and obtained 118 high-quality satellite locations, resulting in an activity area that was approximately 1,969 km^2 (Table 4). We detected Xena multiple times during the winter of 2009/10 at the Easy Pass camera station in Washington but did not recapture her until February 2012. During 2012, Xena used areas similar to those that she used in 2007, but the size of her activity area was considerably smaller (Table 4). Xena was reproductive in 2012, and we located her reproductive den in North Cascades National Park in late April (Appendix, Photo 2). Thus, her smaller activity area was likely related to more localized and restricted movements during the denning period (late February thru April) and during the spring and summer once she was travelling with young.

By placing remote cameras near the entrance to her den, we were able to document that Xena had 1 kit. She removed her kit from the den in late April and, based on the size of the kit and the approximate date when we believe Xena began to den, we estimated the kit's age to be at least 9 weeks. Reproductive females typically move their kits to a new den site once the kits get older and close to weaning (at 9-10 weeks of age). After the snow had melted, we returned to Xena's den site in August and determined that she and her kit had been using the space under a large rock structure (Appendix, Photo 2). Although we collected hair and scats at the site, genetic analyses did not provide us with any new information on Xena's kit.

We live-captured Xena again in 2013 and monitored her movements for 7 months (Table 4, Figure 4). Xena was not reproductive in 2013 and her activity area was substantially larger than it was in 2012 when she had young. Although we haven't recaptured Xena since 2013, we detected her on remotely triggered cameras at 2 different trap sites this past winter (in January and February of 2015), indicating that she has now been a resident female within our study area for 9 years.

Wolverine #5 – Sasha: In 2009, we captured a young nulliparous female (Sasha) at the Twisp River trap and fitted her with a satellite/VHF collar (Table 3). During the first month we monitored her, Sasha traveled approximately 56 km (straight-line distance) southwest to the Entiat and Chiwawa River watersheds. Her movements continued to be centered in this area for the remainder of the summer (Figure 4). We obtained 143 high-quality satellite locations during a 6-month period for Sasha; her activity area was 1,495 km^2 and was located further south in the northern Cascades than any of the other wolverines monitored during our 10-year study (Figure 4, Table 4). Although we monitored Sasha during 2009 only, she has been detected at run-pole camera stations in the Entiat River watershed during the spring of 2012, winter of 2013/14, and most recently in January of 2015. Photo detections of Sasha at remote camera stations reveal that she is in good condition, and her continued presence in this area indicates that she has been a resident female in the southern portion of our study area for 7 years.

Wolverine #6 – Eowyn: In 2010, we captured a young nulliparous female (Eowyn) at the South Creek trap in Washington and fitted her with a satellite/VHF collar (Table 3). During the first 2 months that we monitored her, Eowyn traveled over 483 kilometers north across the Pasayten wilderness and into British Columbia (Figure 5). We obtained 165 high-quality satellite locations during a 2-month period for Eowyn before satellite

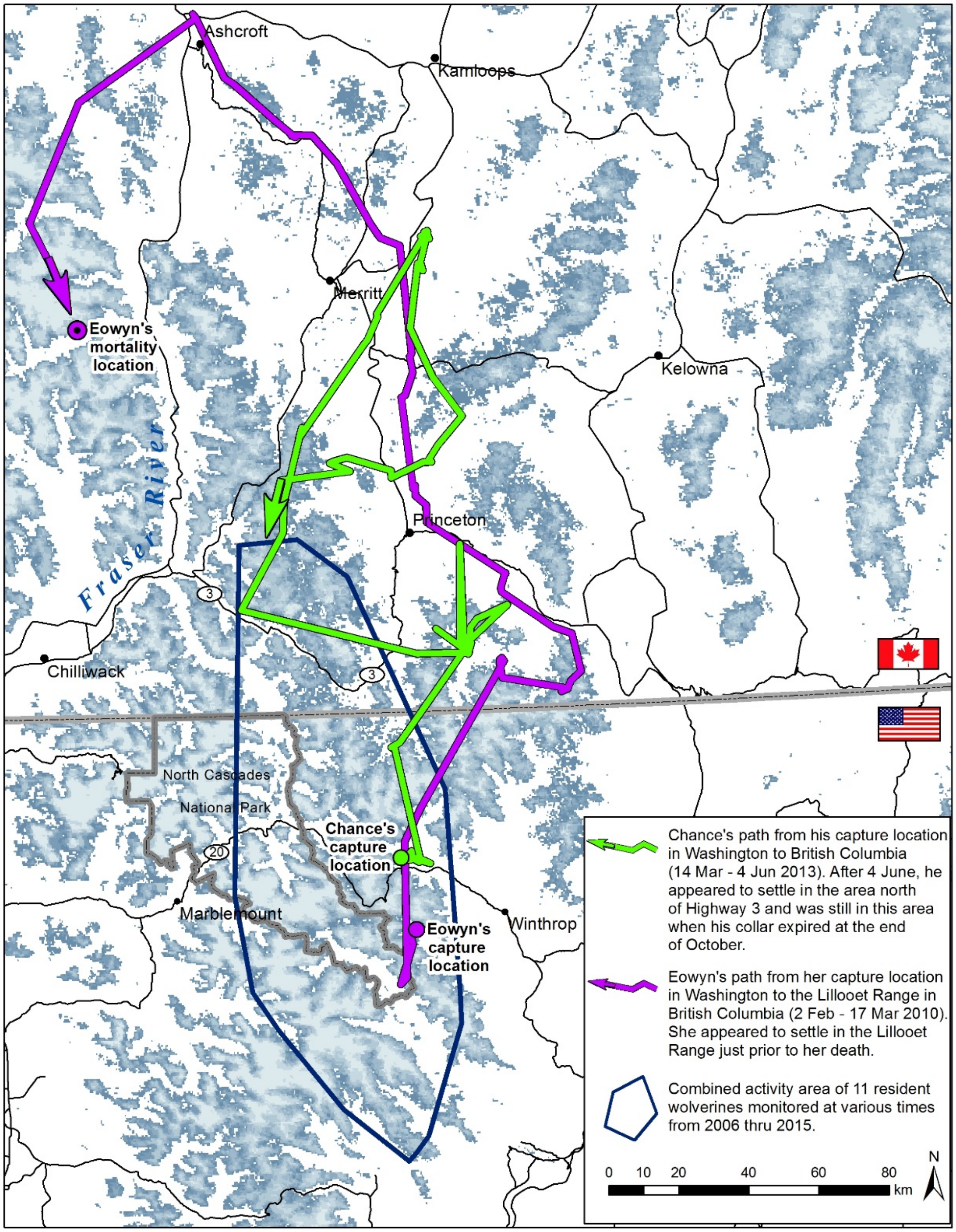

Figure 5. Long-distance movements made by a subadult male (Chance) during 2013 and a young nulliparous females wolverines (Eowyn) during 2010. Movement paths were determined using satellite location accuracy-classes 3 (<250 m) and 2 (250-500 m). The polygon depicting the combined activity area for 11 resident wolverines was determined using satellite location accuracy-classes 3, 2, and 1 (500-1,500 m).

data indicated that her collar stopped moving on March 31. On 12 May 2010, the B.C. crew retrieved Eowyn's collar and skull from a steep slope above the Nahatlatch River in the Lillooet Range, which is at the southern end of the Coast Range in British Columbia (Figure 5). Evidence at the site indicated that Eowyn was killed by a cougar.

Wolverine #7 – Mattie: In 2011, we captured a young female (Mattie) at the Hart's Pass trap and fitted her with a satellite/VHF collar (Table 3). The capture crew suspected that Mattie might be pregnant and thus fitted her with a satellite transmitter programmed to be on 24 hours per day, 7 days per week. However, her subsequent satellite locations did not indicate that she was denning (i.e., her movements were not concentrated in a single area, nor did she repeatedly return to any given area over an extended period of time). We obtained 174 high-quality satellite locations during a 2.5-month period before her satellite transmitter expired in mid-April 2011. Mattie's activity area was 965 km^2 (Table 4, Figure 4) and overlapped part of Rocky's 2011 activity area. Mattie's activity area was also coincident with part of the area that had been occupied by Melanie in 2007. We haven't recaptured or detected Mattie since 2011, so her current status is unknown.

Wolverine #8 – Mallory: In 2011, we captured an adult female (Mallory) at the Rattlesnake trap and fitted her with a satellite/VHF collar (Table 3). Mallory's chest and throat blazes were identical to those of a wolverine detected at our Easy Pass run-pole remote-camera site in March 2010. We obtained 162 high-quality satellite locations during a 5-month period for Mallory and her activity area was 535 km^2 (Table 4). We recaptured Mallory in 2012 at the Easy Pass trap site (Table 3) and fitted her with a new satellite collar. Mallory used the same general area in 2012 (Figure 4) that she used in 2011, however, the overall size of her 2012 activity area was smaller (Table 4). Mallory was reproductive in 2012; consequently, her movements were probably more localized than they would be if she was not denning or travelling with young.

We located Mallory's reproductive den on the Okanogan-Wenatchee National Forest in late April (Appendix, Photo 3). Unfortunately, by the time we could land a helicopter near Mallory's den to install a remote camera (in early May), she had already abandoned the site; i.e., Mallory's kit(s) were at or near the age of weaning by early May and she likely moved them to a new den site. After the snow melted, we returned to Mallory's reproductive den site and determined that she had been using a large log jam that had been created at the bottom of an avalanche chute several years prior (Appendix, Photo 3). Although we collected multiple scats at the den site, genetic results from those samples did not provide us with any information on the identity or potential number of kits that Mallory may have produced. Although we have not recaptured Mallory since 2012, we detected her on remotely triggered cameras at 2 of our livetraps in January and February of 2015, indicating that Mallory is still a resident female in our study area and is at least 7 years of age.

Wolverine #9 – Special K: In February of 2012, we captured a new male wolverine at the Bridge Creek trap site (Table 3). Unfortunately, we could not sedate him enough to safely handle him and fit him with a satellite/VHF collar. Thus we collected a hair sample and released him without a collar. The hair sample provided adequate DNA and subsequent analyses of microsatellite data verified that Special K was a previously unknown male. On 30 July 2012, Special K was detected at a remote run-pole camera station located west of the Cascade Crest near Sauk Mountain on the Mount Baker-Snoqualmie National Forest (identification determined from genetic analysis of hair collected at the station operated by Roger Christophersen, North Cascades National Park). Sauk Mountain represents the western most verifiable detection of a wolverine in Washington. We did not detect this male again for 3 years until we recaptured him this past winter (1 February 2015) in the Easy Pass trap. We fitted him with a KiwiSat 303 VHF/satellite collar and, from late March thru December 2015, we obtained over 300 high quality satellite locations which defined a 2,500-km^2 activity area (Table 4). Because Special K repeatedly visited several of the livetraps during our active trapping period (10 visits and 3 captures at Easy Pass, 6 visits and 2 captures at Bridge Creek, and 3 visits and 1 capture at Twisp River), we only used his locations after the end of trapping on 20 March to calculate his activity area. As of the writing of this report, Special K's satellite collar is still active and we are continuing to monitor his movements. Special K is at least 4 years of age and appears to be occupying at least half of the area that was formerly occupied by Rocky (see Figure 4).

Wolverine #10 – Kendyl: In February of 2012, our collaborators in British Columbia captured a new female in the Memaloose trap (Table 3). Kendyl was fitted with a satellite/VHF collar and we collected 121 high-quality satellite locations on her over a 3-month period before she slipped her collar (Table 4). Her activity area was primarily in southern British Columbia (Figure 4); she ventured south into Washington on apparently only 1 occasion. Although we did not recaptured Kendyl in 2013 (the final year of live-trapping in British Columbia), she was detected at the Memaloose run-pole camera station in British Columbia on multiple occasions between March 22 and May 5 of 2013.

Wolverine #11 – Dasher: In December of 2012, we captured a new subadult male in the South Creek trap (Table 3). We fitted Dasher with a satellite/VHF collar but the collar failed at the end of January 2013. We recaptured Dasher in early February in the Twisp River trap and replaced his satellite/VHF collar with a new one. Unfortunately, Dasher slipped his new collar a week later. However, during the 1.5 months we were able to monitor his movements, we obtained 42 high-quality satellite locations and his activity area was 199 km^2 (Table 4, Figure 4). Most of his movements were within Xena's activity area (Figure 4) and genetic results indicate that Xena is likely his mother.

We sent Dasher's failed collar back to the manufacturer where they determined that the transmitter package had been damaged, allowing moisture to penetrate and corrode the transmitter components. Further examination revealed that the damage may have been inflicted by another wolverine chewing on the transmitter package. Given that Dasher was probably <1 year of age at the time of his capture, he was likely still interacting at times with his parents. Genetic data indicate that Dasher is most likely the offspring of Xena and Rocky. His telemetry location data revealed he was moving within Xena's activity area, and remote video footage taken at the Twisp River trap site revealed Dasher and Rocky travelling together.

Wolverine #12 – Logan: In January 2013, we captured a new subadult male in the Easy Pass trap (Table 3) and fitted him with a satellite/VHF collar. We collected 159 high-quality satellite locations for him over a 5-month period and his activity area was 2,088 km^2 (Table 4). Genetic results from tissue samples collected during his capture indicate that he could be the offspring of Rocky and Melanie.

We recaptured Logan 3 times during the winter of 2013/14 (Table 3). When he was captured on 19 December 2013, he had several recent puncture wounds to his head and torso that appeared to have been inflicted by another wolverine. Although his wounds were significant, they were not life-threatening and we were able to fit him with a KiwiSat 303 telemetry collar. We recaptured him in January but did not immobilize him; however, field personnel were able to observe him in the trap and determine that his wounds were healing well. When we recaptured him in March, we decided to immobilize him to check his condition and replace his KiwiSat 303 collar with a fresh one. His wounds had healed completely and he had gained 1 kg since his capture 3 months earlier. Although we were able to monitor Logan for 10 months and calculate an activity area for him (Figure 4, Table 4), we only acquired a total of 41 high-quality locations from the 2 KiwiSat 303 collars we deployed on him in December and again in March. A sample size of 41 represents a considerably smaller dataset than we have been able to acquire in past years when using KiwiSat 101 collars. For example, in 2013, we deployed a KiwiSat 101 on Logan and acquired 159 high-quality locations during a 5-month period. Consequently, we sent our remaining KiwiSat 303 collars back to Sirtrack for testing. Sirtrack discovered a problem with the wiring between the satellite transmitter and the antenna that was apparently interfering with the collar's transmission signal, and corrected the problem in all of our remaining KiwiSat 303 collars.

<u>Wolverine #13 – Chance</u>: In March 2013, we captured a new subadult male in the West Fork trap (Table 3) and fitted him with a satellite/VHF collar. Within several weeks of his capture, it was evident that Chance was making exploratory movements and did not have an established activity area. During a 12-week period, Chance

travelled over 564 km (Figure 5) north into British Columbia. In early June, after several forays and going well beyond the activity areas of other wolverines we have monitored thus far, he returned to the most northern portion of our study area just north of Highway 3 in British Columbia (Figure 5). Chance continued to occupy this area for the next 4.5 months until his transmitter quit at the end of October. Genetic results indicate that Chance is not the offspring of any of our other study animals. Thus it is unclear where he originated from, and we may have captured him after he had already started to make exploratory movements.

Wolverine #14 – Hobbes: In January 2014, we captured a new subadult male in the Twisp River trap (Table 3) and fitted him with a KiwiSat 303 satellite/VHF collar. About 2 weeks later, the activity sensor in his telemetry collar indicated that the collar was no longer moving. Because of snow conditions and the remoteness of the collar's location, field personnel were not able to access the area until October 2014, at which time they recovered the collar and Hobbes' carcass. Based on the damage to Hobbes' skull, it appears he was killed by another carnivore, possibly a mountain lion (based on the size and spacing of puncture holes). We sent Hobbes' remains to the Integral Ecological Research Center (Blue Lake, California) in hopes that the predator could be identified by swabbing the area around the puncture holes in Hobbes' skull for DNA. Although the swab samples revealed a weak positive for felid DNA, the results could not be replicated and the DNA was too poor in quality to sequence.

***Camera Stations*—**The run-pole remote-camera stations continued to be an effective method for detecting and identifying individual wolverines in our study area. Detailed results for run-pole camera stations operated in the Washington portion of our study area are presented in Table 5. During this past winter (2014/15), we captured photos of a 2 previously unidentified

Table 5. Run-pole camera stations were operated in the North Cascades Ecosystem in Washington for 767 days during the winter of 2009/10, 468 days during 2010/11, 799 days during 2011/12, 446 days during 2012/13, 626 days during 2013/14, and 199 days during 2014/15.

	Camera station																	
Winter	Bridge Creek	Bryan Butte	Easy Pass	Eightmile	Libby	Pick Peak	Slate Creek	Sweetgrass	Buttermilk	Cache Creek	Freezeout	Lake Creek	Billygoat	Hairpin	Rattlesnake	South Fork Gold	Thirtymile	Reynolds
2009/10																		
Camera days	148	21	244	33	32	187	83	19										
# wolverine photos	355[a]	0	102[b]	0	0	0	313[a]	0										
2010/11																		
Camera days	78	26	47	5	62			69	43	42	63	33						
# wolverine photos	4[c]	0	0	0	0			0	0	0	0	0						
2011/12																		
Camera days							175						106	175	121	123	99	
# wolverine photos							67[d]						0	0	8[a]	0	0	
2012/13																		
Camera days							58						68	127	100			93
# wolverine photos							0						0	0	81[e]			0
2013/14																		
Camera days			41				146		79		126			41	76		57	60
# wolverine photos			68[e]				53[f]		0		0			0	0		0	0

	Camera station																	
Winter	Bridge Creek	Bryan Butte	Easy Pass	Eightmile	Libby	Pick Peak	Slate Creek	Sweetgrass	Buttermilk	Cache Creek	Freezeout	Lake Creek	Billygoat	Hairpin	Rattlesnake	South Fork Gold	Thirtymile	Reynolds
2014/15																		
Camera days			19				112								68			
# wolverine photos			0												161[g]			

[a] Rocky

[b] Xena and a previously unidentified wolverine that was later captured and named Mallory

[c] Rocky and Mattie

[d] Rocky and Mallory

[e] Logan

[f] A previously unidentified male wolverine that was identified the following winter (2014/15) and named Ringo

[g] Two previously unidentified wolverines each detected on multiple days: a female subsequently named Stella (DNA identification from hair collected at the camera station), and a male subsequently named Ringo (DNA identification from scats collected at the camera station)

wolverines at the Rattlesnake run-pole camera station. One of the wolverines was a male which we had detected at the Slate Creek camera station during the previous winter (2013/14; Appendix, Photo 4). Unfortunately hair collected at the Slate Creek camera station did not provide any genetic information, and this wolverine did not trigger the hair-snagging clips when he visited the Rattlesnake camera station in 2015. Consequently, in June of 2015, we employed a scat-detection dog team to search the area in the immediate vicinity of the Rattlesnake station and the dog detected 3 potential wolverine scats. Genetic analyses revealed that 1 scat did not have suitable DNA for analysis, but the other 2 scats did have adequate DNA and both were from this new male wolverine which we subsequently named "Ringo". The second wolverine we detected at the Rattlesnake camera station this past winter triggered several of the alligator clips on the hair-snagging frame, and genetic analyses of those hair samples revealed a new female wolverine that we named "Stella" (Appendix, Photo 5).

In British Columbia, our collaborators operated varying numbers of run-pole camera stations for 5 winters: 9 stations in 2009/10, 8 in 2010/11, 7 in 2011/12, and 4 in 2012/13. Both Melanie and Rocky were detected on multiple occasions at the Memaloose and Cambie camera stations between February and April in 2010. During the winter of 2011/12, at least 4 different wolverines were detected: 2 previously unknown wolverines were detected at Sumallo Grove (Appendix, photos 6 and 7), and Kendyl and Melanie were detected at the Memaloose camera station on multiple occasions between February and May. Kendyl was again detected at the Memaloose camera station on multiple occasions during the winter of 2012/13. Camera detections in British Columbia of non-target species included marten, ermine, grizzly bear, black bear, cougar, bobcat, Canada lynx, and spotted skunk.

***Scat-detection Dogs* –**As previously described, a scat-detection dog team was used successfully to locate wolverine scats at a remote camera station several months after wolverines had been detected at the station (Appendix, Photo 8). Genetic analyses verified that 2 of 3 scats collected were from a new (previously unidentified) male wolverine in our study area.

A scat-detection dog team was also successfully used in July of 2015 to locate and collect wolverine scats in a remote area of North Cascades Recreational Area – an area that had been visited repeatedly by one of our collared males (Special K) over a period of about 7 weeks from late March to early May (Appendix, Photo 9). Because Special K's movements during this time coincided with the denning period, we speculated that he might be visiting a reproductive den site. Once the area was accessible, a field crew backpacked into the site with a dog team and conducted an intensive search within a 6-ha area. Although we did not locate any structures that appeared to have been used as a reproductive den, the dog hit on a bear skull (the only sizable remains from a relatively recent carcass) and then detected potential wolverine scats at 3 small latrine sites. In the immediate vicinity of 1 of the latrine sites, the field crew found 2 bear claws and a small clump of bear hair. With the exception of 1 scat sample that did not have adequate DNA, genetic analyses revealed that scats collected at all 3 latrines were from wolverine. Furthermore, scat samples from 2 of the latrines provided an individual genetic profile, both of which were Special K. These results, combined with our field observations, suggest that Special K was periodically returning to this area to feed on a bear carcass.

We also used a scat-detection dog team to search a boulder field that we thought may have been the site of a wolverine reproductive den (Appendix, Photo 10). We originally identified this site in April of 2015 while conducting helicopter searches for potential reproductive dens within the activity areas of known females. This particular site within

Mallory's activity area, and <700 m from her 2012 den, had a network of tracks in the snow indicating that a wolverine was coming and going from a group of large boulders. At the time, we were unable to land at the site to investigate further or deploy a remote camera. Consequently, once the snow melted and we could access the site on foot, we used a dog team to search the boulder field in an effort to locate latrines and other evidence that might indicate that the site had been used by a female wolverine for denning. Because this was our first experience using scat-detection dogs, and wolverine scats at reproductive den sites are quite variable in size, shape, and composition (based on scats we collected at Xena's 2012 den and Mallory's 2012 den), we asked the handler to let the dog search for not only wolverine scats but those of other carnivore species for which the dog was trained, including other mustelids and felids. Of the 16 scats detected by the dog, genetic analyses revealed that 2 did not have suitable DNA for species identification, 3 were from Canada lynx, and the remaining 11 were from Pacific marten. Thus, we were not able to confirm the use of the boulder field by a wolverine. Nonetheless, the use of scat-detection dogs to locate wolverine scat at remote camera stations that have been visited by wolverines, or to locate scats within an area defined by a cluster of telemetry locations from a collared study animal, shows promise. Also encouraging was that the detection dogs were able to find useful wolverine scats (i.e., scats that had suitable DNA for genetic analyses) that had been sitting out in the environment for several months during periods of snow, snow melt, and hot summer temperatures.

Backcountry Snow-tracking Routes—In year 5 (winter 2009/10), we established 2 backcountry snowtracking routes in Washington to backtrack wolverines to obtain DNA samples (scat or hair; Ulizio et al. 2006) in areas that were too remote for trapping. We made a 3-day scouting trip into the Spanish Camp area of the Pasayten Wilderness from February 10-12.

During this trip, we followed 1 putative wolverine track and collected 2 scat samples, but the quality of the DNA from these samples was too poor to determine species. We completed a second trip into the Spanish Camp area from February 18-22, during which we followed 1 putative wolverine track for a short distance, but collected no samples. Finally, we completed a 4-day trip in the Sawtooth area from March 18-21, but we found no putative wolverine tracks and collected no samples. Considering these results, the substantial effort and safety precautions needed to conduct back-country work during winter, and the fact that the duration of snow and weather conditions in the northern Cascades that are favorable for snow-tracking are typically shorter than the time needed to complete a single trip, we did not pursue back-country snow-tracking during any of our subsequent winter field seasons.

IV. Discussion and Management Implications

Due to the substantial logistical challenges involved in conducting a telemetry study of wolverines in the northern Cascade Range, our primary objectives during the first 3 years of the study (winters 2005/06, 2006/07, and 2007/08) were to determine if we could: (1) safely and effectively live-trap and collar wolverines in the northern Cascades of Washington, and (2) use Argos satellite telemetry to investigate their distribution, movement patterns, habitat use, and reproductive ecology.

In year 1, by placing traps in strategic locations, we were able to capture and collar 2 wolverines, including a juvenile female and a subadult male. One telemetry collar malfunctioned soon after being deployed, and dropped off before we could collect more than a few locations and, although the second collar operated for several months, it failed to provide a strong data set of satellite locations. Problems involved both the design of the collar and the duty cycle, which failed to provide us with an adequate number of high-quality satellite locations.

The mechanical failure was the manufacturer's fault, and they subsequently redesigned their collars to correct that problem. However, we concluded that our failure to obtain a large number of high-quality satellite locations from the other collar was probably due to the high topographic relief of our study area, and resulting difficulties in obtaining high-quality satellite locations during only 5 hr each day.

Based on our experiences and recommendations from colleagues, we modified the duty cycle on our satellite collars to maximize acquisition of high-quality satellite locations (by setting the duty cycle to "on" between 0500 and 1900 hrs) and to lengthen our data-collection period from 4 to potentially 8 months (i.e., the collars run for 14 hrs every other day). Also, early on in the study, we reduced the width and thickness of the collar strap and eliminated the timed-release mechanism to reduce both the size and weight (from about 225 to 200 grams) of the telemetry collars, and to minimize the possibility of mechanical failures. These telemetry collars continue to work well and have remained on our wolverines throughout the data-collection period and longer (>12 months). With these modifications, we achieved both of our objectives during years 2 and 3. During that time, we captured 2 new wolverines, recaptured the juvenile female and subadult male from year 1, collected 80–130 high-quality locations for each study animal during a 2–6 month period, and documented that reproduction was occurring in Washington (i.e., Melanie was pregnant in 2007).

During years 4 thru 10 (winters 2008/09 thru 2014/15), we continued to capture new wolverines and recapture many of the study animals we monitored in previous years. To date, we have captured 14 different wolverines in Washington and British Columbia, 5 of which we monitored in multiple years. During 2011/12, we obtained valuable information on the reproductive ecology of wolverines in Washington and located the first reproductive dens ever documented in this region. Overlap in adult male and female activity areas likely indicates reproductive pairs. For example, Rocky's movements during 2012 completely overlapped those of the 2 reproductive females (Mallory and Xena), indicating that he is likely the father of their kits (Figure 6). High-quality satellite location data also indicated that Rocky periodically visited each of the female's den sites. During 2012/13, we captured a young male (Dasher), and genetic analyses revealed that he is likely the offspring of Rocky and Xena. Thus, using both field and genetic data, we can elucidate familial relations among our study animals.

During the course of this study, we have been able to delineate activity areas for 11 wolverines using satellite location data (Figure 4, Table 4) and document long-distance movements by 2 subadults (1 female and 1 male; Figure 5). Furthermore, the activity areas for 9 of 11 study animals were located primarily in Washington, demonstrating that there is a resident population of wolverines in the state. Clearly, recent verifiable wolverine occurrence records in Washington do not represent Canadian wolverines that occasionally wander into Washington. Rather, our results provide support for the current range of wolverines described by Aubry et al. (2007). However, the extent and location of the activity areas we delineated suggest that a relatively small number of wolverines may be capable of establishing home ranges within the state. The conservation of wolverines in Washington will depend on reliable knowledge of their distribution, population status, and habitat relations. This knowledge can only be gained by long-term field research; thus, it is essential that we continue this research and find ways to expand the scope of our activities beyond the boundaries of our current study area.

Satellite location data that we collected on 4 wolverines during 2006 and 2007 were used as part of a larger dataset (telemetry data from wolverine studies conducted in North America and Fennoscandia) to develop a spatially explicit model of wolverine habitat based on

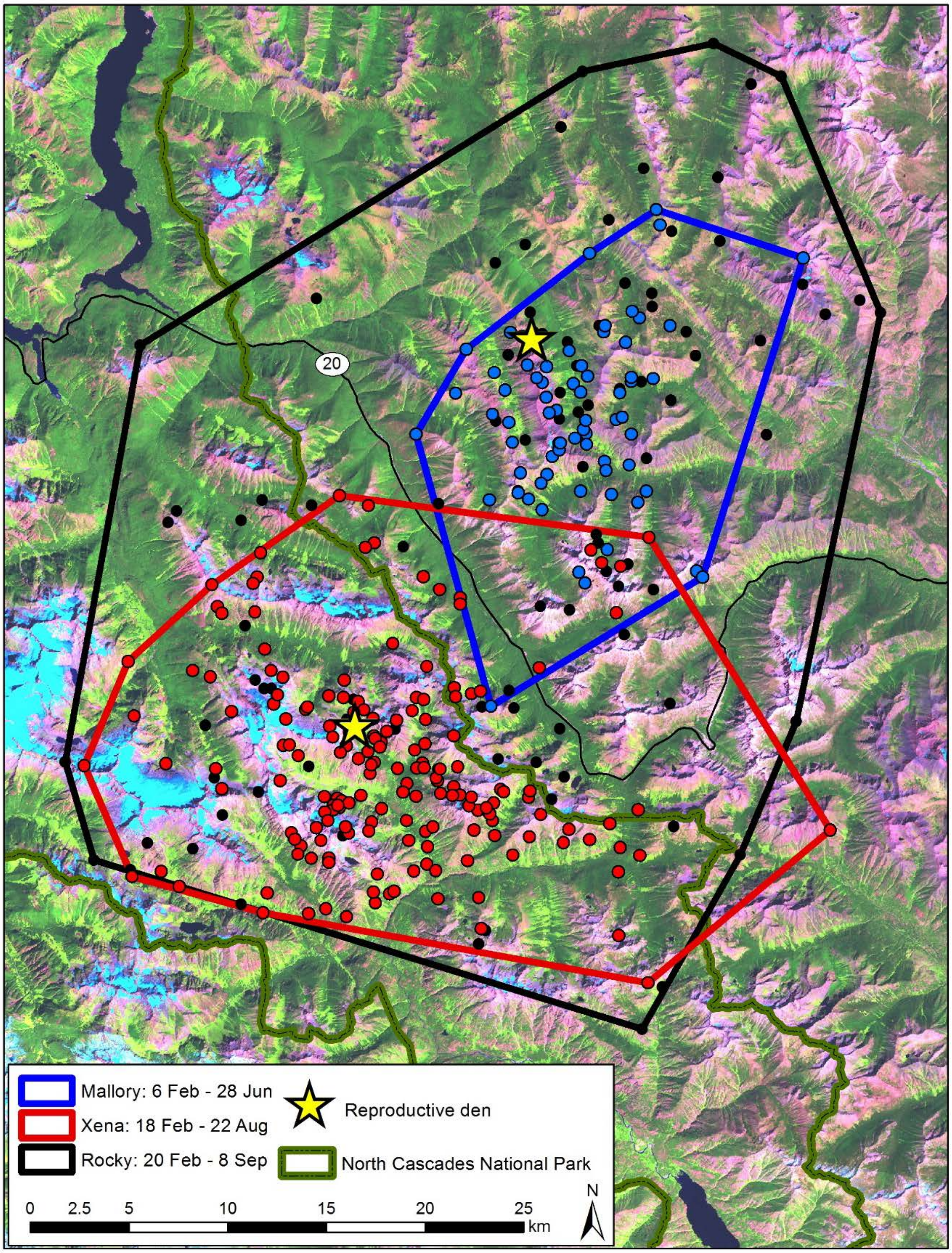

Figure 6. Rocky's movements in 2012 encompassed those of 2 reproductive females (Mallory and Xena), and he appeared to have visited each of the female's dens when they were actively using the den and had young kits.

the wolverine's bioclimatic envelope and their association with persistent spring snow cover (i.e., snow cover thru the wolverine reproductive denning period; Copeland, et al. 2010). Since this model was developed, we have collected an additional 2,476 high-quality satellite locations on 11 wolverines in Washington and British Columbia. The vast majority (91%) of these telemetry locations fall within areas having snow cover that persists into late spring (Figure 7) suggesting that the bioclimatic envelope model is a reliable way to delineate potential wolverine habitat in the North Cascade Ecosystem, and would be useful for both management and conservation purposes.

V. Future Research

This past winter (2014/15) was our final year of trapping and, although we are still monitoring the movements of 1 male wolverine, we are transitioning from the data collection phase of the project to data analyses and publication of final results. During the course of our 10-year study, we live-captured and monitored the movements of 14 different wolverines (7 males and 7 females) and identified 2 additional wolverines (1 male and 1 female) via genetic analyses of scat or hair collected at camera stations. Working with other partners who are conducting camera surveys for wolverine and other forest carnivores, including the Woodland Park Zoo, various Forest Service Ranger Districts, the Washington Department of Fish and Wildlife and Conservation Northwest volunteers, we hope to continue gathering additional genetic samples from wolverines in the North Cascades Ecosystem and in neighboring regions to investigate the connectivity of wolverine populations in this portion of their range. In 2016, we will begin the analyses of telemetry location data to investigate the size and distribution of wolverine home ranges and the effectiveness of several competing habitat models (including the bioclimatic envelope model) for delineating wolverine habitat in the North Cascades Ecosystem.

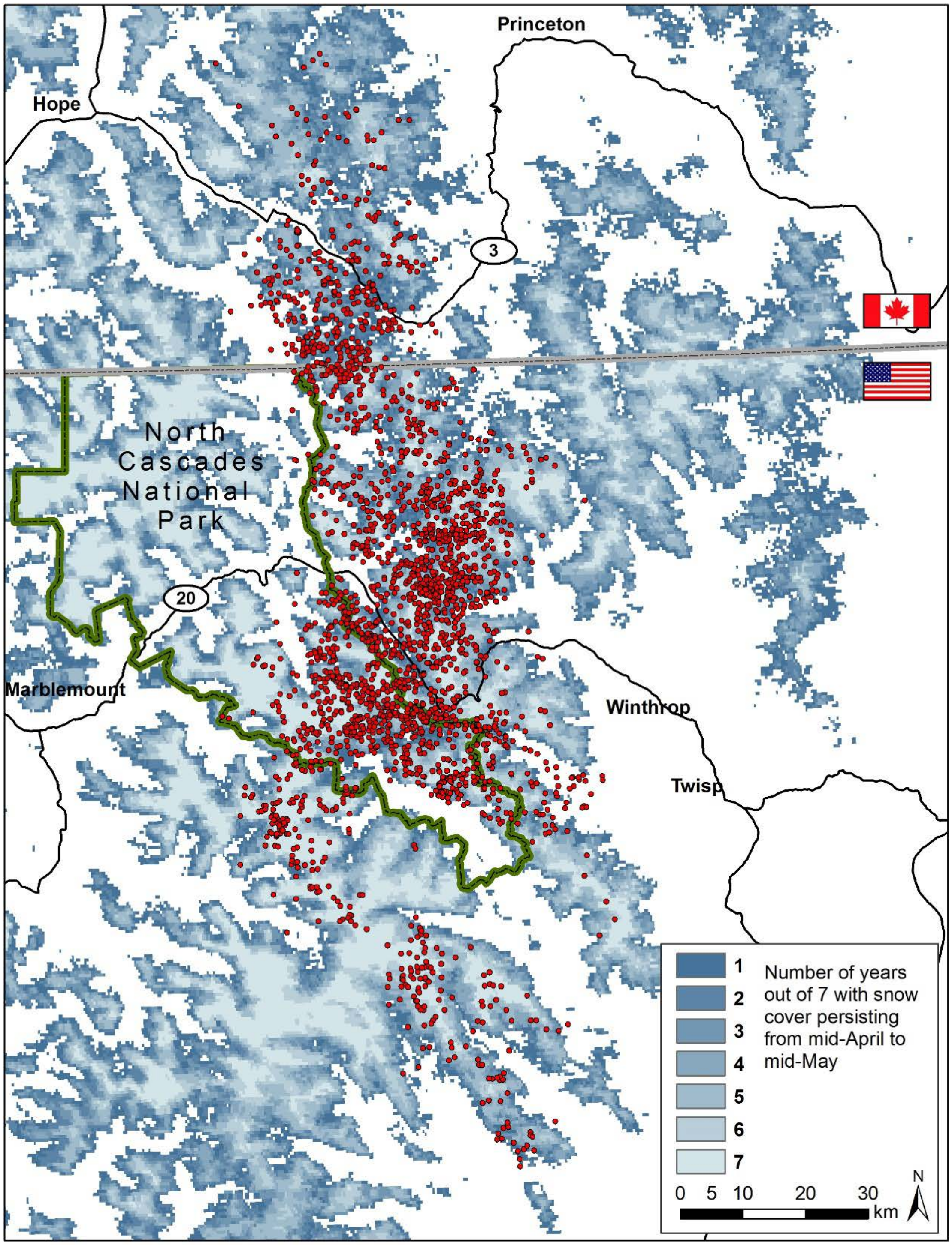

Figure 7. More than 2,400 high-quality satellite locations (red dots) obtained on 11 wolverines monitored from 2008 thru 2015 overlaid on a map of persistent spring snow cover developed by Copeland et al. (2010) and representing potential wolverine habitat in the Northern Cascades Ecosystem. Two wolverines that made long-distance movements are not included.

VI. Partnerships

This research could not have been possible without the collaboration and direct involvement of John Rohrer of the Methow Valley Ranger District, Okanogan-Wenatchee National Forest, Scott Fitkin of the Washington Department of Fish and Wildlife, Eric Lofroth and Rich Weir of the British Columbia Ministry of Environment, and Cliff Nietvelt of the British Columbia Ministry of Forests, Lands and Natural Resource Operations, all of whom have contributed funding or in-kind contributions to the study. Additional funding and support for work conducted in Washington were provided by Seattle City Light; the USFS and BLM Interagency Special Status/Sensitive Species Program (ISSSSP); the USFS National Carnivore Program in Missoula, Montana; the U.S. Fish and Wildlife Service; the Wolverine Foundation; the Seattle Foundation/Tom and Sonya Campion Fund; and the USFS Pacific Northwest Research Station. Funding and support for work conducted in British Columbia was provided by the Habitat Conservation Trust Fund, the Skagit Environmental Endowment Commission, the British Columbia Ministry of Environment, and the British Columbia Conservation Foundation.

The following individuals ably assisted in trap construction, maintenance, and/or the handling and collaring of captured wolverines: in Washington, Bruce Akker, Mo Kelly-Akker, Chase Bolyard, David Bowden, Kat Dees, Andre Dulac, Mila Dunbar-Irwin, Justin Ewer, Sherrie Farmer, Teresa Fish, Lee Ann Grubbs, Mike Harmon, Dan Harrington, Morgan Hartsock, Evan Haug, Jeff Heinlen, John Jakubowski, Adam Kehoe, Gary Koehler, Michael Liu, Alexis Monetta, Andrew Myhra, Bob Naney, Joyce Neilson, Nate Redetzke, Kim Romain-Bondi, Dan Russell, Brandon Sheeley, Bryan Smith, Gabe Spence, Ann Sprague, Blake Stokes, Michael Taylor, Chris Vennum, Katie Weber, Lindsay Welfelt, Steph Williams, Zack Winters, and Aja Woodrow; in British Columbia, Travis Desy, Dan Guertin, Brent Gurd, Matt Rochetta, Heidi

Schindler, and Dylan Taylor. We thank Marvin Streubal and others with APHIS Wildlife Services in Washington for providing beaver carcasses with which to bait our livetraps. Lastly, we are indebted to Jeff Copeland of the Rocky Mountain Research Station for his encouragement, enthusiasm, and invaluable assistance and advice during the initial 2 years of this research.

We continue to work with volunteers at Conservation Northwest (CNW) in Bellingham, WA to conduct remote-camera surveys for wolverines and other forest carnivores, primarily during the snow-free months, in the Cascade Range in Washington. During the past 4 years (2012 – 2015), CNW detected 5 different wolverines in the Chiwaukum Creek drainage south of both our study area and Highway 2. Genetic analysis of hair collected at the site after each of these detections revealed that 2 of the wolverines were females (subsequently named Peg and Lacy) and 3 were males (Bootjack Mountain, Clark, and Spencer). The Bootjack Mountain male was detected at another CNW remote-camera station about 16 kilometers south of the Chiwaukum site. Additionally, CNW volunteers installed a run-pole camera station near Ice Lakes on the Entiat Ranger District of the Okanogan-Wenatchee National Forest (in the most southern portion of our study area) and detected wolverines on multiple occasions during the fall of 2013 and the winters of 2013/14 and 2014/15. Although no genetic samples were collected during any of these survey periods, digital images revealed that at least 3 different wolverines were detected during the winter of 2013/14, including Sasha, a female we originally captured and collared in 2009.

VII. Publications and Presentations

Upon completion of this study, our findings will be published in 1 or more scientific outlets. However, data collected during this study have already been used in 2 important publications on the wolverine's bioclimatic niche and its potential vulnerability to global warming. Telemetry data that we collected on Washington wolverines in 2006 and 2007 contributed to a journal article published in the *Canadian Journal of Zoology* (Copeland, et al. 2010; Aubry is a co-author) that defines the bioclimatic envelope of the wolverine based on the climatic conditions that result in persistent spring snow cover. This publication also includes a spatially explicit model of wolverine habitat for all components of the population during all seasons of the year that can be used for both management and conservation purposes (see supplemental material in Copeland et al. [2010]); it can also be used to provide an empirical basis for predicting the potential effects of global warming on wolverine distribution throughout the world. Results from this study also contributed to a journal article published in *Ecological Applicatio*ns (McKelvey et al. 2011; Aubry is a co-author) that predicted the potential effects of global warming on the geographic extent and connectivity of wolverine habitat in the western contiguous U.S. Information presented in this paper provided the primary empirical basis for the proposed listing of wolverines under ESA that was recently withdrawn (U.S. Fish and Wildlife Service 2013, 2014). Additionally, results from our study contributed to a book chapter on the social ethology of wolverines (Copeland et al. *In press*; Aubry is a co-author).

We have given numerous public and scientific oral presentations that include results from this study, including:

Aubry, K.B. 2006. Ecology and conservation of forest carnivores in the Pacific Northwest. Oral presentation to Methow Conservancy, Winthrop, WA.

Copeland, J.P., K.B. Aubry, K.S. McKelvey, and S.W. Running. 2006. The implications of global warming on a snow-dependent species—a case for the wolverine. Oral presentation at the Defenders of Wildlife's Carnivores 2006 Symposium, St. Petersburg, FL.

Aubry, K.B., J.J. Rohrer, S.H Fitkin, and C.M. Raley. 2007. Distribution and ecology of the wolverine in northern Washington: preliminary results. Oral presentations at the Joint Annual Meeting of the Oregon and Washington Chapters of the Wildlife Society, Pendleton, Oregon: this talk was also given at a tech-transfer meeting of wolverine researchers and USFWS personnel involved in a 12-month status review for the potential listing of wolverines in the contiguous U.S., Missoula, MT.

Aubry K.B., K.S. McKelvey, J.P. Copeland, and P. Gonzalez. 2007. Wolverine range and climatic requirements. Oral presentation to Natural Resources Staff at the Washington Office of the Forest Service, Washington, D.C.

McKelvey, K.S., K.B. Aubry, J.P. Copeland, and P. Gonzalez. 2007. The likely effects of climate change on wolverines. Oral presentation to Natural Resources Staff at the Washington Office of the Forest Service, Washington, D.C.

Aubry, K.B., J.J. Rohrer, S.H. Fitkin, and C.M. Raley. 2007. North Cascades wolverine project. Oral presentation at Workshop entitled, “Washington's Cascades: I-90 and North”, Conservation Northwest, Ellensburg, WA.

Aubry, K.B. 2008. Wolverine secrets. Oral presentation to the Streamkeeper Academy, Northwest Stream Center, Everett, WA.

Aubry, K.B. 2008. Wolverines in Washington. Oral presentation to a troop of Royal Rangers and their parents, Sultan, WA.

McKelvey, K.S., J.P. Copeland, K.B. Aubry, M.K. Schwartz. 2009. The relationship between wolverines and climate: past, present, and future. Oral presentation, Weekly Seminar Series, National Center for Ecological Analysis and Synthesis, University of California, Santa Barbara, CA.

Aubry, K.B., K.S. McKelvey, J.P. Copeland. 2009. Wolverine distribution and relations with snow cover: potential threats from global warming. Departmental Seminar, Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR.

Aubry, K.B. 2010. Wolverine research and conservation. Interagency seminar series (USFS, BLM, USGS, and USFWS), “Spotlight on Science: Sharing Research with Partners”, Portland, OR.

Aubry K.B. 2010. On the track of the elusive wolverine. Oral presentation to the Streamkeeper Academy, Northwest Stream Center, Everett, WA.

Aubry K.B. 2010. On the track of the elusive wolverine. Oral presentation to the Island County Beach Watchers, Washington State University Extension Program, Stanwood, WA.

Aubry, K.B. 2010. Biology and conservation of the wolverine in California. Peninsula Round Table, Burlingame, CA.

Rohrer, J. 2010. Wolverines in the North Cascades. Sun Mountain Lodge, Winthrop, WA.

Aubry K.B., C.M. Raley, J.J. Rohrer, E.C. Lofroth, and S.H. Fitkin. 2011. Preliminary results from the North Cascades wolverine study. Joint Annual Meeting of the Society for Northwestern Vertebrate Biology and the Washington Chapter of the Wildlife Society, Gig Harbor, WA.

McKelvey, K.S., K.B. Aubry, J.P. Copeland, M.K. Schwartz, and J.S. Littell. 2011. Wolverine range, climatic requirements, and the likely effects of climate change on wolverine distribution. 2nd Annual Pacific Northwest Climate Science Conference, Seattle, WA.

Aubry, K.B. 2011. Wolverines and climate change. North Cascades National Park Climate Change Workshop, North Cascadia Adaptation Partnership, Burlington, WA.

Rohrer, J. 2011. North Cascades wolverine study. Okanogan-Wenatchee National Forest Employee Rendezvous, Cashmere, WA.

Rohrer, J. and S. Fitkin. 2011. North Cascades wolverine study. North Cascades Institute Northwest Field Naturalist Retreat, North Cascades National Park, WA.

Aubry, K.B. 2012. The wolverine in Washington: history, distributional dynamics, and conservation status. 2nd Annual Scientific Conference on the Flora and Fauna of Mount Adams, Friends of Mount Adams, Trout Lake, WA.

Raley, C.M., K.B. Aubry, J.J. Rohrer, R.D. Weir, E.C. Lofroth, and S.H. Fitkin. 2012. Wolverine distribution and ecology in the North Cascades Ecosystem. Annual Meeting of the Society of Northwest Vertebrate Biology, Hood River, Oregon. This talk was also presented at the Conservation Northwest Remote Camera Training Workshop, Seattle, WA.

Rohrer, J. and S. Fitkin. 2012. North Cascades wolverine study. North Cascades Institute Carnivore Class, North Cascades National Park, WA.

Rohrer, J. 2012. North Cascades wolverine study. Allen Elementary School Science Fair, Winthrop, WA.

Aubry, K.B. 2013. The wolverine in Washington: extirpation, recolonization, and current status. Departmental Seminar, Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR.

Aubry, K.B. 2013. Wolverine research and monitoring in the North Cascades Ecosystem. Cascadia Partner Forum Pilot Council, online webinar.

Aubry K.B. 2013. The wolverine in Washington. Skihawks Ski Club, Tacoma, WA.

Aubry, K.B., K.S. McKelvey, N.J. Anderson, A.P. Clevenger, J.P. Copeland, K.S. Heinemeyer, R.M. Inman, J.R. Squires, J.S. Waller, K.L. Pilgrim, M.K. Schwartz. 2013. Recovery of wolverines in the western United States: recent extirpation and re-colonization or range retraction and expansion? Annual Meeting of the American Society of Mammalogists, Philadelphia, PA.

Aubry, K.B. 2013. Wolverine research and monitoring in the North Cascades Ecosystem. Wild Links Briefing: A Cascadia Partner Forum Workshop, Conservation Northwest, Manning Park Resort, B.C., Canada. (Aubry could not attend due to government shut down, so the talk was given by Scott Fitkin)

Aubry, K.B. 2013. Wolverines in the North Cascades. Streamkeeper Academy, Snohomish, WA.

Raley, C., K. Aubry, J. Rohrer, S. Fitkin. 2013. Wolverine distribution and ecology in the North Cascades Ecosystem. Conservation Northwest, Summer 2013 Citizen Monitoring Remote Camera Training, Seattle, WA.

Rohrer, J. 2013. North Cascades wolverine study. U.S. Forest Service Annual Carnivore Class, Yellowstone National Park, WY.

Rohrer, J. 2013. North Cascades wolverine study. Central Washington University, Natural Resources Techniques class field trip, Winthrop, WA.

Rohrer, J. and S. Fitkin. 2013. North Cascades wolverine study. North Cascades Institute Carnivore Class, North Cascades National Park, WA.

Aubry, K.B., K.S. McKelvey, and M.K. Schwartz. 2014. Phylogeography of the wolverine in southern North America. Oral presentation at the 6th International *Martes* Symposium, Krakow, Poland.

McKelvey, K.S., M.K. Schwartz, J.P. Copeland, K.B. Aubry, and S.A. Parks. 2014. Moving organisms in a changing world: the case of the wolverine. Oral presentation at the North American Congress for Conservation Biology, Society for Conservation Biology, Missoula, MT.

Rohrer, J. 2014. North Cascades wolverine study. U.S. Forest Service Annual Carnivore Class, Yellowstone National Park, WY.

Rohrer, J. 2014. North Cascades wolverine study. Central Washington University, Natural Resources Techniques class field trip, Winthrop, WA.

Rohrer, J. 2014. North Cascades wolverine study. U.S. Forest Service Region 6 Wildlife Program Managers Mtg, Ashland, OR.

Aubry, K.B. 2015**.** Wolverines in the North Cascades. Streamkeeper Academy, Snohomish, WA.

Aubry, K.B., C.M. Raley, J.A. Rohrer, and S. Fitkin. 2015. The North Cascades Wolverine Study: preliminary results and current activities. Joint Annual Meeting of the Washington Chapter of the Wildlife Society and the South Sound Chapter of the Society of American Foresters, Rochester, WA.

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Rohrer, J. 2015. North Cascades wolverine study. U.S. Forest Service Annual Carnivore Class, Yellowstone National Park, WY.

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Rohrer, J. 2015. Cascade Carnivores. North Cascades Basecamp, Mazama, WA.

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Magoun, A.J., and J.P. Copeland. 1998. Characteristics of wolverine reproductive den sites. Journal of Wildlife Management 62:1313-1320.

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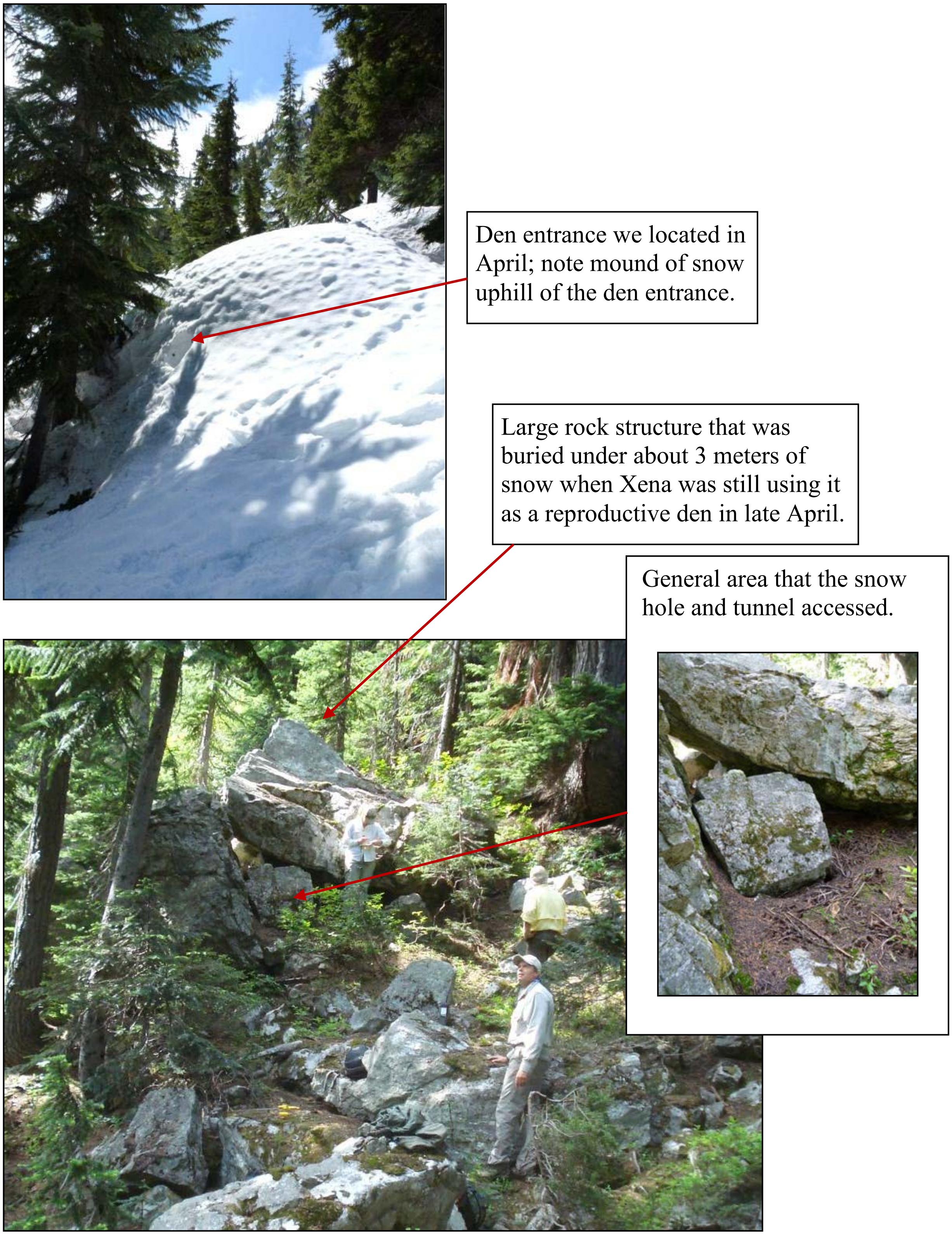
U.S. Fish and Wildlife Service. 2014. Endangered and threatened wildlife and plants; threatened status for the distinct population segment of the North American wolverine occurring in the contiguous United States; establishment of a nonessential experimental population of the North American wolverine in Colorado, Wyoming, and New Mexico: proposed rules; withdrawal. Federal Register 79:47522-47545.

Appendix, Photo 1. Wolverine livetrap constructed of natural logs at Hart's Pass in the northern Cascade Range in Washington (left), and the trigger mechanism located at the back of the trap (center). In British Columbia, wolverine traps were prefabricated using milled lumber (right) and then transported to the trap site for final assembly.



Appendix, Photo 2. Xena's reproductive den site in 2012 located in North Cascades National Park, Washington.

Mallory accessed her den via an opening and tunnel that she dug in the snow that started at the bottom of this tree well.

Space under downed trees used by Mallory and her kit(s). This area still had about 2.4 meters of snow in early May.

Appendix, Photo 3. Mallory's reproductive den site in 2012 located on the Okanogan-Wenatchee National Forest, Washington.

Appendix, Photo 4. Ringo: this male wolverine was initially detected at the Slate Creek camera station in Washington on 2 March 2014. Unfortunately, hair samples collected at that time did not provide adequate DNA for genetic analyses. Two weeks later, he was detected 35 km to the northeast at another run-pole camera station in British Columbia. He was detected again on multiple days in March and April of 2015 at the Rattlesnake camera station, but he did not trigger the hair-snagging clips. Consequently, we used a scat-detection dog team to search the area in the immediate vicinity of the camera station and collected 2 wolverine scats which provided suitable DNA for an individual genetic profile. The above detections during 2014 and 2015 indicate that Ringo is occupying areas within what was Rocky's 2012 activity area.

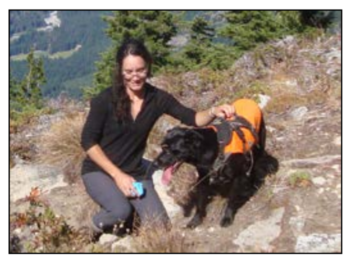
Appendix, Photo 5. Stella: this female was detected at the Rattlesnake camera station on multiple days in March and April of 2015. Hair samples collected from the alligator clips she triggered provided suitable DNA for an individual genetic profile

Appendix, Photo 6. A previously unknown wolverine was detected at the Sumallo Grove camera station in British Columbia in November of 2011 and December of 2012.

Appendix, Photo 7. A previously unknown wolverine was detected at the Sumallo Grove camera station in British Columbia in February and April of 2012.

Appendix Photo 8. June 2015: a scat-detection dog team preparing to search the area around the Rattlesnake run-pole camera station where 2 wolverines had been detected 2-3 months previously.

Appendix, Photo 9. July 2015: a steep slope in North Cascades National Recreation Area searched by a scat-detection dog team (below) after Special K repeatedly visited the area from late March to early May.



Appendix, Photo 10. June 2015: a scat-detection dog team searching a large boulder field in which wolverine tracks on snow were identified from a helicopter in April of 2015.