Wolverine Population Assessment in Glacier National Park

Spring 2006 Progress Report

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The findings presented herein are preliminary results of an ongoing study, provided to meet annual commitments to granting agencies and organizations and update project contributors and supporters. Report prepared in March, 2006. **Front cover photo provided courtesy of Ken Curtis.**

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Progress Report 2004-2005

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Photo courtesy of Bill Garwood

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EXECUTIVE SUMMARY

The Glacier National Park Wolverine Project has just completed its third full year of study. During that time, 19 wolverines have been captured and instrumented providing over 3,000 telemetry-location points. Reproductive den sites, documented for two adult females, occurred on upper slopes in sparse timber beneath downed, woody debris. Females used 2-3 dens prior to weaning of kits. These dens represent nearly 50% of all wolverine dens ever found in the continental U.S. Four kits were captured and instrumented at den sites and monitored through their first summer to document 17 rendezvous sites; these occurred primarily in boulder talus and cliff areas. Kits separated from their mother at 6-7 months-of-age in late September. Kit survival to adulthood has been low as evidenced by 3 of 4 kits dying during their first year. GPS collars were tested at 4-hr, 2-hr, 30-min, and 5-min fix acquisition intervals providing insight into capabilities of documenting patterns and rates of movement, habitat use, and social interactions. GPS data from 2 males indicated movement rates averaging 2 km/hr in a pattern of long-distance movements (commonly exceeding 10 km) interspersed with localization periods of up to 20 hrs. Wolverine traverse the landscape apparently indifferent to topographic features. Glacier National Park wolverine home ranges averaged 496 km^2 for males and 141 km^2 for females. DNA analysis for 20 individuals suggests less genetic structure than expected with relatedness contained by 2 distinct genotypic groups within our study population.

The 3-year study period provided by the Natural Resources Protection Program grant ended in 2004. Glacier National Park and Rocky Mountain Research Station staff met in 2005 and agreed to continuation of the project for 3 additional years pending funding. Additional funding provided by agencies, private grants, and private donations will allow continuation into FY 2007.

The subalpine habitat of Glacier National Park provides the ideal setting for studying wolverine.

INTRODUCTION

Glacier National Park (GNP) encompasses over 1 million acres, consisting of numerous, diverse habitats covering east and west slopes of the Continental Divide in north-western Montana. As a component of the biologically rich Northern Continental Divide Ecosystem, GNP has been characterized as a refuge for wolverine (*Gulo gulo*), and a source for dispersers into surrounding areas of the Northern Rockies (Ruggiero, et al, 2000; Newby and Wright, 1955).

The wolverine is one of North America's most rare mammals and least known large carnivores, with only two previous long-term field research projects completed in the lower 48 United States (Banci 1994). Lack of basic ecological information on wolverine makes the species increasingly vulnerable to impacts within GNP and beyond its boundaries. Glacier is one of the few national parks that support wolverine, thereby providing an ideal research setting for the investigation of a naturally regulated population. Wolverine distribution, abundance, survival, dispersal patterns, habitat use, food habits, and other ecological and demographic factors, as well as their sensitivity to human activity, are poorly understood in the park as elsewhere. Anecdotal sightings and records from periodic track surveys currently provide the basis for assessing general occurrence and distribution, while more in-depth knowledge at both broad scale and site-specific levels is lacking. Land management agencies make decisions that have potential to impact wide-ranging carnivores such as wolverine, and are obligated to base those decisions on sound scientific information. The profundity of this information requires more than a brief two- or three-year investigation of wolverine ecology.

The Glacier Wolverine Project was initially funded and designed for a 3-year period, which ended at the close of the trapping season in 2004. However, fruitful project achievements brought about reconsideration of study duration by GNP and Rocky Mountain Research Station staff, with consensus that the project be extended, dependent on the availability of funding, for three additional years. To facilitate this next phase of research, our work will center on two areas of study, which are well adapted to our logistical capabilities, and will augment our accomplishments to date.

1) **Reproductive ecology**
   a) GNP provides an infrastructure that allows situating our research team in the heart of wolverine habitat. Female wolverine tend to select reproductive den sites that are remote and difficult to access. GNP's facilities provide bases of reasonable access to remote portions of the park, thereby providing a reasonable opportunity to access dens in the spring and monitor females and kits throughout the summer. This information will provide our strongest link between wolverine habitat use and park visitors.
   b) In our first three years, our efforts in locating reproductive dens have resulted in a doubling of the number of identified dens in the contiguous US. We are, and will continue to collect multi-scale habitat parameters associated with each den to supplement our understanding of den site selection.
   c) Through the capture and instrumentation of kits, we are able to follow young individuals into adulthood and dispersal. GNP is considered a core population and a source of wolverine to the surrounding region. Continued monitoring of reproduction will refine our understanding of GNP's role in this regard.

2) **Movement – patterns, rates, and associated ecological parameters**
   a) The 2005 field season provided our first success with the use of GPS technology. Our high recapture rate in Many Glacier allowed us to instru-

ment individual study animals multiple times increasing our opportunity to test a variety of collar designs and GPS fix rates. As such, we are developing an understanding of wolverine movement relative to the rate and pattern of travel, as well as extent of the animal's capabilities, at a level much beyond any research previously attempted.

b) GPS will also enable us to investigate patterns in wolverine use of habitat. Recent advances in the analysis of temporally correlated data, such as we collect with a 5-minute GPS fix rate, will enable us to investigate how wolverine movements correlate with a variety of ecological factors.

STUDY OBJECTIVES

This project will continue to use both conventional and GPS telemetry. Conventional VHF telemetry (intraperitoneal implant transmitters) is necessary to monitor the movements and activity of females relative to reproductive dens and of all study animals during summer months. Satellite telemetry will provide multi-scale movement and habitat use data during winter and spring.

Specific Objectives:

- Continue to live-trap, radio-instrument and monitor wolverine to describe movements and reproductive status.
- Locate natal and maternal dens, and rendezvous sites, and characterize associated landscape features.
- Instrument study animals with GPS and ARGOS collars programmed to collect fine-scale location data (5-minute fix rate), and large-scale dispersal data.
- Explore wolverine demographics and social character, further defining the relationship between reproduction and winter recreation.
- Describe wolverine home ranges, movement, and habitat use.
- Assess wolverine population dynamics including relatedness of captured individuals.

STUDY AREA

GNP is a rugged and biologically productive landscape, which encompasses approximately 1 million acres of wilderness and a rich diversity of flora and fauna making it the core of one of the most intact ecosystems in North America. This warm, moist Pacific-like environment produces dense forests of larch, spruce, fir, and lodgepole pine. In the Lake McDonald Valley, forests of western red cedar and hemlock are common. The park is traversed from east to west by a single road, the Going-to-the-Sun Highway. Elevations range from 960 meters to 3,190 meters above sea level. The park is bounded on the north by the international boundary between the U.S. and Canada. The eastern boundary is defined by the western edge of the Blackfeet Indian Reservation. The Bob Marshall Wilderness Area lies south of the park and a mosaic of Forest Service, State

The Going-to-the-Sun road traverses Glacier National Park from east to west providing motor and trail access into the heart of wolverine habitat. Glacier National Park has become a destination for hikers hoping to see and photograph a wolverine in its natural habitat.

and private land lie west of the park.

Winter track surveys initiated in GNP in 1994 (Yates 1994), historical sighting records from park files, and subsequent track surveys (Buhler et al. 2001) provided insight into the seasonal distribution of wolverine, especially along the eastern slope of the park, which initially formed the core of our study area. The Many Glacier Valley stood out as an area of probable high wolverine density. Logistically, the Many Glacier Ranger Station complex offered housing, communication, and equipment storage and has proven to be the focus of trapping operations. In subsequent years, we expanded our trapping operations to include areas near Avalanche Creek, Two-Medicine, and Belly River based on a need to contact wolverine outside the Many Glacier area.

The GNP Resource Management staff has indicated an interest in shifting the study area to the southern boundary of the park due largely to the anticipated impacts from avalanche control along the Burlington Northern/Santa Fe Railroad corridor. This shift would also allow closer involvement with adjacent National Forest lands (Flathead NF, Lewis and Clark NF). Should timing and funding allow, we will consider shifting project emphasis to the southern park boundary.

METHODS

Capture, Immobilization, and Handling

Wolverine are captured using log box-traps (Copeland et al. 1995). The number and location of traps was determined based on historical presence of wolverine in GNP and habitat values. Seven traps were constructed in 2002 with 3 additional traps added in 2003 and 2004. Traps are baited with trapper collected beaver (*Castor canadensis*) carcasses

Log wolverine trap in Glacier National Park.

and are fitted with remote trap monitors (TBT-600HC, Telonics, Mesa, AZ) that provided an electronic signal when the trap door is shut, allowing remote monitoring on a daily basis. Prebaiting of traps generally begins in mid-December with trapping conducted from early January to early April. Trapping operations cease with the first emergence of bears from hibernation. Wolverine are immobilized by jab stick with a Domitor/Ketamine solution. Study animals are weighed and standard measurements taken; blood, hair, and tissue samples collected. Heart rate, respiration, and body temperature are monitored during processing. Animals are inspected for injuries and ectoparasites. All captured wolverine are surgically implanted with intraperitoneal VHF radio-transmitters (Telonics Mod. 400, weight: 100g). Implant transmitter surgery was conducted on site by a licensed veterinarian using standard aseptic surgical procedures. Completing surgery and processing requires about 40 minutes. In addition, some study animals are fitted with telemetry collars, using either ARGOS and/or GPS satellite technology.

We attempt to capture and instrument young-of-the-year wolverine (kits) shortly after weaning in an effort to document kit survival, length of dependency period, maternal and conspecific association, and to describe rendezvous sites. Once we believe the kits are weaned, we use their mother's telemetry signal to locate the kits and capture them by hand. All capture and handling procedures are conducted under University of Montana Institutional Animal Care and Use Committee review and approval.

Study Animal Monitoring

Throughout the year, we rely primarily on conventional VHF telemetry to routinely locate study animals. Due to management concerns regarding fixed-wing aircraft overflights and potential disturbance to park visitors, telemetry flights are kept to a minimum, with telemetry data gathering done by ground-tracking methods whenever possible. Aerial telemetry occurring in months of reproductive denning (March through May) are essential to locate females at specific den sites. Additional monthly flights are necessary to monitor survival, general distribution, and dispersal of study animals.

Current technological advances that provide lightweight, more power-efficient GPS have enabled researchers to consider GPS technology for small carnivores such as wolverine. This study has played an important role in that development as we have worked directly with manufacturers in the creation of smaller, more ergonomic collar systems, and improved design to avoid potential collar related injuries. However, our need for a GPS collar suitable for wolverine, which will reliably acquire high frequency location data for an entire year is still unavailable due to battery limitations. Consequently, our high wolverine recapture rates and a GPS collar design, which allows on-site battery replacement and data download, enable us to acquire short duration, high fix-frequency data. These data allow us to investigate wolverine movement at various temporal and spatial scales during winter months. This will help us better understand the capacity of wolverine movement, along with insight into the ecological constraints of wolverine movement across the landscape.

We investigated GPS collars from 2 manufacturers, H.A.B.I.T. Research Ltd. (HABIT Locater Systems, Inc., Victoria, British Columbia, Canada) and Lotek (Lotek Wireless Inc., Newmarket, Ontario, Canada). HABIT collars were programmed from the manufacturer to attempt GPS acquisition at 1-hour intervals, with data stored in collar memory (Fig. 1). They were designed to provide data download via remote communication cues from a specially adapted receiver. Lotek col-

Figure 1. Female wolverine fitted with H.A.B.I.T Locator Systems GPS collar in Glacier National Park, 2005.

Figure 2. Technician downloads data from Lotek GPS collar on immobilized wolverine in Glacier National Park, 2005.

lars provide the advantage of field replacement of batteries and user programming of collars (Fig. 2). This allowed for experimentation of varied fix rates throughout the capture period, and thus, a quicker understanding of GPS capabilities and its application to wolverine. As such, we varied the frequency of GPS fix attempts at 4 hours, 2 hours, 30 minutes, and 5 minutes as we recaptured study animals. In addition, the Lotek collars include tip-switches that quantify movement in the x-axis (left-right) and y-axis (up-down) at 5-minute intervals. These activity sensors function apart from the GPS so the activity data stream is continuous from the time of collar activation to battery failure. The collars also record ambient temperature at each 5-min interval. All collars included a mechanical release device, programmed to release the collar from the animal 24 weeks after arming, and a VHF beacon for use in locating a collar that dropped off the animal.

Precision of GPS location data must be considered and evaluated for potential bias and error. GPS fix rate (number of locations acquired versus number of locations attempted) may vary by species or across individual ani-

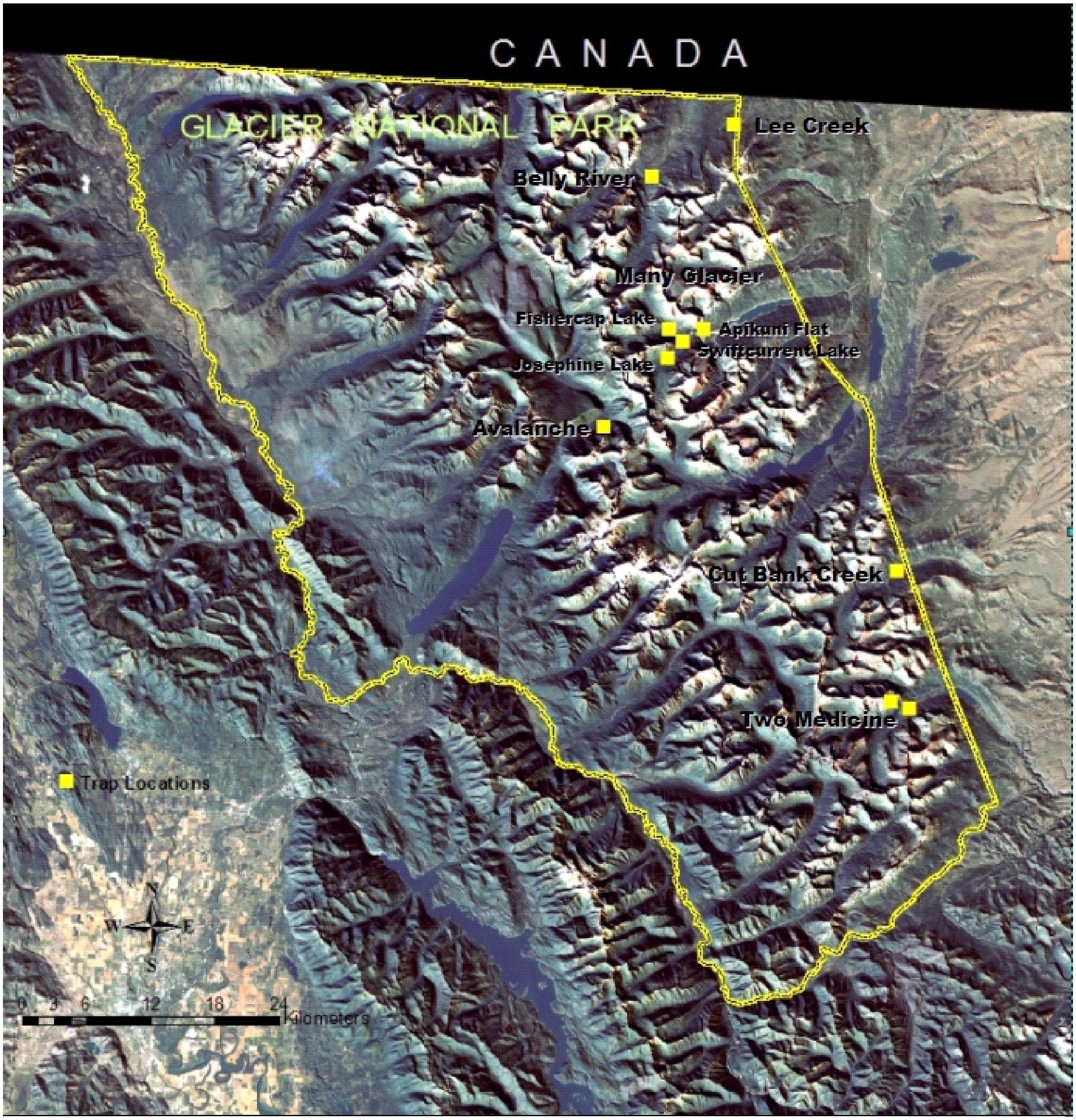

Figure 3. Glacier National Park wolverine project study area and wolverine trapping sites, 2005.

mals (D'Eon and Delparte 2005). Behavior of an animal may influence position and orientation of the GPS antennae thereby reducing effectiveness, as will environmental factors such as terrain, aspect, overstory height or changes in habitat (D'Eon 2003, Jerde and Visscher 2005). We are currently testing GPS collars to establish a measure of error. What we provide in this report are preliminary findings based on uncorrected data.

Home Range

The mating system of the wolverine is most commonly described as polygynous, wherein a dominant male controls access to multiple females. Spatial structuring as viewed by home ranges should reflect such a system. In the case of the wolverine, we would expect multiple female home ranges occurring within the home range of a single male. In addition, the home range is a reflection of an individual's spatial requirements in terms of finding food. Species that rely on patchy resource availability tend to have large home ranges. Home ranges may also provide in-

Table 1. Information on wolverine capture, status , and marking characteristics in Glacier National Park, 2003-2005. Ear tag colors included to provide identification of study animals for park visitors.

ID	Initial Capture Date	Capture Site	Estimated Age	Current Status	Eartag[a]	Collar
M1	1/26/03	Many Glacier	Adult	Active	blue/blue/right	ARGOS/GPS
F2	1/30/03	Many Glacier	Adult	Active	red/green/left	Not collared
M3	2/14/03	Many Glacier	Yearling	Active	yellow/yellow/right	ARGOS/GPS
F4	2/17/03	Many Glacier	Adult	Active	green/red/left	GPS
F5	3/1/03	Many Glacier	Yearling	Mortality	red/red/left	Not collared
M6	4/8/03	Many Glacier	Adult	Unknown[b]	red/blue/right	ARGOS
F7	1/27/04	Avalanche	Yearling	Active	blue/red/left	Not collared
M8	2/13/04	Many Glacier	Yearling	Mortality	none	Not collared
M9	5/6/04	Alder Creek	Juvenile	Mortality	yellow/yellow/right	Not collared
M10	5/6/04	Alder Creek	Juvenile	Mortaity	white/blue/right	Not collared
F11	2/24/05	Avalanche	Adult	Active	yellow/yellow/right	Not collared
F12	2/28/05	Two Medicine	Yearling	Active	blue/blue/left[c]	GPS
M13	3/4/05	Two Medicine	Yearling	Active	green/green/right	Not collared
M14	3/13/05	Two Medicine	Yearling	Unknown[d]	red/red/right	GPS
F15	3/30/05	Many Glacier	Adult	Active	green/green/left	Not collared
M16	3/30/05	Two Medicine	Adult	Active	yellow/red/right	Not collared
F17	4/4/05	Two Medicine	Adult	Active	red/yellow/left	Not collared
M18	5/7/05	Many Glacier	Juvenile	Mortality	blue/yellow/right	Not collared
M19	5/7/05	Many Glacier	Juvenile	Active	yellow/blue/right	Not collared

[a] Rototags are coded by color as front side of ear/back side of ear/left or right ear.
[b] Contact with M6 was lost in March 2004.
[c] Ear tag lost as of January, 2006
[d] Contact with M14 was lost in April 2005.

Table 2. Wolverine live-capture results in Glacier National Park

Year	# Traps	Trap nights	Captures (Individuals/captures) (captures by sex)	Capture Rate (wolverine/trap nights)	Kits Captured
2003	5	80	6 / 20 3♂♂ 3 ♀♀	1 wolverine/4 1 individual/12	
2004	6	366	8 / 30 4 ♂♂ 4 ♀♀	1 wolverine/12 1 individual/40	2
2005	7	487	12 / 33 5 ♂♂ 7 ♀♀	1 wolverine/15 1 individual/41	2

sight to social structuring based on the juxtaposition and overlap of neighboring home ranges in regard to relatedness of individuals. We estimated home ranges as simple minimum convex polygons. We report home ranges for individuals with relocation samples >30 points, and provide comparisons of home range overlap.

Habitat

Developing sound guidelines for the management of resources and people within landscapes inhabited by wolverine requires an understanding of wolverine/habitat relationships. Specific habitat associations for the wolverine are not well described beyond the inference of a tie to remote, subalpine habitats. By studying how wolverine move across the landscape, we hope to elucidate the species relationship with topographic and habitat structure. And further, how habitat preference and avoidance relates to the presence and distribution of people in GNP. The study of wolverine habitat relationships is a secondary objective of this study, but we intend to address it as data allow.

Reproduction and Denning

Reproductive success is measured primarily by direct field evidence of reproduction gleaned during capture and handling along with subsequent monitoring of reproductively mature females. Animals captured during late stages of pregnancy may be confirmed pregnant by palpation and may indicate such by inspection of teats or mammary tissue. Blood samples are collected from females during processing for measurement of progesterone (Mead et al. 1991) although the efficacy of serum progesterone as a conclusive measure of pregnancy in wolverine is not well substantiated.

Wolverine generally give birth from late February through early March. We closely monitor via fixed-wing aircraft, movements of reproductively mature females during that period for localization at a potential den site. It is important to note that wolverine dig holes in the snow for a variety of reasons—

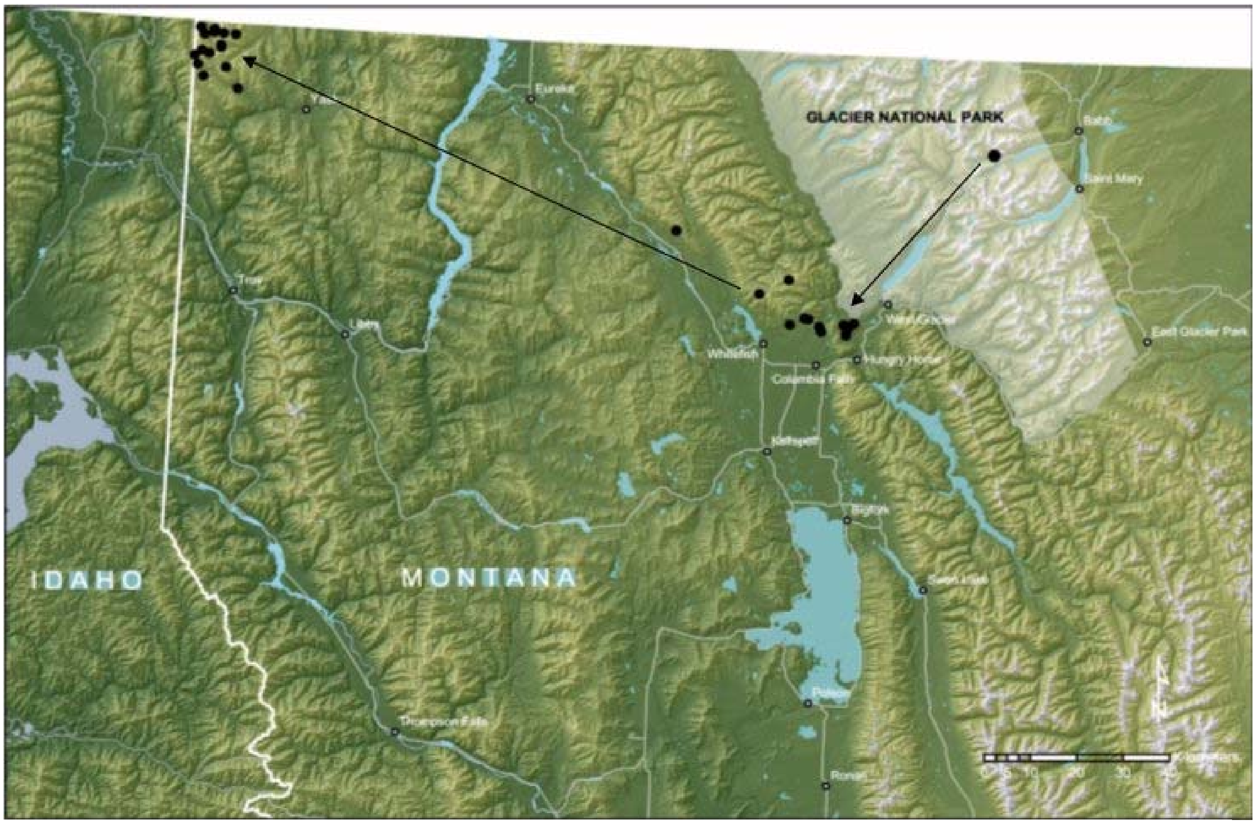

Figure 4. Black dots represent the locations of subadult male M8. Black arrows depict his direction of movement from the east side of Glacier National Park subsequent to his capture in February 2004. M8 moved over 200 kilometers to Northwest Montana where he was subsequently taken by a trapper in December, 2004.

food access, exploration, and reproductive denning. If a specific site is identified and a den suspected, we continue to monitor the site via aerial and ground telemetry to record the female's duration of stay and movement to maternal dens (rearing dens other than the site of parturition used prior to weaning) if such occurred. Following weaning (9-10 weeks post-parturition) the female and kits leave the reproductive den site and remain in close contact through a period of dependency, which has been reported to last until the kits are 6-8 months old (Copeland 1996). We monitor the female and kits throughout this period to document when the kits become independent of their mother, and also to document and describe *rendezvous sites*, or places at which the female will leave the kits while she forages or mates. Our interest is in locating such sites, describing their structure and character, and the timing of association between mother and kits. To do so, we attempted, once a week, to radio-track the female and kits to locate and describe such sites. We limited these attempts to one time/ week in the belief that weekly disturbance would not alter the female's choice of rendezvous site.

Food Habits

Wolverine scats are collected opportunistically and kill or foraging sites documented and described. Scats are frozen until they can be dried. Food habit data gleaned from wolverine scat collection is generally biased toward winter when snow-tracking provides opportunity for collection, and toward denning females whose activities tend to be concentrated. As such, our analysis will center on the foraging ecology of the denning female. While food-habits was not initially identified as a primary objective of this study, it has become apparent that mountain goat may be an important component of GNP wolverine winter diet – most likely in the form of carrion, but possibly as live prey as well.

DNA Analysis

Hair, scat, and tissue samples collected from individual wolverine were submitted to the Rocky Mountain Research Station Wildlife Genetics Laboratory for genotyping. A panel of 17 microsatellite loci was run on each individual allowing examination of paternity and gene flow. To provide a preliminary assessment of relatedness, we examined genotypic similarity by principal components analysis (PCA).

RESULTS AND DISCUSSION

Capture and Marking

Trapping occurred in the Many Glacier Valley, Belly River, and Upper McDonald Creek in 2004, and in 2005 we added the Two Medicine Valley (Fig. 3). Trapping success for this study is the highest recorded for wolverine live-capture in North America (11 trap nights per capture through the entire study period), which is most likely related to the unique setting of our operation – wherein, our traps are situated directly within the home ranges of several wolverine. Studies using similar methods generally report capture rates of 30-40 trap nights per capture.

To date, 19 individual wolverines (11 male, 8 female) have been captured and instrumented (Table 1.). Fifteen wolverines were captured

Table 3. Distance traveled between fixes and rate of movement for 2 male wolverine, and efficacy of Lotek GPS collars in Glacier National Park, 2005.

Frequency	n	Mean (m)	SD (m)	Range (m)	Meters/ hour	Attempted fixes	Success-ful fixes	Fix rate
5 Minute	146	151	129	25-645	1,809	552	282	51.1%
30 Minute	12	1,049	815	98-2,096	2,098	147	25	17.0%
2 Hour	15	,694	1,591	30-5,795	847	96	42	43.8%
4 Hour	91	2,323	2,898	25-16,727	581	548	199	36.3%

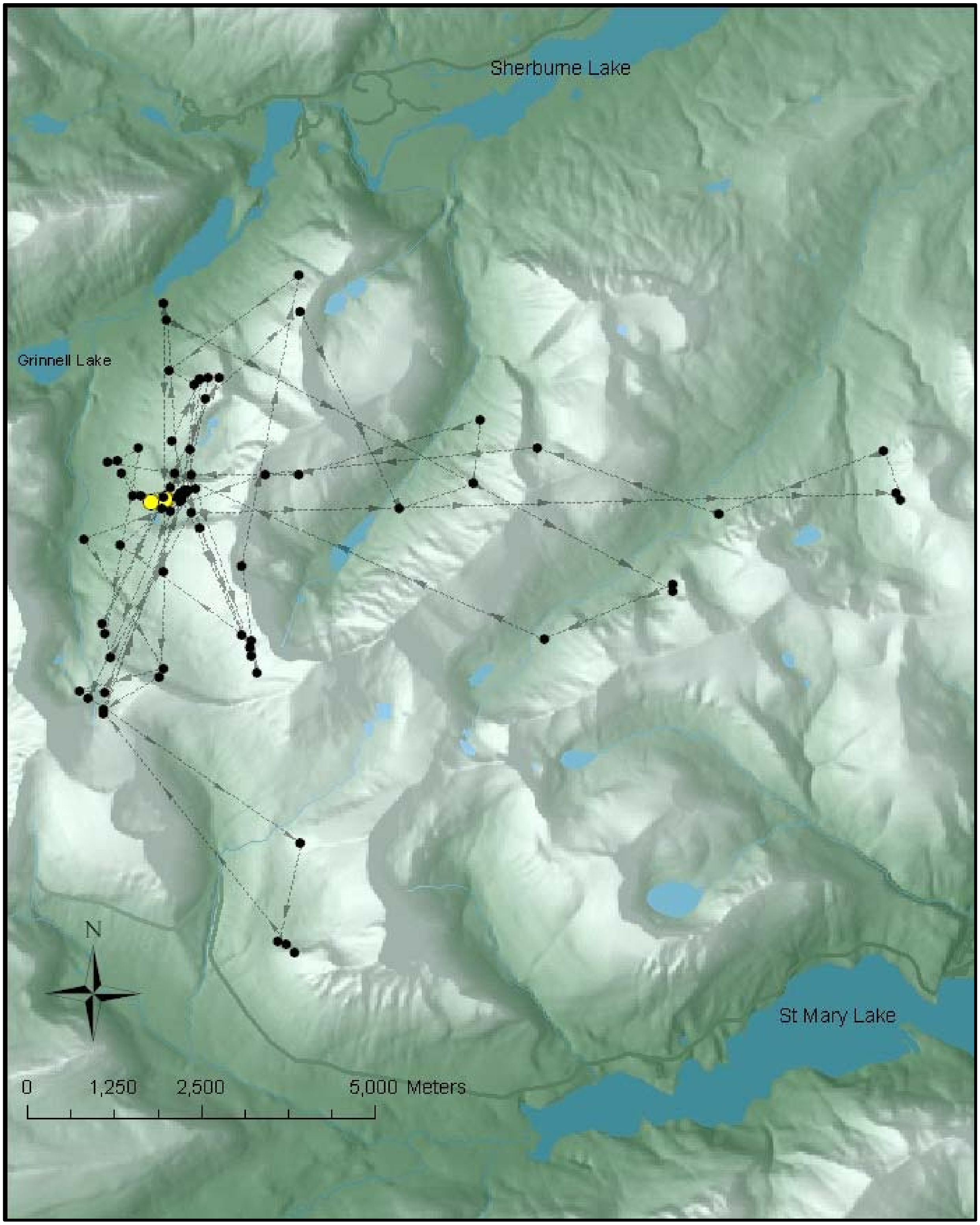

Figure 5. GPS locations (black points) for female F2 during 18 days of her denning period in March 2005. GPS was set to 2-hour fix rate. The yellow points mark her natal and maternal den.

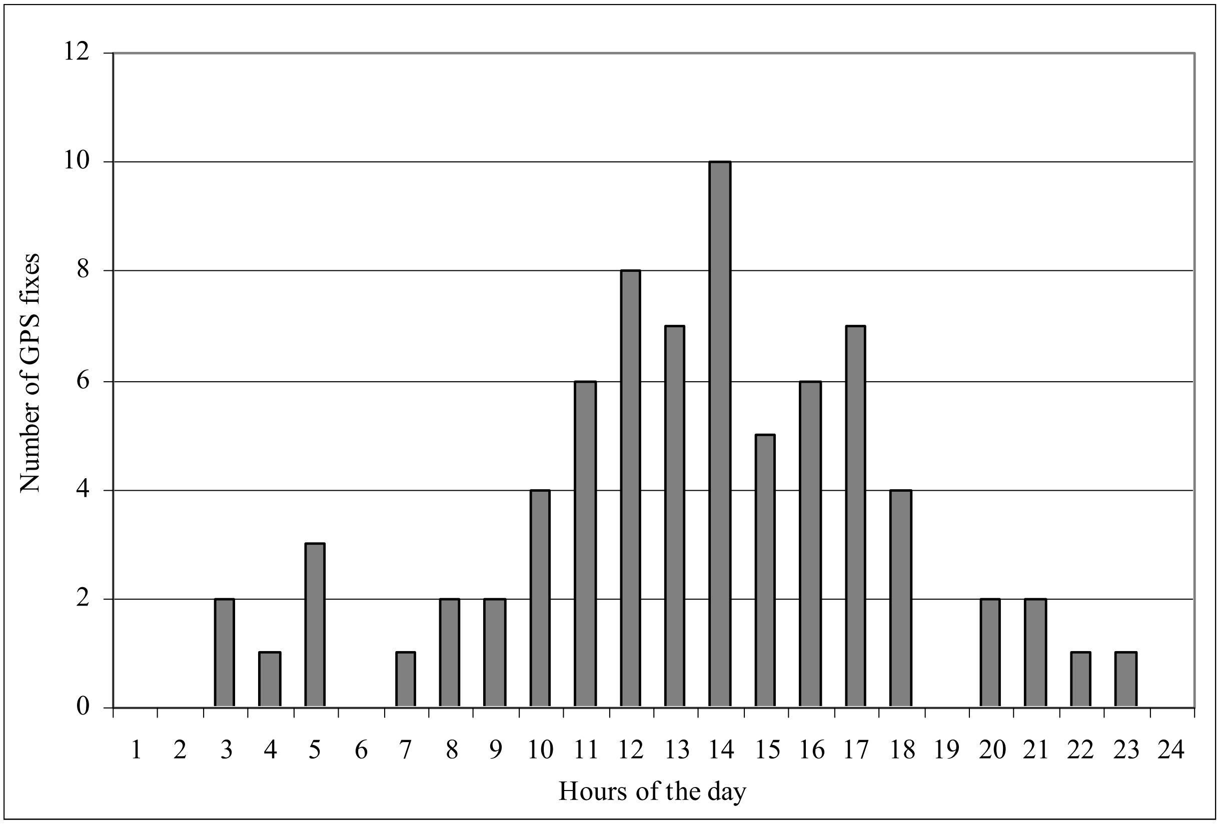

Figure 6. GPS fixes accumulated throughout the day for a denning female wolverine from 5 March to 23 March in Glacier National Park, 2005.

in log box traps a total of 83 times and 4 kits were captured by hand at maternal dens. During 3 trapping seasons, 933 trap-nights were tallied using 9 different trap sites for a capture rate of one wolverine/11 trap nights and one individual/62 trap nights (Table 2). Over 3,600 telemetry locations have been gathered for all wolverine since 2003. Of 10 male wolverine monitored between 2004 and 2005, 3 were adults, 3 were yearlings, and 4 were juveniles. A fourth adult male (M6) was lost from the study in March 2004. Five of the 8 females were considered adults and 3 were yearlings when captured. In 2005, nine wolverines were added to the study population, 5 of which resulted from full-time operation of the Two Medicine traps. (Table 2). Within the previous study group, four individuals were re-instrumented, replacing intraperitoneal transmitters that had run out their battery life. At this writing, 13 individuals are continuing to be monitored (6 male, 7 female). In May of 2004 and 2005, 2 litters of two kits each (all males) were captured by hand, and instrumented with intraperitoneal implant transmitters, at maternal den sites. Kits were estimated to be 10-12 weeks of age at capture.

Mortalities.—Both 2004 kits died during

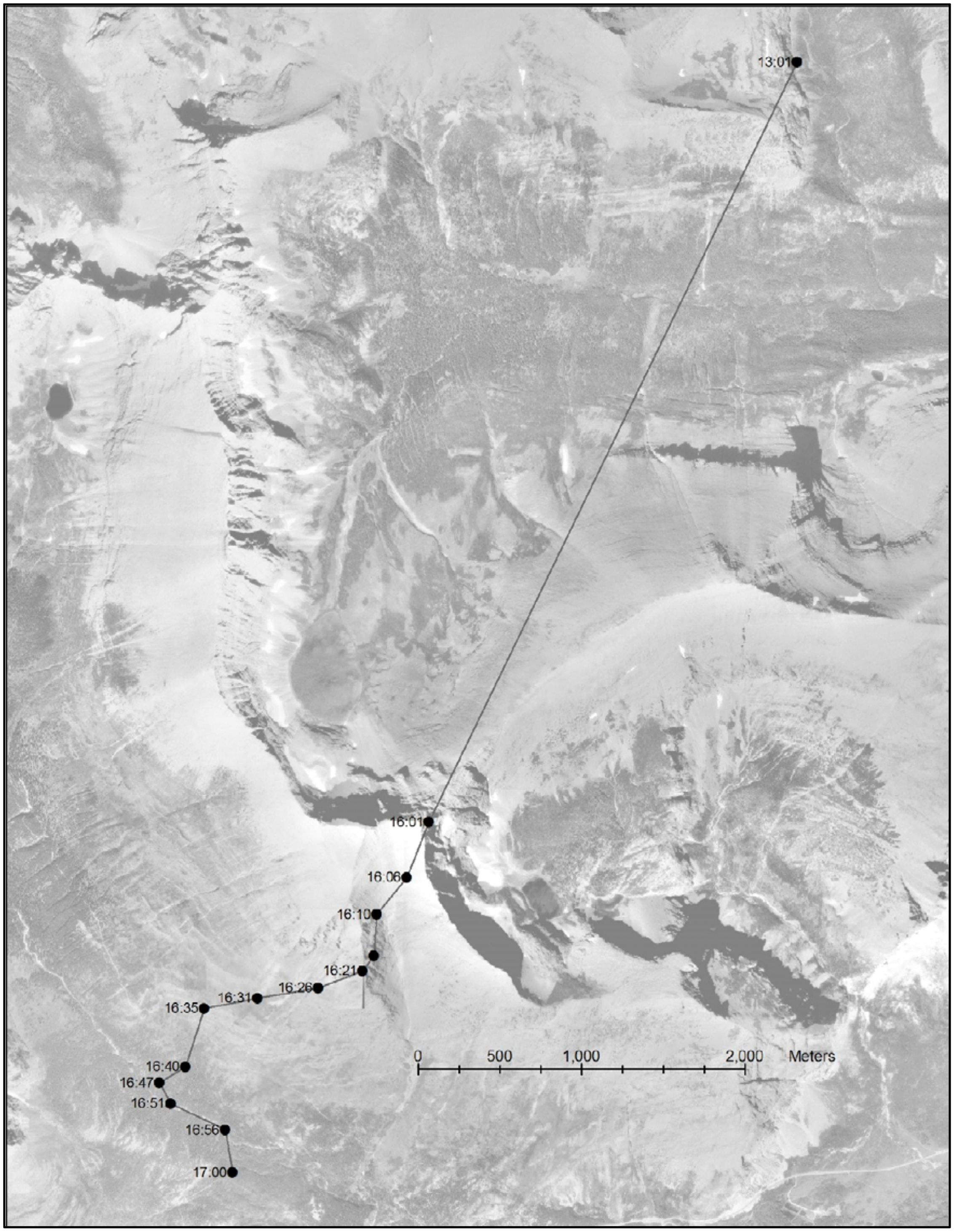

Figure 7. Sequential movement path of adult male wolverine (M3) over 4-hour period in Glacier National Park, 2005. The Lotek GPS collar was programmed to attempt fixes every 5-minute for one hour each day while attempting a fix every 4 hours throughout the day. The points at the beginning (13:01) and the end (17:00) mark the 4-hour fix points. Embedded in that period was a 5-minute sequence for 1 hour, which more precisely defines the animals actual movement path.

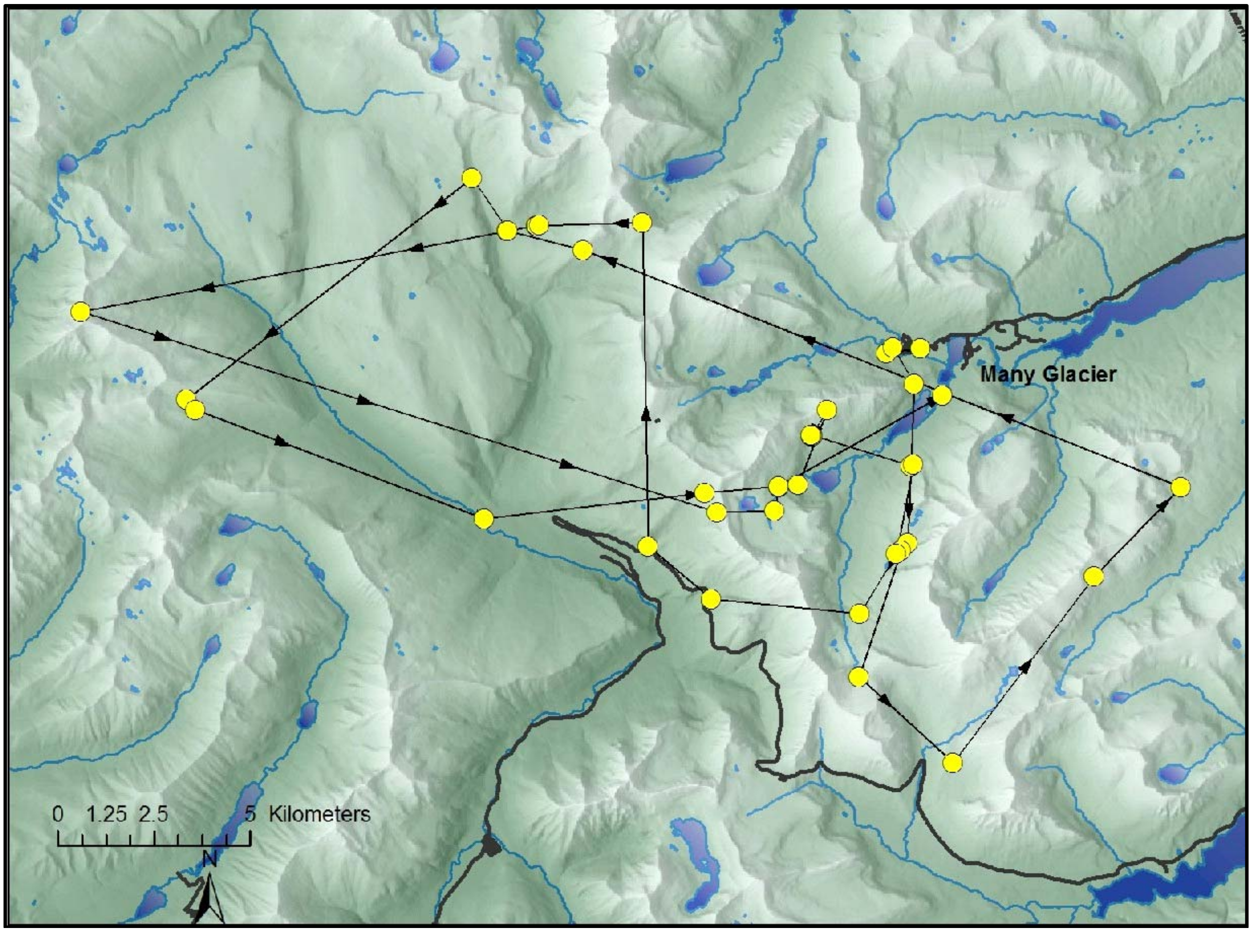

Figure 8. Global Positioning System (GPS) locations for an adult male wolverine (M1) in Glacier National Park, 2004. Male M1's GPS collar was programmed to attempt a fix every 2 hours. The collar acquired 47% of attempts (43 fixes). The graphic depicts his movement over an 8 day period in March, 2004.

their first year. One was legally taken by a trapper outside the park boundary, and the second of unknown cause at approximately 9 or 10 months of age. One of the 2005 kits was killed by an unknown predator at 8 months of age. A 3-year-old female (F5) died in an avalanche in 2005. We are currently conducting a formal survivorship analysis of our study population.

In our 2004 progress report, we described the disappearance of subadult male M8. Believed to be a yearling at capture in February 2004, M8 left GNP about a week after capture. He moved into the Whitefish Range near Hungry Horse at which time we began closely monitoring his movements. He disappeared from the Whitefish Range in early April, in spite of efforts to maintain daily contact. In late July, researchers conducting a grizzly bear flight in the northern portion of the Kootenai National Forest detected M8's telemetry signal. The bear researchers continued to monitor M8 near American Creek and the Northwest Peaks Natural Area until he was legally taken by a trapper in December 2004. He had traveled over 200 kilometers as measured by straight-line distance (Fig. 4).

GPS Studies

Five individuals were fitted with GPS collars in 2005: one adult female (F2) and one subadult female (F12) with HABIT collars, and 3 adult males (M1, M3, M14) with Lotek collars. F12's collar quit transmitting its VHF beacon after 1 week. The VHF beacon on M14's collar ceased transmitting after 2 weeks. All contact with M14 was lost in early May. M1's collar functioned successfully for 12 days in which he was twice recaptured and collar data downloaded. After his third release he was not recaptured until the following trapping season early in 2006. He was still wearing his color. The mechanical drop off device on the Lotek collars failed to function in all cases. M3 slipped his collar in August and it was retrieved near Belly River. A recent observation of a collared wolverine in the Whitefish Range west of GNP could be M14. If so, it appears his collar failed to release as well.

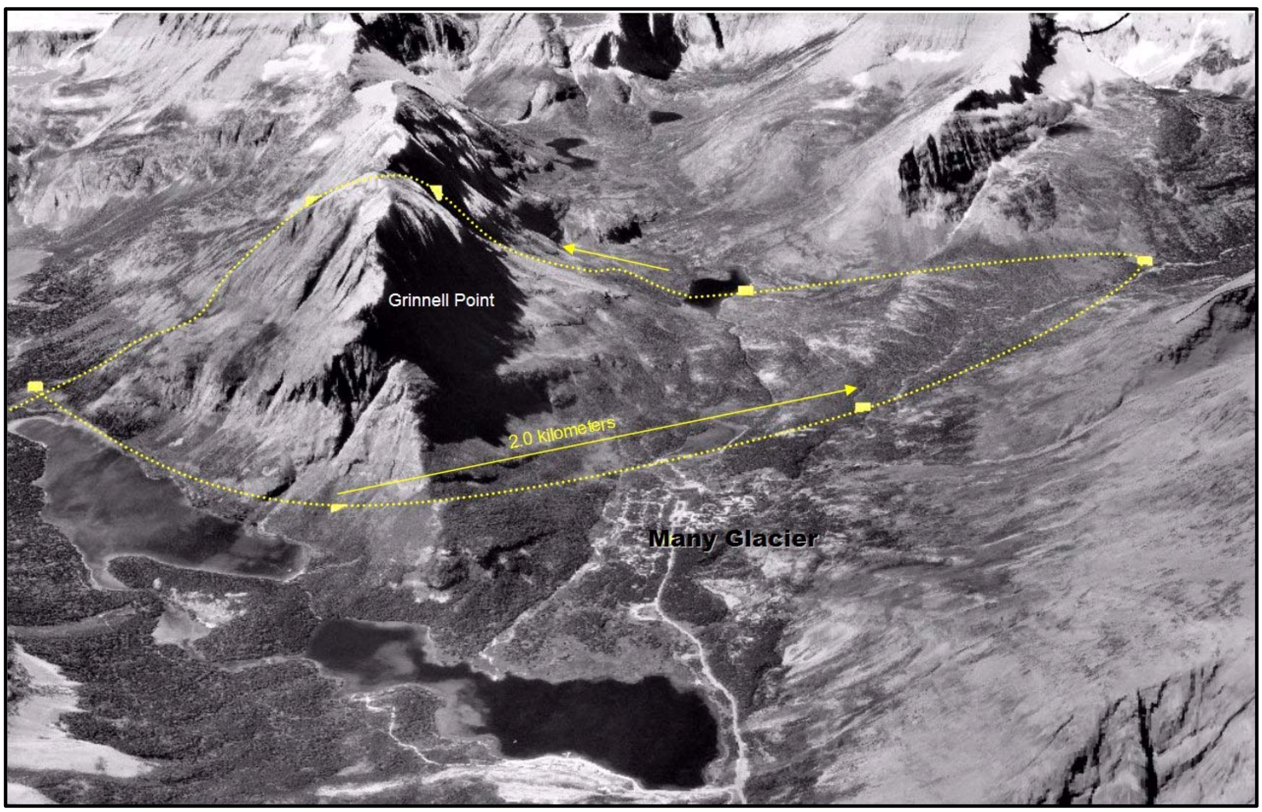

Figure 9. Illustration of a 4-hour movement of male M1 in Many Glacier Valley, March 2005. M1's GPS collar was programmed for a 0.5hr fix rate. He moved nearly 11 km in 4 hours from our Lake Josephine trap (left of image) to Wilbur Creek (right of image) and back, ascending 800m over Grinnell Point.

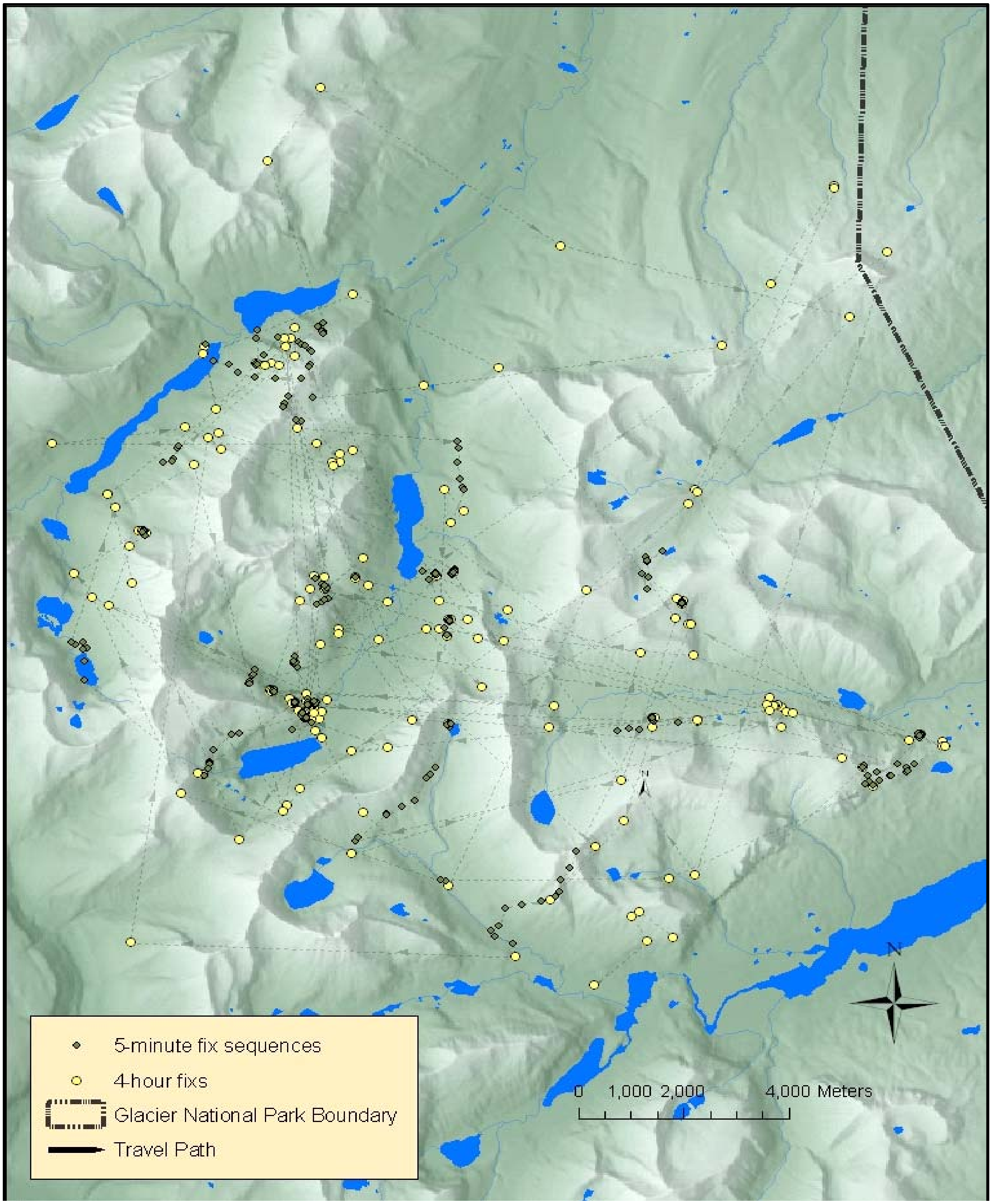

Figure 10. GPS movements of male wolverine M3 in Glacier National Park, 2005. The graphic depicts M3's movements from 21 March to 20 June. Yellow dots are fixes taken every 4 hours. Green dots are 1-hour sequences of 5-minute fixes.

F2 carried her collar for 18 days, from 5 March to 23 March, at which time she was recaptured and the collar data downloaded. The collar provided 74 fixes for a fix acquisition rate of 17% (Fig. 5). F2 was denning during this period, which likely reduced satellite exposure due to long periods of time in the den. If this is correct, then acquired GPS fixes should reflect the times of the day in which she was active outside the den. A graph of the accumulated GPS fixes, by hour of day, over the 18-day period indicates a fix rate centered on mid-day, with 77% of the fixes occurring between 1000 and 1800 (Fig. 6).

Wolverines M1 and M3, fitted with Lotek GPS collars, provided a combined fix-rate success of 40.8% (Table 3). Fix-rate (proportion of fixes compared with attempts) was highest when the frequency was set to 5 minutes (Table 3). We calculated the distance traveled between sequential points for each time period (Table 3) and found that the distance traveled/unit time tended to decrease with increasing time between fixes as we

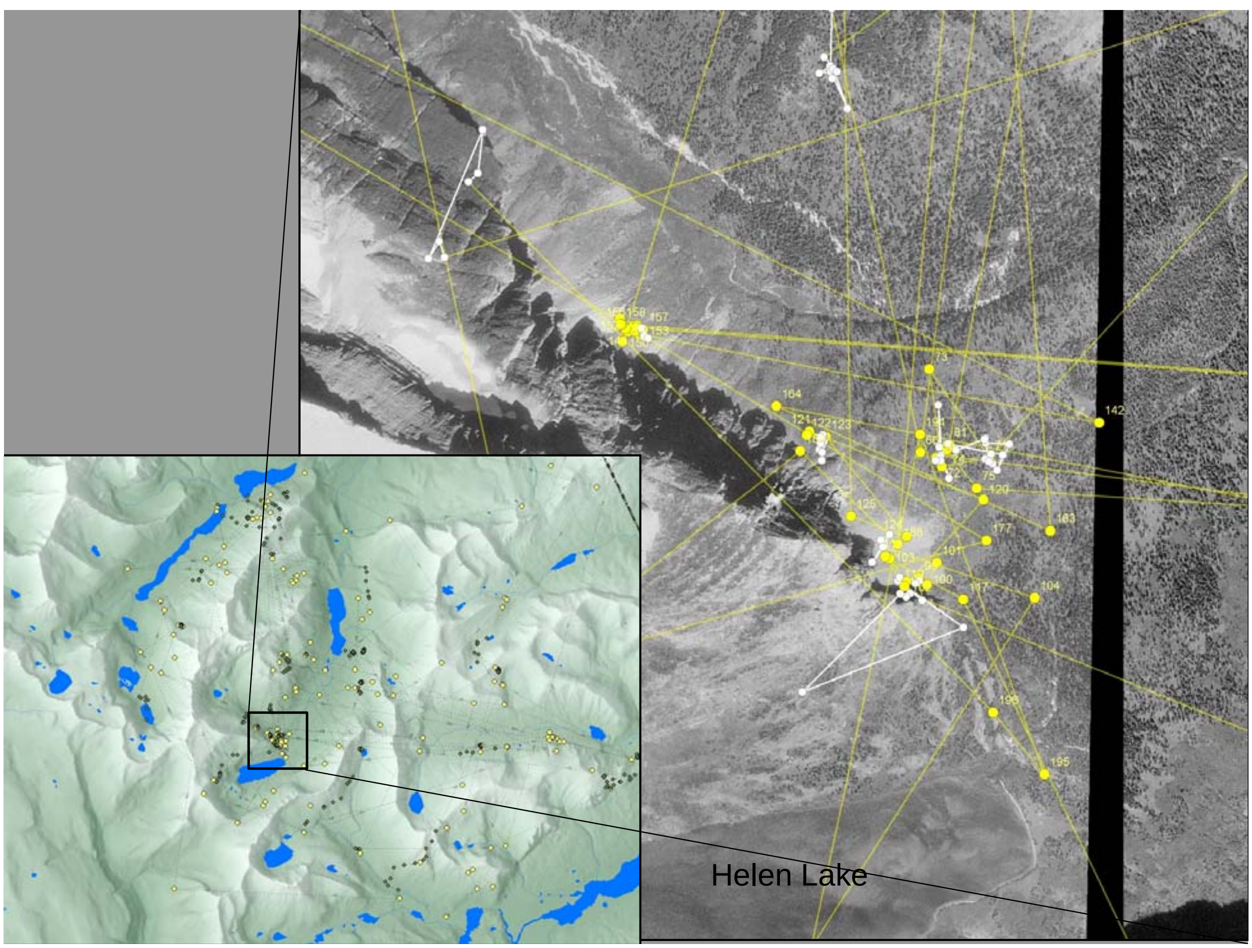

Figure 11. Close-up view of clumped grouping of male wolverine M3's GPS locations near outlet of Helen Lake in Glacier National Park, 2005.

Table 4. Minimum convex polygon home range sizes for wolverine in Glacier National Park, 2005.[a]

Animal ID	Current Age/Sex	N (locations)	Home Range (km^2)
M1	Adult Male	171	475
F2	Adult Female	204	146
M3	Adult Male	152	517
F4	Adult Female	205	156
F5	Adult Female (mortality)	123	121
F7	Subadult Female	38	140

[a]Home range analyses included locations from all years.

would expect. As time sequences between fixes shortened, the natural tortuosity of the animal's movement became more evident (Fig. 7).

Male M1 provided two GPS datasets. He was fitted with a GPS collar programmed to attempt a fix every 2 hours on 3 March. He was recaptured and the collar downloaded on 12 March. The collar provided 43 fixes for a 47% fix rate. Summing the distance traveled between each consecutive location resulted in a total movement of 132.9 km, or 16.7 km/day (Fig. 8). A remarkable characteristic of M1's movement was his visitation to F2's active reproductive den. Consecutive fixes at 0800 and 1400 on 3 March found M1 within 490m and 260m of the den, respectively. A fix at 1600 on 9 March found M1 within 80m of her den.

Following the 12 March download, we reprogrammed M1's collar, increasing the fix attempt frequency to 0.5 hours. We recaptured him and downloaded the collar 3 days later finding he had traveled a total distance of 39.2 km at a travel rate of just over 1 km/hour. During a particularly interesting sequence, M1 traveled an 11 km loop from 0800 to 1200 from our Josephine Lake trap to Wilbur Creek and back, which included an 800m ascent over Grinnell Point (Fig. 9).

Male M1's 0.5 hour fix rate provided a more refined movement path but at this travel rate he was still moving an average of over 1km

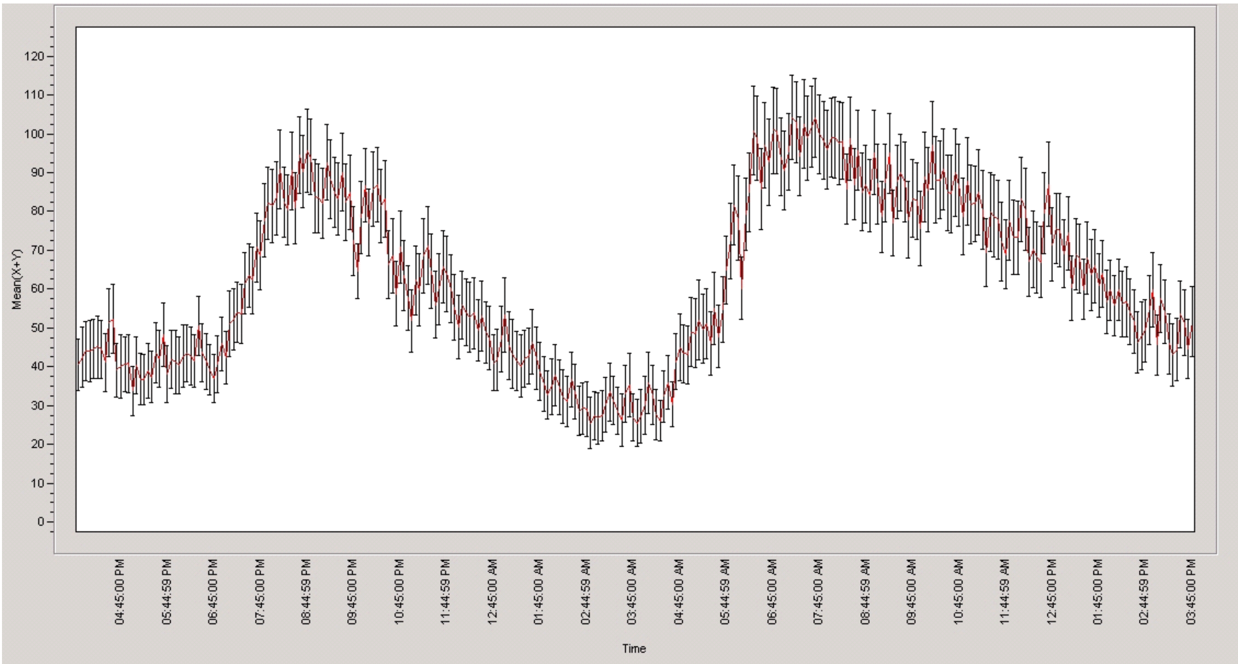

Figure 12. Diel activity cycle of wolverine M3 over 90 day period, March-June, 2005. Activity sensors (left-right, up-down tip switches) in his collar record and total incidents of movement every 5-minute period. Graph depicts mean and standard error of activity recorded within each 5-minute period, of a 24-hour day, summed over the 90 days.

between points, which was too course to investigate fine-scale movement paths. The Lotek GPS collar is capable of attempting fixes at varying intervals down to 5 minutes, but doing so severely reduces battery life. Lotek estimates a 9-10 day battery life at this fix rate. To experiment with the efficacy of a 5-minute fix rate without sacrificing excessive battery life we programmed a collar to attempt GPS acquisitions at a 4-hr fix rate with instructions to attempt 5-minute acquisitions for 1 hour every other day, rotating the hour through the 24-hour period. With this programming, the collar was estimated to function for nearly 100 days. Male M3, first captured as a subadult in 2003, subsequently established a home range in the Belly River region, north of Many Glacier. He was fitted with this collar on 21 March 2005, which he carried until 20 June when the data storage filled. The collar acquired 481 of 1,090 attempted fixes for an overall fix rate of 44% (Fig. 10). Of the total fixes, 282 were associated with 46 attempted 5-minute sequences (a sequence is comprised of 12 possible fixes, or 1 fix attempt every 5 minutes through the hour). The collar recorded some 5-minute data within 37 of the 46 programmed sequences. The number of fixes varied from 0-12 providing a fix rate of 51% (Table 3). Eight sequences captured all 12 attempted fixes for the hour.

M3 moved at a rate of approximately 600 meters/hour as measured by his 4 hour data,

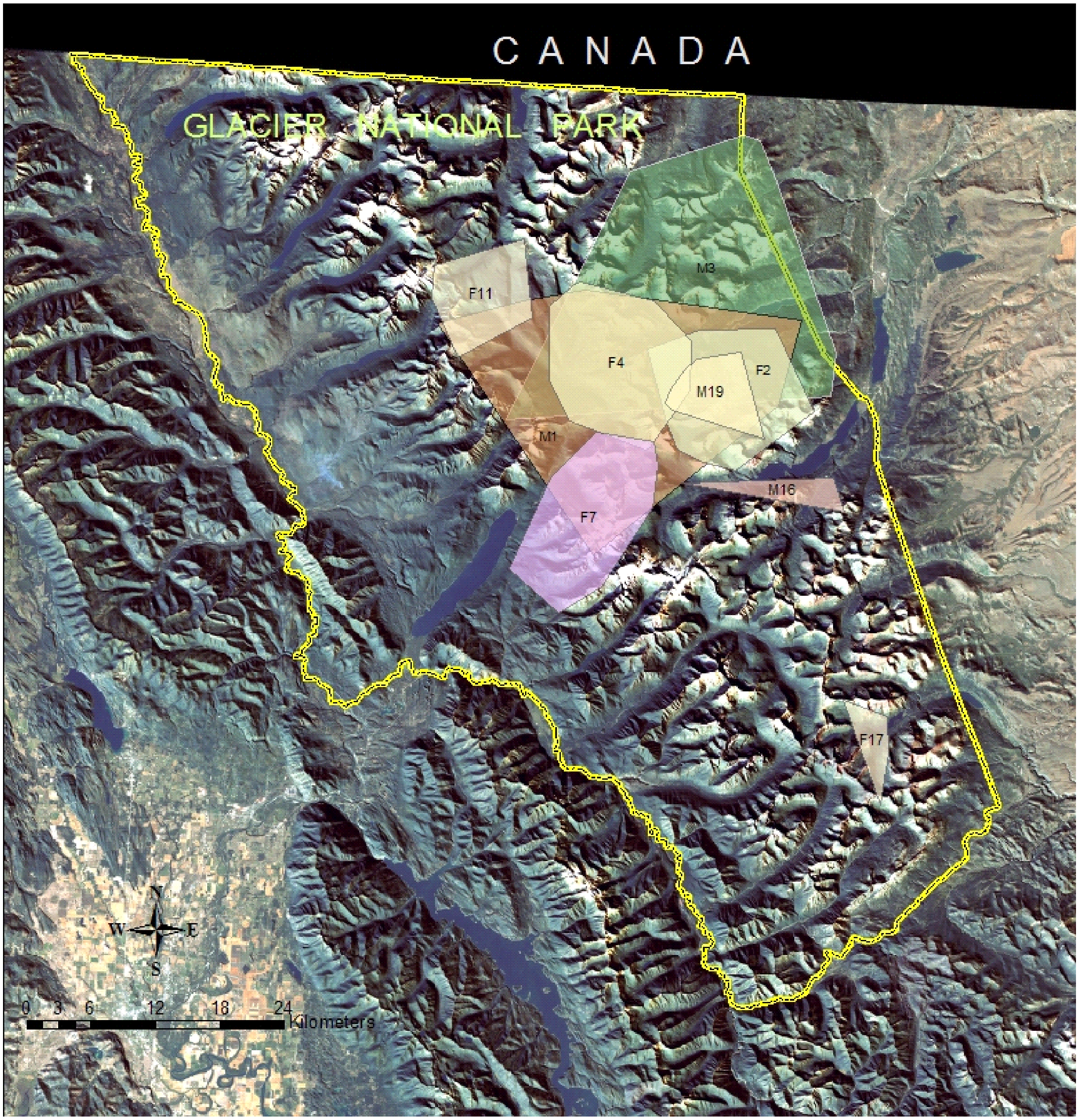

Figure 13. Home ranges of wolverine in Glacier National Park, 2005. Only the home ranges of M1, F2, M3, F4, and F7 were constructed from relocation samples >30. The remainder of the polygons are included to display the spatial juxtaposition of study animals.

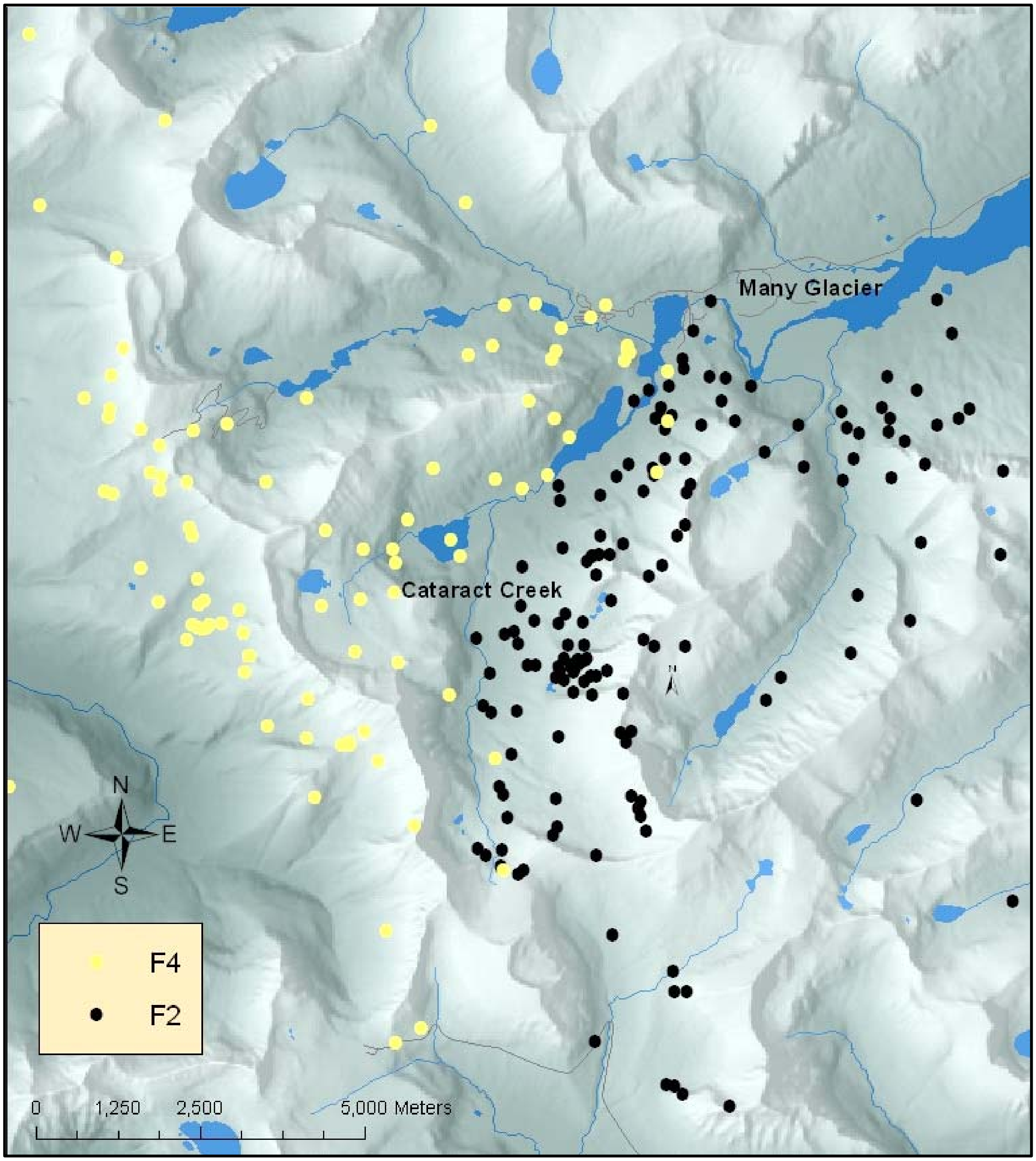

Figure 14. Spatial juxtaposition and notable demarcation of locations for adult female wolverines F4 and F2 in the Many Glacier area of Glacier National Park, 2003-2005.

Figure 15. Immobilized 12-week-old kit of female wolverine F4 awaits processing in Glacier National Park, 2004.

and at a rate of 1.5 km/hour as measured by his 5-min sequences (Table 3), indicating the increased tortuosity of his path when measured at a finer scale (Fig. 7). The distribution of his points was not indicative of a traditional route followed over time, but more of a largely random distribution of locations surrounding several areas of clumping (Fig. 10). We investigated one of these clumped areas, which occurred near the outlet of Helen Lake (Fig. 11); on closer inspection it was broken into several separate clumps. At one of these sites we found the remains of a mountain goat carcass.

Activity and temperature data provided by the Lotek collars is currently under analysis, but it appears that GPS fix rate is related to animal activity. The likelihood of a successful fix was significantly greater during periods of increased activity ($P < 0.001$). M3's activity through this period also appeared to cycle around a 6-hour period (Fig. 12). Activity also appeared negatively correlated with increasing temperature, based solely on temperature data from M3's collar (R^2 =

0.52, P < 0.000).

Deployment of GPS collars and experimentation of various fix rates shows that we can successfully use GPS technology on wolverine within certain constraints. By "front-end loading" the GPS to acquire at a high frequency interval, we can maximize the efficiency of the system with a high expectation of success. This also provides a better match to the movement characteristics of the wolverine. GPS fixes spaced by as little as 4 hours may be separated by as much as 15 kilometers, providing little understanding of movement trajectory or habitat preferences. At a fix rate of 5 minutes, we are seeing wolverine move 200-300 meters between fixes, providing fine-scale results while maintaining adequate distance between points to account for GPS error.

Our GPS datasets are providing a detailed understanding of wolverine movement and revealing patterns of spatial use previously undescribed. The wolverine's notable ease of travel across extreme topography supports our notions of wolverine tenacity and durability while raising questions about the ener-

Figure 16. Maternal den of female wolverine F4 in Glacier National Park, 2004. The den cavity occurred within the natural openings beneath this fallen whitebark pine.

getic costs of such movements. Male M3's 4-hour fix data indicates a pattern of movement characterized by long-distance movements interrupted by short stays, averaging about 20 hrs in duration, at localized sites. We would assume these stops are related to foraging sites, as evidenced by mountain goat remains discovered near Helen Lake, but they could be linked to reproduction or social interaction as well.

High frequency locations provided by GPS are also reinforcing our understanding of wolverine sociality. M1's 2-hour data collected in March 2005 found him in close proximity to females that were confirmed or believed to be denning. Female F11 was believed to be pregnant at her capture at Avalanche Creek in February. We monitored her activity in March and April concluding that if she had a den, it was somewhere in the area of Trapper Peak in the Livingston Range. On 2 other occasions during M1's week of travel in March, his GPS data placed him on Trapper Peak, within a few hundred meters of the area we believed F11 to be denning. On two occasions, M1 also visited an area being frequented by female F4. Although she was never confirmed to have produced kits, she did localize and excavate sites consistent with denning behavior. Together, these incidents suggest the resident male may maintain close association with denning females. The 2006 denning period will, hopefully, provide an opportunity to replicate this behavior, should it occur.

Home Ranges

Six individuals provided adequate location samples for minimum convex polygon home range analysis (Table 4). Adult male home ranges averaged 496 km^2 (n=2) and female home ranges averaged 141 km^2 (n=4). Male home ranges (M1, M3) overlapped by 30%, while the home ranges of females' resident to the Many Glacier valley (F2, F4) overlapped by an average of 7% (Fig. 13). Adult females F2 and F4 were the most consistently monitored females. The Cataract Creek-Josephine and Swiftcurrent Lake waterway appears to define a demarcation between the home ranges of these females (Fig. 14). Adult male M16, captured in the Two Medicine Valley was most commonly relocated in the St. Mary Valley, indicating he may have established residency directly south of male M1.

Reported wolverine home range sizes vary from 422 km^2 to over 1,400 km^2 for male wolverine in northwest Montana (Hornocker and Hash 1981) and central Idaho (Copeland 1996), respectively. In GNP, wolverine home range sizes appear to be on the small end of the scale, but home range estimates are difficult to compare across studies, as home range size can vary largely with differences in sample size and home range estimators. Currently, it appears that 3 wolverines are established residents of the Many Glacier Valley. M1 is the resident male along with resident females F2 and F4. Male M3 and female F15, residents of the Belly River area,

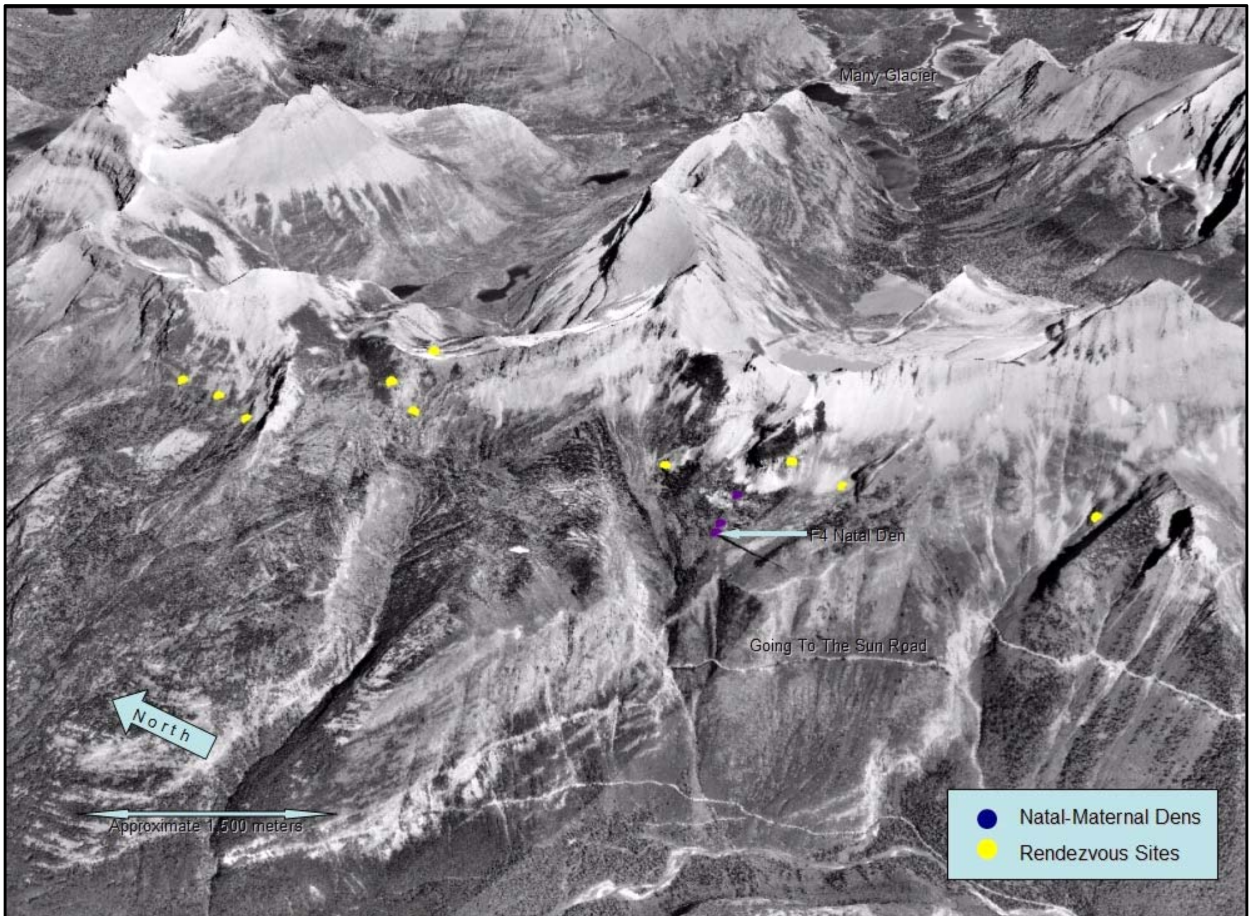

Figure 17. Natal and maternal dens, and rendezvous site locations for female wolverine F4 in 2004.

make occasional forays into Many Glacier, most likely stimulated by the availability of food at our traps. Females F11 and F7 are westside wolverine. Their connection with a resident male other than M1, if one exists, has not been established. Associated with the Two Medicine area are several individuals whose spatial juxtaposition has not yet been well defined. Adult male M16 may be the resident male for the south-eastern portion of the park, and appears to center his activity on the St. Mary Valley. Females F12 and F17 are likely Two Medicine residents that may or may not be linked to M16. Focus of our resources and time would require a switch from the Many Glacier Valley to the southern portion of the park to elucidate these social and spatial relationships further.

Reproduction and Denning

In 2004, elevated serum progesterone indicated pregnancy in 4 females (F2, F4, F5, F7), based on blood samples collected at captures that occurred after 31 January. Behavior observed during subsequent tracking indicated that both F4 and F5 had localized at den sites in late February. Female F4 localized in the Alder Creek drainage in late February, appearing to use a series of 2 dens through April and into early May. On May 6 we investigated the sites, finding old evidence of wolverine presence at the two dens. Female F4 was located at a third, previously undocumented site, at which 2 male kits were discovered, captured, and instrumented with intraperitoneal implant transmitters (Fig. 15). Each weighed 3 kg and estimated by tooth eruption to be 10 weeks of age. Female F5 was radio-tracked to a site on Mount Cannon in early March although subsequent visits to the site to search for a den were unsuccessful. The behavior of female F7 during the denning period provided no indication of denning.

The natal and two maternal dens of F4 were similar in structure. They were associated with downed snags on a gentle, sparsely treed slope (Fig. 16). The sites occurred on a western aspect ranging in elevation from 1,800 to 1,880 m and separated by 315 m (Fig. 17). The dens were partially excavated and mapped at the point of discovery and were revisited during the summer for detailed description of the den site and surrounding habitat features. Weekly investigation of rendezvous sites began following weaning. We documented 10 rendezvous sites from mid-May to mid-August. Nine of the sites were associated with boulders or cliff areas. The tenth was a downed log. All of the 2004

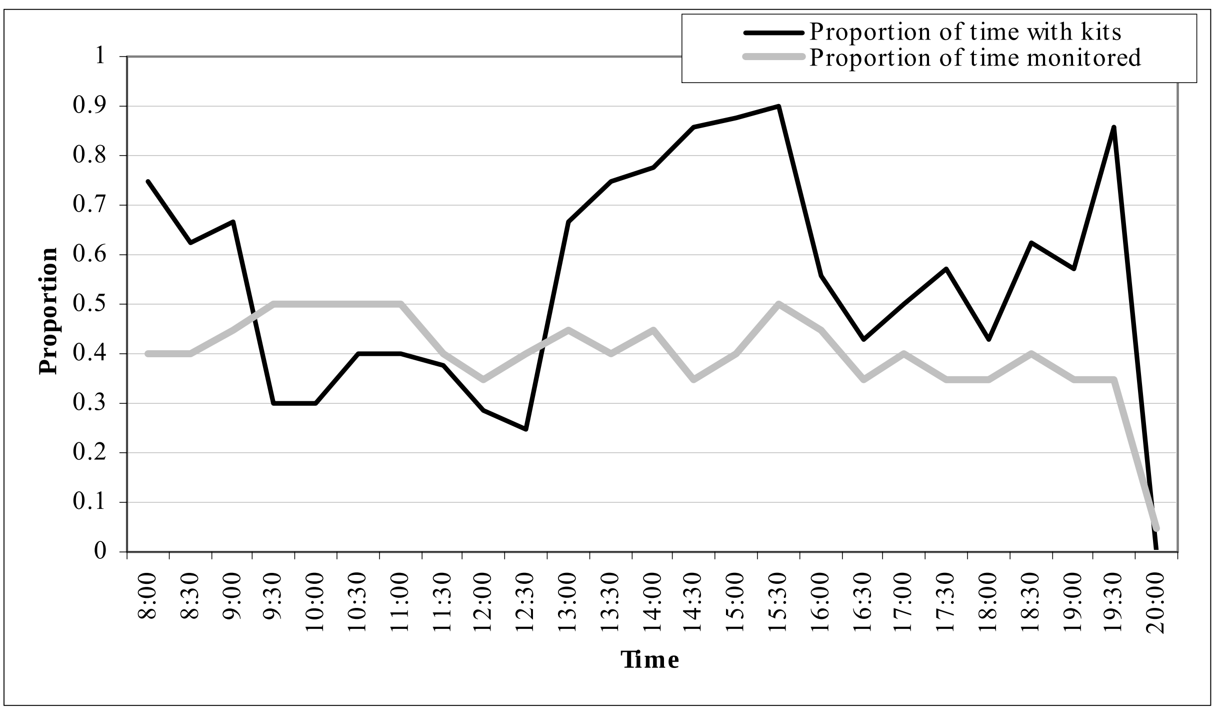

Figure 18. Proportion of time female wolverine F4 spent with her kits versus the proportion of time we monitored her throughout a 12-hour period. Data represent mean values for 20 monitoring sessions that occurred from May to September, 2004. We were not able to monitor the female through the entire 12-hour period in all 20 sessions. Therefore, the gray line depicts the proportion of monitoring sessions in which each time was included.

Figure 19. Natal den of female wolverine F2 in Glacier National Park, 2005. The den cavity occurred within the natural openings beneath this fallen whitebark pine.

rendezvous sites occurred near tree line ranging from 1,876 to 2,173 m elevation (Fig. 17).

The proximity of F4's rendezvous sites to the Highline Trail and Granite Park Chalet provided an exceptional opportunity to monitor her association with the kits. During 20 sessions, we monitored F4's and her kit's association for an average of 5 hours/session (SD = 5.8). F4 was away from the kits on average 45% of the time. Her direct association with the kits appeared to cycle through approximate 3-hour periods (Fig. 18).

In 2005, 4 females were added to the study population (Table 2), 3 of which were adults. In addition, we monitored the activities of 3 previously instrumented adult females for indication of denning. We found no evidence of lactation in F17 captured in Two-Medicine in April. Female F15 trapped in Many Glacier was lactating at capture and moved into the Belly River subsequent to processing. Her movements indicated she was denning but subsequent visits to the site in May found no presence of kits. Female F11, captured in the Avalanche Creek trap in late February moved into the Livingston Range and while she appeared to localize, we were unable to

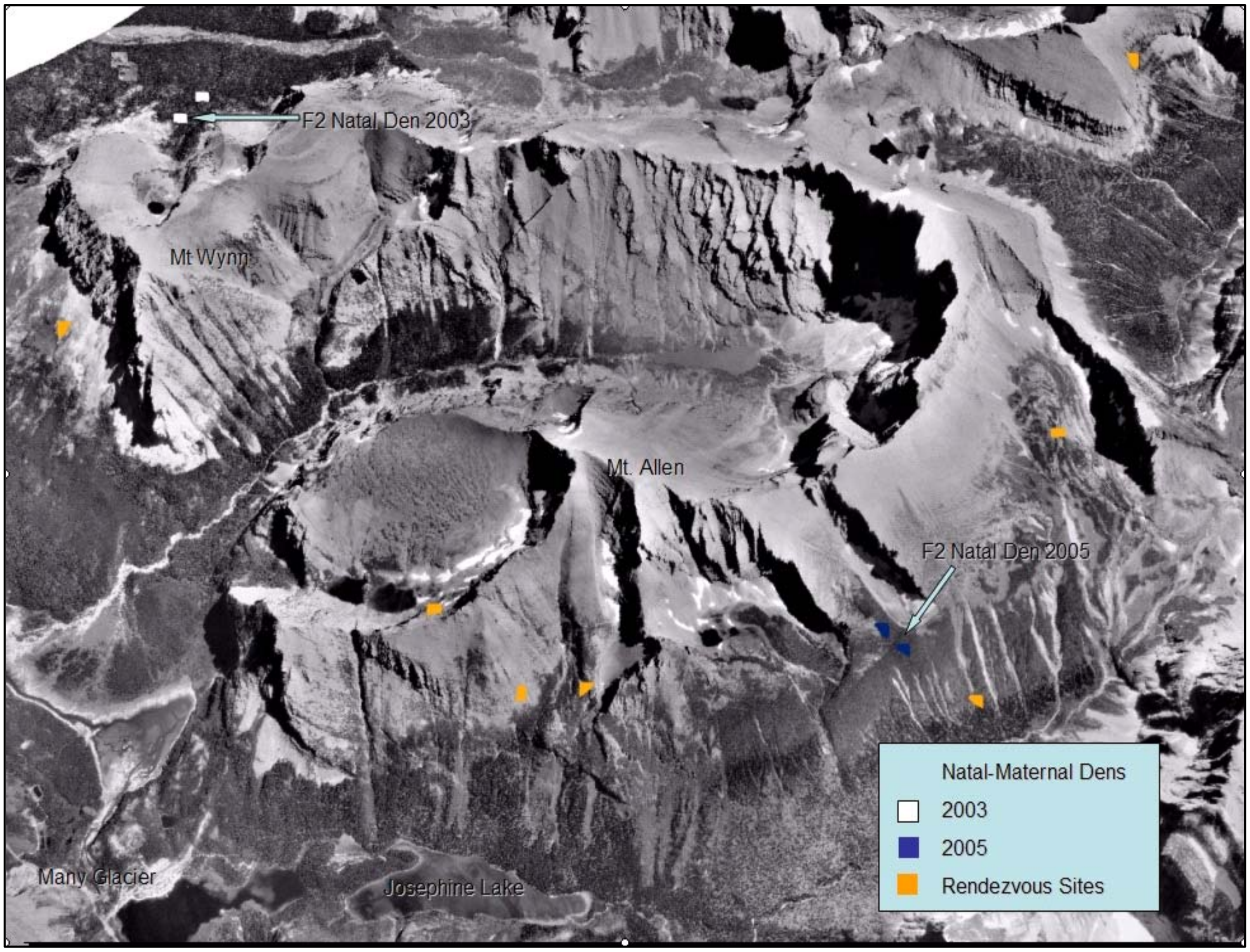

Figure 20. Natal dens, maternal dens, and rendezvous sites for female wolverine F2 in Glacier National Park, 2003, 2005.

confirm the presence of a den. We made no ground-based effort to search for dens or kits associated with F11. Movements of female F5 indicated the possible presence of a den near Logan Pass, which we monitored into April when F5 was killed in an avalanche near the site. A subsequent necropsy found no evidence of lactation. Females F4 and F2 became localized in their movement in late February. Both were monitored closely during the denning period. Localization and holes on the snow were observed for both females, and were visited by field crews in mid-May. The sites used by F4 provided no indication of kit presence, but goat remains were found. Two male kits were discovered near an Allen Mountain den site associated with F2. Both (M18, M19) were captured and instrumented with implant transmitters. The natal den of F2 occurred in scattered subalpine fir krumholtz on an east slope at 1,971 m elevation. The natal den site was situated beneath a fallen, dead whitebark pine (Fig. _. F2 used 2 maternal dens prior to weaning kits, both of which were of the same type structure on the same slope in similar habitat as the natal den, separated by 220 meters. We documented 7 rendezvous sites between 12 May and 25 September. The sites were similar to those of F4 the previous year in that they generally occurred near tree-line (Fig. 20). The habitat characteristics of F2's rendezvous sites have not yet been detailed. They ranged in elevation from 1,700 to 2,330 m.

We will complete a comprehensive analysis of reproductive rates once we can refine reproductive history for each female and genetic relatedness for all individual study animals.

Food Habits

Approximately 80 scat and foraging site samples have been collected and stored awaiting analysis. The majority of samples were collected in connection with reproductive den sites wherein there appears to be a significant use of mountain goat, remains of which were discovered at several non-den foraging sites as well. During summer, several incidents of wolverine predation on rodents were evident, with several park visitors reporting and/or photographing wolverine predating upon hoary marmots (*Marmota caligata*) and Columbian ground squirrels (*Spermophilus columbianus*) along the Highline Trail (Figs 21,22).

Figure 21. Female wolverine F5 with hoary marmot, Glacier National Park, 2004. Photo courtesy of Ken King.

Figure 22. Adult female wolverine F4 with Columbian ground squirrel in Glacier National Park, 2004. Photo courtesy of Bill Garwood.

Wolverine would probably not persist in the absence of ungulate populations, and evidence suggests at least a seasonal reliance on local rodent abundance (Gardner 1985; Magoun 1985, 1987; Banci 1987, Copeland 1996). The wolverine is capable of taking large ungulates as live prey (Myrberget 1968, Pulliainen 1968, Magoun 1985, Landa et al. 1997), but most ungulate presence in the wolverine diet likely results from scavanging (Hornocker and Hash 1981; Gardner 1985; Magoun 1985, 1987, Banci 1987, Copeland 1996). Ungulate remains in central Idaho constituted 46% of scats by proportion (Copeland 1996). The use of ungulate carrion by wolverine in winter generally accompanies a winter distribution shift downward into coniferous forest types, presumably to search for ungulate carcasses. The wolverine of GNP maintain a persistent year-round association with the subalpine ecotone, which is a direct overlap with wintering mountain goat habitat. As such, mountain goat may play a critical role in providing necessary winter food in the form of carrion, or, possibly as live prey.

DNA Analysis

The Rocky Mountain Research Station Wildlife Genetics Lab provided genotype profiles for 20 wolverine samples (19 trap captures and 1 scat sample from a non-captured individual), developed from analysis of 17 microsatellite loci from tissue and scat. PCA indicated a separation of genotypes into 2 distinct groups (Fig. 23). Principal components analysis simply compares the similarity of the microsatellite loci set across all individuals; it is not a definitive analysis of relatedness. Nevertheless, our expectation was for a continuum of similarity rather than a well-defined grouping given the spatial extent of our study population. The area encompassed by our study animals equals over 40% of GNP and indicates that 2 adult males may dominate the genotypic structuring for nearly half of the park.

CONCLUSION AND MANAGEMENT ISSUES

To date, the reproductive dens of only 6 female wolverines have been identified and described within the contiguous US. As with long-distance movement, wolverine reproduction is a rare event that is difficult to detect. A primary concern presently facing land management agencies is the potential impact of human activities, primarily winter recreation, on wolverine reproductive denning. To address this we need to address two separate questions: 1) what sites are being selected for dens, and 2) are human activities occurring in the same places and at the same time as denning. By first determining the range of scale-dependent variability in den site habitat we can begin to understand if habitat selected for denning is limited. If den sites are very

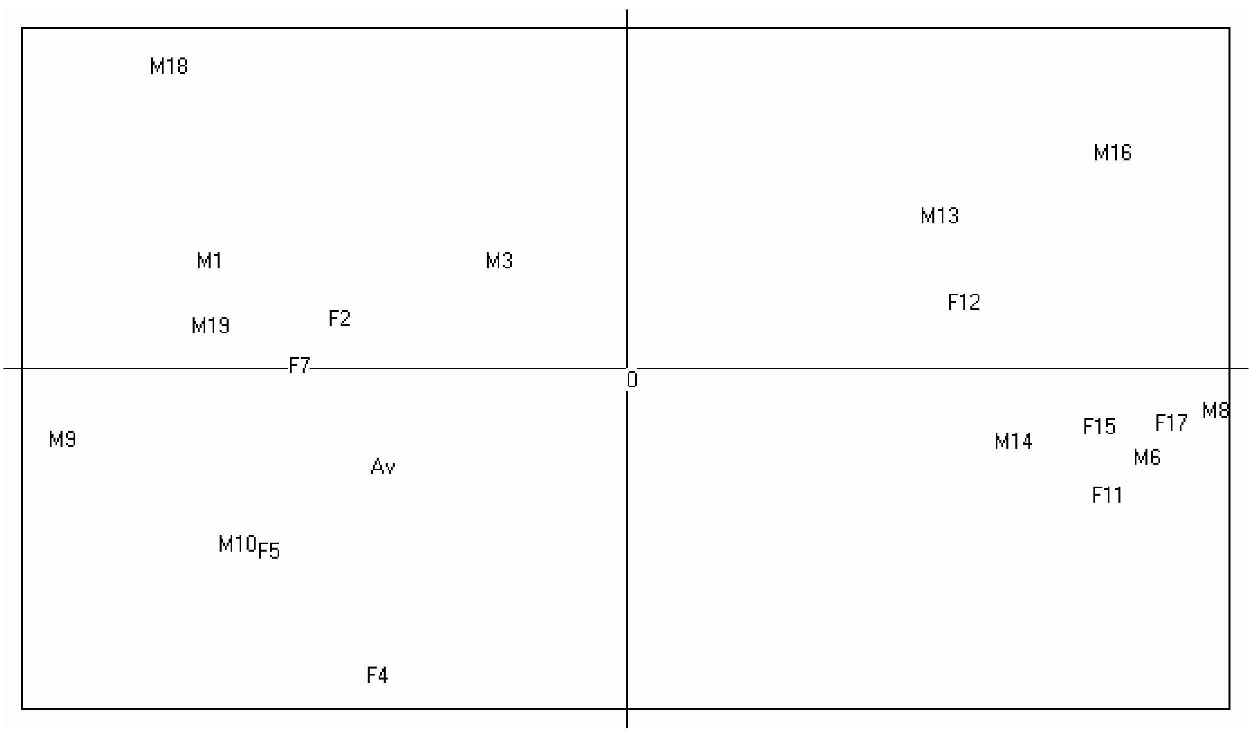

Figure 23. Principal components analysis of 17 microsatellite loci for 20 Glacier National Park wolverine. The distance between individuals indicates similarity of genotypes based on 2 principal components, which, in this case, classify the genotypes into 2 distinct groups. The marker "Av" designates an individual that was identified by a scat collected at the Avalanche Creek trap.

specific we can then empirically compare both temporal and spatial use of habitats selected for both wolverine denning and human recreation.

A paucity of information exists on rendezvous sites. Magoun (1985) described numerous rendezvous sites in arctic Alaska suggesting the female may move kits to a new site every 1-9 days. Copeland (1996) described 10 rendezvous sites used by 2 adult females and kits in central Idaho. Five of the sites occurred in association with talus boulders while 5 were characterized as coniferous riparian. The primary commonality among these sites appears to be a component that aids in hiding the kits, whether it be under a boulder or in a thick, brush understory. Rendezvous sites in GNP were often at the base of a cliff, which may tend to reduce the broadcast of the kits odor or limit the directions from which a passing predator can come upon the kits. As with reproductive dens, the character of rendezvous sites needs further exploration.

GPS technology is allowing us to track wolverine at a scale of 5-minute movements. A single week of 2-hour data provided insight into wolverine movement and habitat use that normally requires 20 years of conventional radio telemetry relocations. These data are a beginning to understanding wolverine habitat relationships within GNP and the surrounding region at a level never before possible.

On the opposite end of movement dynamics are the broad-scale, dispersal related movements. An understanding of the frequency of broad-scale movements and the probability of individuals surviving such events is crucial to our ability to manage the landscape and the human activities that may affect connectivity across its range. Long distance movements by wolverine, generally by young males, have been noted in virtually every wolverine study (Inman et al. 2004) but only as an occasional incident. This is likely due to the fact that wolverine studies are expensive and logistically difficult, and generally only last a few years; exacerbated by the fact that wolverine exist at low densities. As such, our opportunity to document dispersal movements is small. The magnitude of understanding wolverine dispersal is exaggerated by the fact that wolverine populations are often isolated. Gene flow among these subpopulations may depend upon these rare movement events.

Additionally, GNP has become a destination for those intrigued by the possibility of seeing a wolverine in its natural habitat. The photo on the title page of this report along with several others (Figs. 20, 21) are examples of photographs taken of GNP study animals by park visitors in 2004 and 2005. No other National Park – in fact, no other place in the world provides such a realistic opportunity to observe one of the most rare and fascinating creatures on the planet.

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Female F5 poses along the Highline Trail in Glacier National Park, 2004. Photo courtesy of Ken Curtis.