Restoration of Wolverines: Considerations for Translocation and Post-release Monitoring

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Preface

Reintroducing wolverines to historically occupied, suitable habitat could function as a major proactive step toward improving wolverine status and genetic diversity in the contiguous United States. Discussions about the possibility of wolverine reintroduction into Colorado were reinitiated during 2009 after lynx reintroduction efforts there were declared successful and an individual male wolverine was radio-tracked as it moved into the state becoming the first verified record in Colorado in 90 years. However, because wolverine reintroduction had not been previously attempted, there was a need to assemble information and develop the most appropriate techniques in case this management option became desirable. In this document we emphasize options and alternatives (or obvious nonstarters) as an adaptive approach for initial reintroductions should they become feasible.

This document was prepared by the Wolverine Translocation Techniques Working Group. The WTTWG included experts in wolverine research and ecology, veterinary medicine, carnivore translocations, population modeling, and wildlife monitoring.

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Summary

Successful reintroduction of wolverines to historically occupied, suitable habitat could function as a major proactive step toward improving wolverine status and genetic diversity in the contiguous United States. However, because wolverine reintroduction has not been previously attempted, there is a need to assemble information to develop the most appropriate techniques in case this management option becomes desirable and politically feasible. In this document we describe pros and cons of various approaches (and identify obvious nonstarters) and advocate an adaptive approach for reintroductions. We find this preferable to a more prescriptive approach because the "right" answer is largely unknown without prior experience. We suggest that ongoing assessment and modification of capture, transport, and care of captive animals is used to ensure the highest probability of survival and site fidelity. Wherever possible, activities should be undertaken in a manner that maximizes the ability to learn from experiences and adapt to improve. Protocols will likely change as more information and experience is accumulated. We suggest sourcing wolverines that maximize genetic diversity of the reintroduced population after consideration of other factors such as the sustainability of removals from source populations and matching habitat and prey between source and relocation sites. A mixture of wolverines from multiple locations including Alaska, British Columbia, Yukon Territory, and Northwest Territory would provide a broad genotypic representation. Additional areas that provide unique genetic material (e.g., Manitoba, Nunavut) could also prove beneficial but would require careful selection due to smaller source populations and differences in habitat/prey/mortality sources. Total numbers translocated from any one site should be carefully considered based on locally available data. Our consensus regarding the number of wolverines to move during an initial translocation was strong for a larger number of individuals over several years (i.e., >10/year for multiple years) rather than a smaller, more conservative number. This approach would protect against stochastic failure and reduce time to reestablishment. To determine season of capture and method of release most likely to be successful, we considered effects that translocation may have on wolverine survival, site fidelity, and reproduction. Consensus formed around winter captures (Oct–Dec) followed by a provisioned release (release into natural snow-covered chambers where supplemental food has been placed) after a short stay at a captive transfer facility. The option of retaining pregnant females at a captive facility until or just prior to parturition (Feb 1 or later if ultrasound or other information is available) may help improve site fidelity. This could be particularly useful if large movements away from the reintroduction site are deemed to be a problem. Because same-year reproductions may occur and are valuable for improving site fidelity, genetic diversity, and successful establishment of a population, careful consideration of how to release males, if at all, is warranted (some species have been reestablished by moving pregnant females and allowing male offspring to mature, disperse, and breed). We provide details of aspects to consider during capture, handling, inspection, and transportation of wolverines. We also briefly discuss monitoring of translocated populations.

1 BACKGROUND

1.1 Why Consider Wolverine Translocations?

Wolverines occupy remote and rugged areas in tundra, taiga, boreal, and montane environments across the northern hemisphere (Copeland and Whitman 2003). They are territorial, have low reproductive rates, and naturally exist at low densities (3-10/1,000 km^2; Magoun 1985, Persson et al. 2006, Persson et al. 2010, Inman et al. 2012a). Populations were extirpated or nearly so from Scandinavia and the contiguous United States by the early 1900s (Persson 2003, Aubry et al. 2007). Wolverine population declines, similar to many large carnivores, resulted in large part from conflicts with humans. In North America, major factors in declines likely included unregulated commercial trapping, killing and poisoning to prevent wolverines from raiding trap-lines, and the widespread practice of poisoning carcasses to kill large predators (Aubry et al. 2007). Declines of wolverines occurred early relative to several other carnivores, likely a result of their small populations and vulnerable demographics. The species is on the IUCN Red List (threatened and endangered species) in Scandinavia and under consideration as a threatened species in the contiguous United States (Gärdenfors 2010, Kålås 2010, United States Fish and Wildlife Service 2010, United States Fish and Wildlife Service 2013).

Wolverines in the contiguous U.S. exist as a metapopulation that occurs in islands of high-elevation, alpine habitat across 10 western states that have the biological capacity for approximately 600 individuals (Inman 2013). Wolverines appear to have been extirpated, or very nearly so, from the contiguous U.S. by about 1930 (Aubry et al. 2007). Since that time, wolverines in the northern portion of the historical range have largely recovered. Current distribution of breeding populations is limited to Montana, Idaho, Wyoming, and Washington, where approximately 300 individuals are thought to exist (Aubry et al. 2007, Inman 2013). However, breeding populations have not existed in the southern half of historical distribution for nearly a century (Aubry et al. 2007). Large areas of suitable habitat that wolverines historically occupied include the Southern Rocky Mountains, primarily in Colorado, and the Sierra-Nevada of California. Reoccupation of these areas by wolverines could increase population size by an estimated 45% (Inman 2013). However, these areas are relatively isolated from currently occupied range due to the long distances and, in the case of the Southern Rockies, low elevation arid habitats through which wolverines would have to disperse. This may be more of an issue of concern for females, which have a lower propensity to undertake large dispersal efforts across atypical habitat (Greenwood 1980, Dobson 1982, Pusey 1987, Vangen et al. 2001, Flagstad et al. 2004, Inman et al. 2012a, Inman 2013). Therefore, it appears unlikely that natural dispersal would result in population reestablishment in the Southern Rockies at this time. In addition, even if natural recovery did occur, it would likely take several decades (Newby and Wright 1955, Newby and McDougal 1964), and would almost certainly result in an extremely low degree of genetic heterozygosity (Cegelski et al. 2006, Schwartz et al. 2009).

Wolverines occupy a cold, low productivity niche where snow cover is present for much of the year (Copeland et al. 2010; Inman et al. 2012a, Inman et al. 2012b). Therefore, climate change has the potential to acutely impact wolverines (McKelvey et al. 2011). The Southern Rockies of Colorado sit at the southern periphery of the wolverine's global distribution, thus it seems counter-intuitive to suggest that this area could serve as a "climate-safe" refuge. However, much of the wolverine's distribution in the far north consists of areas near sea level and topographically flat. If global temperatures continue to rise, these flat, low elevation areas in the north may see snow packs recede more rapidly than in southern areas with high elevations and rugged terrain with large areas of north-facing slopes. Some climate models suggest that climate change will affect higher elevations (> 9,000 feet or 2,750 m) in Colorado less than most other areas for the foreseeable future (Mote et al., 2005; see Cross and Servheen, 2009). The Southern Rockies of Colorado has the highest average elevation of any region in the contiguous U.S., including 54 peaks over 14,000 feet (4,250 m). Even though Colorado lies at the southern periphery of the wolverines global distribution, its high elevations and rugged terrain may serve to retain colder temperatures and greater snow-cover necessary for wolverines compared with other portions of the species range. Thus, while climate change will not improve the suitability of wolverine habitat in Colorado or other mountainous areas of the contiguous U.S., 50-100 years from now these areas may offer some of the best remaining and most resilient wolverine habitat in North America.

Reintroduction of wolverines to historically occupied, suitable habitat could function as a major, proactive step toward improving wolverine population status and genetic diversity in the contiguous United States. However, because wolverine reintroduction has not been previously attempted, there is a need to assemble information for consideration in developing the most appropriate techniques.

1.2 Important Considerations for Wildlife Translocations

The Reintroduction Specialist Group (RSG) of the IUCN's Species Survival Commission developed guidelines for reintroductions and other translocations, however these guidelines are not species or even taxa specific (IUCN 1987, IUCN 1998). The IUCN guidelines are designed to be applicable to the full spectrum of conservation translocations. They are based on principle rather than example, much like the intent of this document. The IUCN document is intended to ensure that a reintroduction is justified because it will result in a "quantifiable conservation benefit" and does not cause adverse side effects of greater impact. Specifically, the IUCN guidelines focus on: 1) Pre-project activities, including an in depth and interdisciplinary feasibility assessment and background research on the ecology of the species as well as other reintroduction efforts, evaluation of release sites and types of releases, an evaluation of the reintroduction site including assessment of suitable habitat, reduction of previous causes of population decline, disease concerns, animal welfare, and the availability of suitable release stock and the associated release of captive stock. Additional discussion covers the social and legal feasibility and considerations associated with a reintroduction, risk assessment, and planning; 2) Reintroduction implementation, including release strategies; and 3) Post-release considerations, such as monitoring, continuing management, and dissemination of information. The IUCN guidelines discuss these and other topics in greater detail and provide a sound framework under which translocations should be considered and, if appropriate, implemented. Our specific objective here is to focus on important elements related translocation of wolverines including the number of animals to release, availability of stock, evaluation of donor and release sites, capture considerations, release techniques, and post release monitoring.

1.3 Objective: Thinking Through Wolverine Biology to Improve Survival, Site Fidelity, and Reproduction During Translocation

A group of North American biologists and veterinarians with knowledge and experience relevant to wolverine translocations was convened in Fort Collins, Colorado in May 2010 and again in Laramie, Wyoming in March 2012 to discuss the technical details of wolverine translocation. Concepts and suggestions generated at these workshops formed the basis for much of what we included here. We generally framed discussions around the southern Rocky Mountains because it constitutes a large area of suitable but currently unoccupied habitat and because Colorado Parks and Wildlife was granted permission by their Commission to engage the public on the issue of wolverine reintroduction. This document is intended to emphasize options and viable alternatives (or obvious nonstarters) for initial reintroductions. We find this far preferable to a more prescriptive approach because the "right" answer is largely unknown without prior experience. Ultimately it will be the responsible agencies (source and receiving) that decide precisely what approaches they will take within their respective jurisdictions. We do not address the potentially different considerations of augmentation (i.e., reinforcement *sensu* IUCN 2012) vs. *de novo* reintroduction in this document.

2 WOLVERINE SOURCE SITES

Choosing the location(s) for capturing wolverines that would be translocated requires balancing several components – familiarity of wolverines with the mortality and food sources of the new area, genetic composition, and sustainability of removals.

2.1 Ecological Similarity of Mortality and Food Sources

Successfully establishing a population depends on survival, site fidelity, and reproduction of the translocated individuals. These factors are all likely to be influenced by the individual's familiarity with potential mortality sources and foods available in the new area.

Natural sources of wolverine mortality include starvation, avalanche, and predation by gray wolves, cougars, black bears and other wolverines; human-caused mortality sources include trapping/hunting, poaching, poisoning, and road/rail-kill (Krebs et al. 2004, Inman et al. 2007, Persson et al. 2009). To the greatest degree possible, we recommend obtaining wolverines from source populations that face the same potential mortality sources as occur in the reintroduction area. For instance, we might expect slightly higher mortality rates for wolverines reintroduced from source populations without large felids (cougars) if those animals are reintroduced into areas with that potential mortality source. However, many wolverines kept in captivity, including some born in captivity, never lose their cautious behavior when exposed to humans they are unfamiliar with or strange noises. Therefore instinctive cautiousness may be more important than specific familiarity and learned behavior when it comes to predator avoidance. At a minimum, it will be necessary to monitor survival of translocated individuals in a way that allows examination of whether familiarity/learned-behaviors influence survival at the release site, (i.e., differences in cause of mortality by source site).

The effect of food on survival, site fidelity, and reproduction may not be simply limited to the amount of potential carrion/prey. Other factors, such as learned hunting behavior, could be influential. Whereas the ability of wolverines to locate ungulate carrion is unlikely to be affected if ungulate species differ between the source and reintroduction areas (e.g., caribou versus elk), wolverine hunting likely involves some learned behavior that could influence success rates. It is clear that wolverines scavenge extensively during both winter and summer (Mattisson et al. 2011a); however, the timing of wolverine birth/juvenile-growth suggests that both winter and summer foods are important (Inman et al. 2012b). In addition to scavenging, wolverines may prey on neonatal ungulates during summer (Gustine et al. 2006, Inman et al. 2007b, Mattisson et al. 2011a), and studies from the southern extent of distribution suggest that use of marmots may be extensive (Lofroth et al. 2007, Packila et al. 2007). If hunting for marmots or neonatal ungulates is likely to provide a substantial portion of food at the reintroduction site, individuals sourced from areas with similar prey species, habitats, or hunting strategies may demonstrate greater site fidelity, higher survival, and higher reproductive rates after reintroduction.

2.2 Genetic Considerations

The following suggestions are aimed at balancing the goals of maintaining adequate genetic heterogeneity to reduce founder effects and inbreeding depression, and restoring individuals that will be genetically similar to the historical population. We also note that genetic considerations should not override practicalities such as higher survival due to familiarity with prey and potential sources of mortality.

Ideally, prior to reintroduction we would have extensive knowledge of the historical genetic substructure of wolverines in North America, historical knowledge of the composition of wolverines present in potential reintroduction sites, and an understanding of the adaptive role of any genes that were found to be unique in the reintroduction sites. In our investigations thus far, we have uncovered 5 historical samples from Colorado and Utah and have a limited understanding of historical population genetic substructure (Schwartz et al. unpublished data). It appears that the Southern Rocky Mountains had one haplotype consistent with a southern clade (haplotypes found in California's Sierra Nevada, Idaho, Utah, and Colorado) and one haplotype consistent with a northern clade (Haplotype "Cegelski O", found only in Revelstoke Canada in the modern samples; Schwartz et al. unpublished data). This suggests that 2 distinct clades existed with the Southern Rockies acting as the suture zone for those clades. However, we note that the adaptive significance of the genetic differences of these clades is unknown.

Restoring the Southern Rocky Mountains with the southern clade is now impossible because this haplotype (which was 3 substitutions from anything else found in North America) is now extinct. Interestingly, the northern haplotype (Haplotype "Cegelski O") is now restricted to 1 location in the Rocky Mountains and is highly related (1 substitution) to a more common haplotype found in many locations (Alaska Range, Eurasia, Eastern Nunavut, Wyoming, Revelstoke, the Kenai Peninsula, southern Alaska, northwestern Alaska, and northern Alaska; Tomasik and Cook 2005, Cegelski et al. 2006).

Given that restoration of the historical southern type is not an option, the next consideration is whether to reintroduce with 1) the closest geographic population, 2) the closest genetic population, or 3) to use a mixture (Schwartz 2005). Using the geographically closest population is a conservative approach which assumes that some local adaptation has occurred. Unfortunately, we know little about local adaptation in wolverines and less about the genes that may lead to local adaptation. From first principles of population genetics, we know that when effective population sizes are low, selection is not very efficient and genetic drift can become the dominant evolutionary force (Hartl and Clark 1989, Allendorf and Luikart 2007). When an effective population size is large, natural selection has the potential to overpower genetic drift at loci involved in adaptations. Given that wolverine populations were likely never very large in the U.S. and were probably structured by family groups in mountain ranges (Copeland 1996, Squires et al. 2007, Inman et al. 2012a), we believe that the genetic profile in many of the mountain ranges were shaped by genetic drift and that selection was weak. This assumes that the selective pressures were not extreme. Therefore we see no compelling genetic evidence that we restrict our source animals to the most geographically close population.

The second option would be using the closest genetic profile to animals that occurred in the Southern Rockies historically. Mitochondrial DNA shows a structured signal, likely associated with female philopatry and the recovery of wolverine from glacial and trapping refugia. This suggests using animals of haplotype "Cegelski O" from Revelstoke or a closely related haplotype, "Wilson H", which is ubiquitous. Given the close proximity (in terms of substitutions) of these haplotypes from many other Rocky Mountain haplotypes, choosing only animals with specific haplotypes does not appear warranted. Research is beginning to acquire a full mitome (~16,000 bp) dataset on wolverine in the Rocky Mountains, but so far this preliminary analysis does not suggest unique geographic structuring (Schwartz et al. unpublished data). Nuclear DNA results suggest mixing among populations in the northern portion of the range with significant structure between the north and the south and significant structure within the Rocky Mountains (Kyle and Strobeck 2002, Cegelski et al. 2006, Schwartz et al. 2007, Schwartz et al. 2009), associated with small populations influenced by genetic drift (see above). There are no nuclear DNA available from historical samples in the Southern Rockies to evaluate substructure. In summary, we recommend that the use of any haplotypes found in the Rocky Mountains would provide the necessary genetic components while allowing the most logistic flexibility.

The third strategy would be to mix individuals from multiple populations and allow natural selection to occur over time (Temple and Cade 1988, Tordoff and Redig, 2001). By mixing individuals, we would encourage increased heterogeneity in the populations. Arguments for heterogeneity include 1) better long-term persistence (lower odds of bottleneck), 2) a broader range of characteristics from which local adaptation can eventually occur, and 3) the possibility of hedging against climate change impacting wolverine populations in their more northern but low-elevation core habitats where genetic diversity is currently highest (Wilson et al. 2000, Kyle and Strobeck 2002, Chappell et al. 2004, Cegelski et al. 2006). The risk associated with mixing individuals is that outbreeding depression could occur (Templeton 1986, Tallmon et al. 2004). However, most analyses suggest that outbreeding depression rarely occurs in animal populations, especially among species that range widely like wolverines, and our historical DNA analysis and understanding of gene flow suggests that most potential source populations were not likely separated for >20 generations (Schwartz et al. 2007, Schwartz et al. 2009, Frankham et al. 2011). Therefore current first principles suggest that reestablishing gene flow would not lead to outbreeding depression. Overall, this means we should focus more on minimizing inbreeding depression and maintaining heterozygosity and less with outbreeding depression.

In summary, we 1) want to do no harm to the source population by removing individuals from small populations; 2) should be more concerned about inbreeding depression than outbreeding depression; 3) want to maximize heterozygosity in the animals used for translocation as we do not know what genetic variation will be important for reintroduced animals to survive; 4) should avoid translocating close relatives (though see below); and 5) should consider mixing our source populations, with the exception of those areas that have been isolated for long periods of time. Item 4 follows from 2 and 3; however, in natural wolverine populations, adjoining females are often genetically related and daughters often live in their mother's home range. As long as unrelated males are introduced with these females, there may not be a problem with some females being related; it may even be better to have a mother and her 1- or 2-year old daughter released together to increase site fidelity. Regardless, obtaining diverse mitochondrial and nuclear DNA would be beneficial, which would argue for obtaining animals from several source sites. Analysis of wolverine genetic composition to date suggests that the highest heterozygosity occurs in Alaska and northern Canada (Wilson et al. 2000, Kyle and Strobeck 2002, Chappell et al. 2004, Cegelski et al. 2006, Schwartz et al. 2007). While nuclear DNA can be similar across these northern geographies, mitochondrial DNA shows more differentiation and could therefore provide more specific guidance for site selection.

2.3 Sustainability of Removals

Participants at the May 2010 workshop recommended that removals of animals from source populations be sustainable and that reintroduction programs meet or exceed IUCN guidelines. The IUCN reintroduction guidelines do not provide specific recommendations on exactly how or to what degree sustainability of removals from the source population should be demonstrated. In the case of the wolverine in North America, we believe that this important topic can be addressed successfully with existing information. We begin with the assumption that the potential wolverine reintroduction areas in the contiguous U.S. (Colorado and California) would each require no more than 25 wolverines be translocated per year for no more than 3 years (discussion below on numbers and sex ratio). This would mean acquiring a maximum of 50 wolverines per year for 2–3 years if both areas were sourced simultaneously (100–150 total for the two release sites).

British Columbia (BC) would likely be one of the primary target source populations given the factors considered above related to genetics and similarity of ecological conditions. BC is also the area with the most detailed information at present. Wolverines in BC have been harvested commercially for nearly 2 centuries, and annual harvest has ranged from 40 to 634 since 1919 (Lofroth and Ott 2007). Lofroth and Krebs (2007) estimated total wolverine population of BC to be 3,532 (95% CI 2,693–4,759). In more recent years (1985–2004), approximately 170 wolverines were harvested per year in BC, and recruitment was estimated to be 196 wolverines per year (Lofroth and Ott 2007). These numbers suggest that approximately 5% of the provincial population is harvested annually and that this rate is sustainable in British Columbia. BC appears capable of producing 150 wolverines per year, far more than necessary or desirable on an annual basis, even if two potential release sites operated simultaneously.

Given the need for a broad genetic representation and minimizing pressure on any one source population, utilizing one or more source populations in addition to BC is clearly desirable. Total number of wolverines taken annually over the 15-year period 1989–2004 in Yukon Territory averaged 144 (Slough 2007). Wolverine harvest in the Northwest Territories over the same 15-year period averaged 107 per year (Slough 2007). In Alaska, an average of 545 wolverines was taken per year 1984–2003 (Golden et al. 2007a). In all cases, these consistent harvest levels for over a decade in recent years suggest relatively stable populations. Wolverine harvest also occurs in additional Canadian provinces (primarily Manitoba and Nunavut; Slough 2007), but at lower numbers. These areas might also be considered due to the possibility of unique genetic contributions (Zigouris et al. 2012), but likely at smaller numbers.

Excluding Manitoba and Nunavut, these data suggest that approximately 950 wolverines are harvested sustainably each year in Alaska, British Columbia, Yukon Territory, and the Northwest Territories. Even if reintroduction efforts were ongoing on both prospective sites, 50 wolverines represent only 5% of current annual take. We believe it possible to arrange translocation captures such that they would occur in lieu of harvest. However, this does not appear to be necessary given that the total number of translocated individuals would be low relative to annual harvest. While numbers at a provincial or state level seem reasonable, we note that this depends, of course, upon procuring individuals from a few areas rather than focusing too much in any one area. While provincial numbers appeared sustainable, some individual wolverine units in BC were likely overharvested during the period examined by Lofroth and Ott (2007). Clearly, working with provincial and state agencies to choose specific locations and appropriate numbers would be important. In general though, utilizing 2-3 sites in each of BC, Alaska, Yukon, and NWT would provide animals with the desired genetic makeup and could yield up to 100-150 wolverines over a 2-3 year period in a sustainable manner.

2.4 Summary of Source Site Considerations

Based on the above factors, we suggest an approach that allows for the best genetic composition of the reintroduced population with due consideration of other factors that may influence survival, site fidelity, reproduction, minimizing impacts within a source population, and efficiency and expenses of capture and translocation logistics. The source for wolverines should not be over-represented by any one geographic area. Ideally, animals should be obtained from across the range in North America. Captures from multiple locations within British Columbia, Alaska, Yukon, and Northwest Territories should be capable of providing a broad representation of nuclear and mitochondrial DNA and sufficient numbers in a sustainable manner. Total numbers translocated from any one site should be carefully considered based on locally available data. Matching habitat, prey, and potential mortality sources of the source and relocation sites should be done to the extent possible, without over-representing that genetic component or harming the local source population. Because these factors could be key for survival, specific efforts to analyze survival by source area/habitat similarity should be made. Additional areas that provide unique genetic material (e.g., Manitoba, Nunavut) could also be beneficial but would need to be carefully selected due to smaller total population sizes; similarity of prey and potential mortality sources from these areas should also be considered.

3 NUMBER OF WOLVERINES TO RELEASE AND TIME TO REOCCUPATION

3.1 Number of Wolverines to Release

Here we consider information on wolverine territory size, sex ratio, and density in order to estimate appropriate targets for releases. Because of large home range requirements and territorial behavior, wolverines naturally exist at low densities across their range (Golden et al. 2007b, Lofroth and Krebs 2007, Royle et al. 2011, Inman et al. 2012a). Significant blocks of habitat, on the order of thousands of square kilometers, will be required to support a sustainable population of wolverines. Adult female home ranges are generally 100–400 km^2; adult male home ranges are usually >500 km^2 and typically overlap that of 2-3 adult females (Hornocker and Hash 1981, Magoun 1985, Banci and Harestad 1990, Copeland 1996, Landa 1998, Hedmark et al. 2007, Krebs et al. 2007, Persson et al. 2010, Mattisson et al. 2011b, Inman et al. 2012a), suggesting an adult sex ratio of approximately 2M:5F. Thus, 5 adult females and 2 adult males would require an area of 500-2,000 km^2 of wolverine habitat. Assuming the lowest density, 7 adults would require 2,000 km^2 of wolverine habitat (i.e., 3.5 adults/1,000 km^2). This number falls within the range of density estimates from the southern edge of wolverine distribution (density estimates from Idaho, Montana, and southern British Columbia were 3.5-5.8 per 1,000 km^2; Copeland 1996, Lofroth and Krebs 2007, Inman et al. 2012a). Thus it seems reasonable to use a density/sex-ratio of 7 adult wolverines (2M:5F) in a 2,000 km^2 area of habitat as a population target.

It will not be necessary or desired to release enough animals to immediately occupy the available habitat. A more appropriate goal is to provide enough animals to enable natural reproduction to produce the animals which will eventually occupy the available habitat within a reasonable time span. For example, a reasonable expectation might be that 1 of 2 adult males and 3 of 4 adult females will remain within the release area and survive through the first year after release. Given this scenario, achieving a 2M:5F ratio would require release of 4 adult males and 7 adult females (11 wolverines per 2,000 km^2 of habitat). If the goal of the reintroduction is to release enough animals to reoccupy 20% of the potential habitat, then this release would suffice for 10,000 km^2 of habitat. The state of Colorado has approximately 40,000 km^2 of wolverine habitat (Inman 2013) which would require 4 releases of 11 wolverines (4M:7F). To continue this example, a logical release strategy would involve a year-1 release of 22 wolverines at 2 sites followed by a similar year-2 release at 2 additional sites. An alternative might be year-1 release of 11 wolverines at one site, followed by evaluation of success and subsequent appropriate releases. Release of a greater proportion of males (e.g., 7M:7F) could provide more opportunity for mate selection, and could be practical given capture logistics in source areas. Males that do not pair with released females would not necessarily be lost to the population. They could expand into unoccupied areas and find mates through additional releases or reproduction in the release area. Release of males should be carefully considered with the overall strategy (see below).

3.2 Expected Time to Reoccupation

Reoccupation of a 40,000 km^2 area by a wolverine population that begins with release of 44 individuals over a 2-4 year period will depend on survival and reproductive rates. If, as outlined above, groups of 2 adult males and 5 adult females remain within the release area and survive (for each group of 11 that are released, assuming 2 groups released each year), 10 breeding "pairs" (one male can "pair" with multiple females) would be present at the end of the year of the first translocation, and another 10 breeding "pairs" would be present at the end of the second year of translocation. We use this to estimate the time required to achieve occupation of 40,000 km^2 of habitat as below. Our main purpose here is to compare relative times to habitat "saturation" based on different release strategies rather than to make an accurate estimate of time until saturation.

We formalized the wolverine life cycle as follows. We considered only the female part of the population and structured it into several age classes. Female wolverines include juveniles (age 0), subadults (age 1) and sexually mature females (age 2-16). Reproduction takes place from age 2 to age 13. Based on data from Persson et al. (2006, 2009; n = 141 female reproductive years, and n = 184 female survival years), we computed numerical values of demographic parameters as (mean and 95% CI): juvenile survival sj and subadult survival ss = 0.79 (0.69-0.90), sexually mature individual survival sa = 0.89 (0.84-0.93), mean number of female offspring per 2-year old female per year $f2$ = 0.05, and mean number of female offspring per sexually mature female per year f = 0.38 (0.17-0.57). We developed a female stochastic stage-structured population model from the wolverine life cycle and parameterized with the values above. We included demographic stochasticity by modeling survival with a binomial law and reproduction with a Poisson law. We included environmental stochasticity by obtaining yearly parameter estimates from normal draws with mean and SD of parameters. To mimic density dependence at habitat saturation, we capped the population at a carrying capacity of 100 sexually mature females. The age of released females was derived from the empirical distribution of captured females. We ran 10000 stochastic simulations and computed the mean trajectory, from which we also derived the number of years for the population to exceed a given size (Figures 1 and 2). Figures 1 and 2 show the median of all simulations with 95% CI and some simulations attempt to grow above 100 females because only the number of sexually mature individuals is limited. Actual survival and reproductive rates and their variability are, of course, unknown; however, these figures give a good basis for understanding the tradeoffs between modest versus larger numbers of founders.

3.3 Summary of Number of Wolverines to Release and Time to Reoccupation

While we avoid use of prescriptions in this section, our strong consensus is to go with a larger number of wolverines (i.e., >10/year for multiple years) rather than a smaller, more conservative number. This would protect against stochastic failure and also improve genetic diversity.

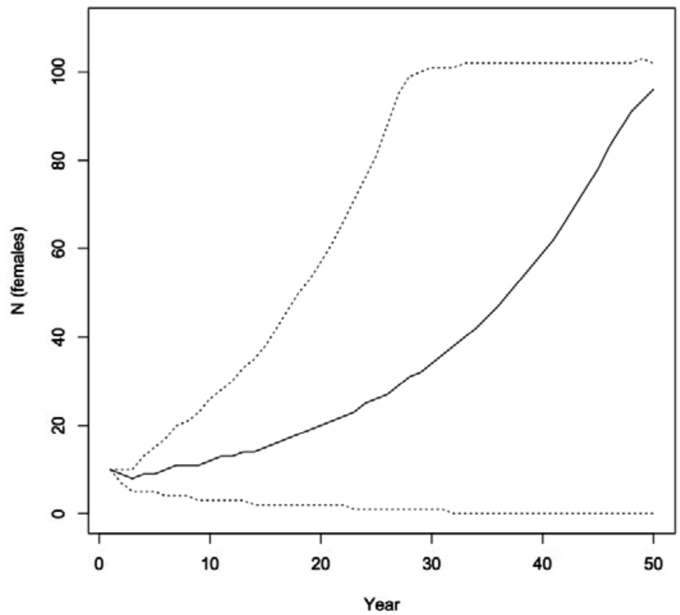

Figure 1. Scenario based on reintroduction and survival of 10 adult females during year one only and no subsequent release. Predicted population trajectory for a reintroduced wolverine population based on reproduction and survival estimates from Sweden (Persson et al. 2006, 2009) and exponential growth but with a population cap at 100 sexually mature females. The estimated number of years at which the female population size reaches 30 = 28 years; 40 = 34 years; 50 = 38 years. Median is continuous line and 95% CI are dashed lines.

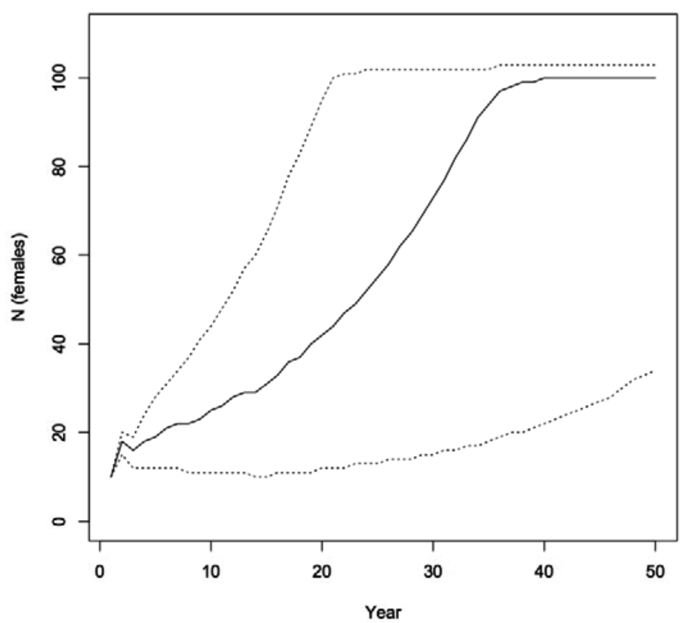

Figure 2. Scenario based on reintroduction and survival of 10 adult females during year one and an additional 10 adult females during year two. Predicted population trajectory for a reintroduced wolverine population based on reproduction and survival estimates from Sweden (Persson et al. 2006, 2009) and exponential growth but with a population cap at 100 sexually mature females. The number of years at which female population size reaches 30 = 15 years; 40 = 20 years; 50 =. 24 years. Median is continuous line and 95% CI are dashed lines.

4 CHOOSING A SEASON OF CAPTURE AND METHOD OF RELEASE TO MAXIMIZE SURVIVAL, SITE FIDELITY, AND REPRODUCTION

Capture season, release method, and timing of release may all significantly influence the success of a translocation effort for wolverines (Table 1). Different options are available and decisions must be made based upon the specifics of wolverine biology. As a wolverine reintroduction has never been previously conducted, we do not have prior knowledge on the most effective means to ensure success. Paramount objectives include maximizing survival, site fidelity, and, if possible, reproduction at the release site. Of course, minimizing time in captivity, logistical difficulties, and expenses are also necessary considerations.

Wolverines are delayed implanters that typically breed May–July; nidation occurs mainly during late December through January and gestation then lasts approximately 45 days such that the peak of birthing occurs 1 February-15 March (Inman et al. 2012b). Parturition can occur before and after this time but January and April births appear to be uncommon. While the vast majority of adult females are pregnant in a given year, <50% typically retain a litter through the end of May, thus resorbtion, early litter loss, or juvenile mortality occurs frequently in the wild (Rausch and Pearson 1972, Banci and Harestad 1988, Copeland 1996, Persson et al. 2006, Inman et al. 2007b). Given this naturally occurring situation, we expect some litter loss is unavoidable, although we obviously want to try to minimize losses if pregnant females are translocated.

We describe and compare in detail below two potential timeframes for capturing wolverines that appear most likely to minimize the potential for adverse effects on reproduction and recruitment in both source and reintroduced wolverine populations. The first capture option is during "spring" (April–mid-May) and would focus on males and non-lactating females who would not be pregnant. Lactating females captured in the spring would be immediately re-released. However, determination of lactation is not feasible without anesthesia, which may preclude the use of this capture timeframe (discussed further below). The second capture option is "early winter" (October–December) after young wolverines are likely to be sufficiently independent from a nutritional standpoint and most females would likely be pregnant, immanent, or with recently implanted blastocysts.

The two potential capture timeframes are conducive to different release strategies. One release strategy is to hold animals in a suitable pen in native habitat at the release site and after a period of captivity in the pen, releasing the animal (a traditional 'soft release' strategy). A second release strategy consists of opening a transport crate to release wolverines into the wild at a remote site (a 'hard release'). Finally, a third strategy would be a transport-crate-release into a naturally secure

Table 1. Factors potentially improving survival, site fidelity, and reproduction at wolverine release sites.

Survival
Sourced from area with similar habitat/prey/mortality sources as release site.
Good body condition.
Season of release when food availability highest (spring/summer).
Provisioning of food (especially with winter release).
Providing a secure release 'den' with known food source.
High quality habitat at release site (e.g., low road density, high prey density)
Site Fidelity
Presence of litter.
Less time between release and birth of litter.
Increased time in captivity at release site (including soft release).
Season of release when food availability highest (spring/summer).
Provisioning of food (especially with winter release).
Providing a secure release 'den' with known food source.
Presence of opposite sex (real or perceived via distribution of scats).
Reproduction
More middle age-class females in the release (4-12 yrs).
Provisioning of food (especially with winter release).
Absence of unrelated males.

and somewhat enclosed location that has been prepared with carcasses for food (e.g., boulders covered in snow wherein a wolverine is released into a tunnel leading to food and then filling the tunnel entrance with snow); we refer to this as a 'provisioned release.' Placing the edible portions of ~two ungulate carcasses at a release site should provide a known and significant food source. Further provisioning (i.e., placing 3-4 more carcasses in the general vicinity) may help site fidelity and wolverine fitness. If the wolverines depart their release area, dropping carcasses (via fixed wing aircraft or helicopter) near their location should be considered.

All of these techniques would be preceded by a period of captivity at a holding/transfer facility where various tasks such as equipping individuals with radio-monitoring equipment, veterinary exams and treatments, etc. would occur. Time held at the holding facility would be determined by veterinary health assessments and logistics associated with the chosen release strategy. Note, that the longer animals are held at such a facility, the less the release mimics a hard release (which traditionally would include only a few hours in captivity).

We suggest that the following 4 capture/release options are likely most suitable and vary by capture season, birth location, and release type/dates (see Figure 3):

1. Spring captures, no pregnancies

A) hard or provisioned release during Apr–Jun.

2. Winter captures, some pregnancies

B) hard or provisioned release during Nov–Jan, wild births.

C) births in remote soft release pen, open pen doors during Mar–Apr.

D) births at captive/transfer facility, provisioned release during May.

Below we present the pros and cons of each capture time frame/release option (see summary in Table 2).

4.1 Spring Captures Option

Non-lactating females and males would be candidates for translocation during spring capture. At this time of the year, non-lactating females' young from the previous year would likely be independent and daughters, if present, would likely to take over their mother's home range replacing the adult female in the source population (Aronsson 2009). Females also likely would not be pregnant for the upcoming season because breeding would not yet have occurred in most instances. Based on the vast majority of wolverine births having occurred by March 15 and 10 weeks to weaning (Inman et al. 2012b), it should be evident upon anesthetized examination from mid-March to mid-April whether a female is lactating and has new young or not. However, this would not be possible to assess in the field using box traps unless anesthesia occurs on site. By mid-April, lactation may not be obvious in the case of earlier births (e.g., Feb 1), so the risk of misidentifying a female with weaned but dependent offspring becomes greater even with anesthesia.

There are several potential drawbacks of the spring option (summarized in Table 1). There is only a one-month time frame during which captures are possible due to the need to positively identify lactation. A soft-release strategy, which may be more desirable because it could result in greater site fidelity, cannot be implemented during this timeframe because wolverines would be moved later in the year and emerging bears will be attracted to the ungulate carcasses used at the soft-release pens. Another drawback of the spring option is that females would not be pregnant upon arrival. If it is difficult for the released males and females to quickly find each other and breed within the approximately 3 months remaining in the mating season, litters may not be born at the release site for nearly 2 years post-translocation. Because all individuals have a survival rate <1.0, the increased time between release and reproduction means there is a greater chance that females would succumb to mortality prior to reproducing. Even if the females survive, the eventual time to population establishment would be delayed due to the loss of up to 2 cohorts due to reproductive inactivity (see below).

The pros of the spring option include higher levels of natural food being available (spring and summer). Although soft release might be preferable for fidelity, the hard or provisioned release necessary with the spring option could result in better site fidelity than a hard or provisioned release during winter because food resources would be more plentiful during spring/summer. On the other hand, winter captures could also use a hard or provisioned release during spring when food becomes more plentiful, it would simply require more time in captivity or longer times for provisioning near release sites. The necessary hard or provisioned release associated with spring captures eliminates the need to construct, visit, or maintain soft-release pens in remote areas thereby reducing logistical problems and expenses. By translocating non-pregnant females, the spring capture option also eliminates the potential difficulty of dealing with pregnant or parturient females at captive or release sites and any potential for litter loss. Finally, the spring capture scenario would avoid the issue of potential infanticide by males (Persson et al. 2003).

4.2 Winter Captures Options

Females captured during October/November/December are likely to be pregnant but implantation may not yet have occurred. Implantation can, and has, occurred during December. Hormone (progesterone) assays are unreliable for determining pregnancy status (Mead et al. 1993), and

Table 2. List of pros and cons for spring vs. winter capture/release strategies for translocating wolverines.

Spring Capture		Winter Capture	
Pros	Cons	Pros	Cons
• Survival and site fidelity could be improved because natural food availability is higher	• Some risk of females having dependent young at source site.	• Survival and site fidelity of reproductive females could be improved with offspring present leading to less movement and road crossings	• Natural food availability lower in winter without provisioning
• Females not pregnant so litter loss not an issue	• Could require vet at trap site to anesthetize and determine lactation status	• Soft release possible and could further improve site fidelity (although very difficult)	• Soft release logistically difficult, expensive, and impractical
• Hard or provisioned release may provide better logistics and reduce costs	• Potentially lower site fidelity and therefore survival because no wolverine litters present.	• Potential for more immediate reproduction	• Potential for longer male captivity and for releasing males near unrelated young (unless males released following year).
	• Reproduction could be 2 yrs post release	• Potential for additional genetic diversity for founding population via paternity of offspring	
	• Slightly reduced odds of adult female survival to first reproduction after release	• Hard or provisioned release may provide better logistics and reduce costs	

ultrasounds this early would also be inconclusive. Young of the previous year would have been weaned 4–6 months previously and are generally independent. The winter option could accommodate any of the potential release strategies – hard, provisioned, or soft, and releases could occur during various months.

The winter option has several benefits. Although there is lower natural food availability for 2-3 months after transfer to the release sites during winter, this obstacle could be overcome with either a longer period at the transfer facility or by providing food until natural food becomes more plentiful (e.g., marmots emerge from hibernation). Soft release is possible under this option because the earlier capture period allows enough time at the soft release pen prior to bear emergence from hibernation.

The winter option may improve both survival and site fidelity if females have newborn young present as has been shown to be the case with black bears (Eastridge and Clark 2001). This option may also improve the odds of eventual population establishment, and careful consideration of this impact should be made. The population is at its most critical stage soon after reintroduction - numbers are at their lowest point, so the population is vulnerable due simply to demographic variation. In simulations based on the survival and reproductive rates used above, a population beginning with 11 adults and 3 offspring goes extinct 6% of the time over 50 years. Extinction rate goes up to 10% with no offspring present during the first year. If reproduction doesn't take place for 2 years, extinction rate rises to 25%. These simulations suggest that probability of success can vary greatly depending on how soon reproduction occurs and that presence of offspring can increase the odds of establishing a population.

Potentially reduced movements due to the presence of a litter should increase site fidelity, thereby resulting in females remaining within higher elevation wolverine habitat on public lands, crossing roads less frequently, and spending less time at lower elevations where human activities are more prevalent. Adequately provisioning the area with carcasses could further encourage site fidelity and higher survival rates. Site fidelity might also be improved with more time in the reintroduction area prior to release into the wild (at soft release pens as in 2C or at the transfer facility as in 2D). Reproduction during the year of release reduces the potential for females to succumb to mortality prior to reproducing (reproduction may occur 2 years earlier than under spring option). Earlier reproduction also reduces the time necessary to occupy available habitats. Finally, reproduction could also provide additional genetic diversity as the paternity of young would likely be different than the males that are translocated.

There are also drawbacks to the winter option. While hard release could be used, it would either occur during a period of lower natural food availability or require a longer captive period at the transfer facility. The provisioned release (tunnel provisioned with food) would improve this situation to a degree, but would still either occur during low natural food or require a longer captive period. Provisioning the general release site with carcasses could also help remedy the seasonal food issue (and presence of offspring might help use of provisioned resources). Another potential drawback is that parturition could occur at the transfer facility, especially if there are early births. Young born in captivity present another management conundrum. Some females recently removed from the wild have given birth and raised litters in captivity even in the presence of a number of wolverines in close proximity. However, whether wild females would regularly tend litters successfully under captive conditions is unknown. On one hand, litter loss in the wild is thought to result primarily from lack of food availability (Persson 2005) and to some degree predation by other unrelated wolverines (Persson et al. 2003). On the other hand, litter loss also occurs in captivity with plenty of food, so stress and individuality may play a role. If females tolerated captivity another option could be considered – let them raise litters in captivity and release the entire family during May when the natural food supply is good and holding the animals at the new site to hopefully reduce homing and increase site fidelity.

4.3 Hard- or Provisioned-release

After acclimation and conditioning at holding facility, females would be transported to the remote release site in appropriate crates and released. These releases would occur Oct-Jan under the winter captures option (pregnant females) and April-May under the spring captures option (non-pregnant females; Fig. 1). We suggest minimizing the amount of time at the holding facility until veterinary clearance has been granted or if logistics to release multiple animals together dictate other needs (e.g., females with offspring).

Preparing provisioned release sites should begin well before the animal is released. We suggest that a boulder site or downed trees that will be naturally covered with snow well into the spring/early summer should be selected and marked and a tunnel dug down through the snow into the boulders where the food carcasses should be placed. More snow will accumulate, so the carcasses and tunnel should be marked and the tunnels extended to the carcasses just before release. The idea is to provide a deep, well protected tunnel in which the wolverine will feel secure and find a substantial food source. Wolverines will likely abandon a site with a short entrance almost immediately. We also suggest placing remote cameras at the provisioned release site to document how long the individuals stay at the site and if they return to utilize the provisioned food. Areas frequented by wolverines over time could be further provisioned by drops from fixed wing aircraft, helicopter, or snowmobile. Location of carcass drops should be recorded in UTM coordinates to compare with satellite data. Food provisioning at the release site could be continued for 3–4 months, if feasible, or until the released animals no longer use the site. Location and timing of provisioning should be modified as needed. Marmot emergence coincides with this release time frame, thus providing an additional food source.

4.4 Soft Release

For soft releases, females captured in early winter (Oct-Dec) should be transported to the soft release site holding structure by mid-January. The vast majority of births will not occur until at least February, permitting up to a month during which wolverines can be equipped with telemetry collars or implants, etc. at the transfer facility. Winter food availability is a limiting factor for wolverine reproduction, and supplemental feeding increases the reproductive potential of the females and cub survival (Persson 2005). Soft-release pens, which would be closed and occupied by the female during February and March, should contain frozen ungulate carcasses and have secure structure (rocks or downed logs) covered with deep snow under which the female and young can reside. Soft release (i.e., gates opened) should occur during April or May and provisioning at these sites should continue through June or until animals no longer use the site. There is the potential to attract bears with this technique; however, with adequate rock structure, the wolverines should be able to cache foods in locations inaccessible to bears (i.e., too small for bears to enter and too heavy for bears to move). On this schedule, a pregnant female captured in November or December would be released after ~4-5 months in captivity. If this release occurs into an area where animals were released in earlier years, the current location of previously released wolverines, including males unrelated to the cubs, should be taken into account when considering the release location of a pregnant female. Individual animals that are clearly stressed (e.g., pacing, efforts to escape), should be released early.

Soft release pens constructed on-site require dimensions of approximately 7' high x 8' wide x 16' long (2.5 m x 2.5 m x 6 m). Wolverines have been held in similar-sized enclosures for months in captivity, however the larger pens are the better. The walls and floor of the pens should be constructed of 9-gauge chain link fencing. Snow will pad the chain link floor. Firmly secured climbing platforms, climbing logs and water dishes should be available in each pen. Liquid water should be made available when feasible; however, wolverines commonly consume snow and ice chunks for their water needs. Ice chunks should be small enough that they can be crushed easily. Again, habituation due to human contact at the pens (visual, auditory, and olfactory) should be minimized. Contact with domestic animals (especially felids and canids) should be eliminated.

After considering the needs associated with maintenance of soft-release pens, we believe that a soft release would prove extremely challenging and highly impractical. Because a floor would be necessary, securing enough boulders or downed trees in a pen of adequate size would be difficult. If pens are constructed during summer, the whole pen could be below the snow level while the wolverines occupy the pen. This situation would require near constant attention with new snowfall or drifting snow inundating the pen, and if so, a chain link roof will not be adequate. If there is no roof on the pen, keeping the wolverine inside with snow accumulating in the pen becomes a logistical challenge. The best one could hope for is a pen built completely of chain link and let snow accumulate over it with a "tunnel" constructed of culvert material through which you add food. However, water (snow) for liquid will be a problem since the inside of the pen will become icy and feces will accumulate; the only other option is to keep shoveling off the snow from the chain link roof, clean the pen frequently, and add fresh snow and food. There are other problems which include keeping adequate water and disposing of feces. We conclude that the costs of soft release outweigh the potential benefits and that this option is not a viable alternative at this point.

4.5 Sex and Age-class Considerations

Male release – We do not know whether the presence/absence of the opposite sex will affect initial site fidelity, therefore we lack information for deciding whether to release males or females first. However, it is widely assumed that in many if not most carnivores, females cue in most strongly on habitat quality, while males cue in on the presence of females. If the presence of other wolverines increases fidelity, scats from captive wolverines could be distributed at the release sites to mimic the presence of other animals. However, this technique would require careful consideration of disease potential and examination of whether it is having the desired affect rather than the opposite.

Because same-year reproductions may occur and are valuable for improving the chances of success and genetic diversity, careful consideration of how to release males, if at all, is warranted. Infanticide by non-related males can occur (Persson et al. 2003), and other carnivore reintroductions have found success without moving males by allowing male offspring born at the release site to function as the male portion of the population. However, because offspring birth and survival are not guaranteed and the number of pregnant females would be relatively limited even under a 'high-volume' release strategy, male release may be required. In addition, it could take 2-3 years for male offspring born at the release site to become sexually mature. To the extent possible, males should only be released in proximity to females that are not pregnant and without a litter unless captured at the same trap site as the male in the source area (suggesting their territories overlap and that any offspring belong to the male). Another option for male release would be to move pregnant females, allow offspring to mature, and release males at a later date (such as year 3). Capturing, housing, and releasing groups of related or socially familiar individuals (overlapping adult males and females and their young) could potentially enhance site fidelity. In the case of offspring, this would come at the cost of genetic diversity.

Use of young, dispersing-aged animals only – Use of dispersing-aged wolverines has both potential pros and cons. Removal of these animals from the source population would mimic the natural process to a greater degree and would likely result in less impact to the populations there (although we note that this is unlikely to be a long-term issue in any case). The instances of pregnancy and any complications thereof would be reduced. Using this age-class might help address public support issues if litter loss occurs at captive facilities or through infanticide. On the other hand, the effects of using young wolverines on site fidelity at the reintroduction area are completely unknown. This age class appears to be naturally inclined to make large movements, suggesting the potential for lower site fidelity. However if relocated to an unoccupied area (territory) with sufficient food, this age-class may find their most immediate needs met and be less inclined to 'home' back to their capture site. Use of this age-class would obviously reduce immediate reproduction, increase time to habitat saturation, and increase the risk of stochastic failure.

4.6 Summary of Capture Season and Method of Release

We considered the specifics of wolverine biology and their implications for survival, site fidelity, and reproduction in order to judge which season of capture and method of release is most likely to be successful. Consensus formed around option 2B, winter captures (Oct–Dec) followed by provisioned release (release into natural snow-covered chambers where food has been placed) after a short stay at the captive transfer facility. The option of retaining females at the captive facility until just before parturition (Feb 1 or later if ultrasound or other info is available) could potentially be used to increase site fidelity. Because same-year reproduction may occur and would prove valuable for improving the chances of success and genetic diversity, careful consideration of how to release males, if at all, is warranted. Infanticide by non-related males can occur and could be elevated in a translocation situation. Other carnivore reintroductions have had success without moving males by allowing male offspring born at the release site to function as the male portion of the population. However, because offspring birth and survival are not guaranteed, male release may be required. To the extent possible, males should only be released in proximity to females that are not pregnant and without a litter unless captured at the same trap site as the male in the source area.

5 WOLVERINE CAPTURE AT THE SOURCE AREAS

5.1 Capture Techniques

In most cases, the cooperating agency at the source sites would lead the capture effort. At the discretion of cooperating agencies, private trappers could also be involved. Protocols specific to provincial or state requirements should be followed and standardized to the extent possible.

Helicopter darting is used most often in Scandinavia (Persson et al. 2006, Arnemo et al. 2012). Both stationary (Copeland et al. 1995) and portable wooden box traps (Lofroth et al. 2008) have been used to successfully capture wolverines (Copeland et al. 2007, Krebs et al. 2007, Squires et al. 2007, Royal et al. 2011, Inman et al. 2012a). Care should be taken to ensure trap lids are heavy enough to prevent wolverines from pushing the lid up and attempting to squeeze through, or fitted with an adequate latch system; this can be fatal for wolverines. Traps should also have adequate drainage and ventilation such that condensation does not occur, as it can lead to hypothermia. Use of trap transmitters greatly improves logistics, and specialized trap transmitter devices improve the certainty with which the trap door is known to be open or closed (e.g., TBT-500, Mesa, AZ). Use of pre-baits and remote cameras where photos of wolverines are obtained prior to opening the trap or bringing in a portable trap can make field logistics much more efficient and thus less expensive. Research efforts on wolverines have not employed leg hold traps for capture because the above methods are considered less likely to result in injury.

5.2 Wolverine Handling

Professional immobilization of wildlife includes a thorough pre-immobilization assessment of health and stress. This assessment can prevent accidental death due to an identifiable pre-existing condition that renders the animal incapable of handling additional stress from immobilization. For example, immobilization can be risky for very old, sick, or injured animals. Or, if the animal is wet, hypothermia could occur and greatly complicate the immobilization and safety of the animal. Appendix 1 provides a wolverine immobilization form that leads those conducting the immobilization through the assessment process each time. Growling and moving about the trap is normal and expected.

Throughout the process, from first veterinary inspection to final release, it will be necessary to anesthetize individual animals several times. The intent of the process described below is to minimize the number of times that sedation/immobilization would need to occur and to maximize safety of the individuals. We recommend use of a variable-powered CO_2 pistol (CO_2 PI, Dan-Inject, Austin, TX) as a quick and effective delivery of an immobilization dart in a box-trap. Syringe poles can also be effective, but generally require more time to deliver the injection successfully and thus place more stress on the wolverine. Wolverines often react/move when the syringe pole nears them, leading to less effective injection placement. On occasion, wolverines can remove the syringe from the end of the syringe pole, requiring reloading, more time, and stress to the animal. The needle may also break while administering the injection. Using a distracting decoy pole to divert attention of the wolverine may allow more efficient placement of the injection with a syringe pole.

A variety of chemical combinations have been used to immobilize wolverines (Hornocker and Hash 1981, Magoun 1985, Copeland et al. 2007, Krebs et al. 2007, Persson et al. 2009, Inman et al. 2012a). The protocol used should be approved by the attending veterinarian and drug acquisition, handling, holding, and disposition overseen by the veterinarian. The protocol that has been used successfully on the most wolverines is likely that of Arnemo and Fahlman (2007). This protocol is most frequently used with helicopter-based captures. The dose consists of approximately 7.5mg/kg ketamine + 0.25mg/kg medetomidine, and provides a depth of anesthesia that is necessary for surgical implant of intraperitoneal radio-transmitters. Implant surgery can occur in the field or at the holding facility near the release area. Doses vary based on sex/age class of wolverines, level of restraint, and purpose of immobilization. Starting point doses are provided in Appendix 1 based on Arnemo and Fahlman (2007). Atipamezole (for reversal of medetomidine) should be available whenever this drug combination is used.

Oxygen administration during immobilization is recommended at a rate of 0.5 liters/min to compensate for the effect of altitude on partial pressure of arterial oxygen (Fahlman et al. 2008, Inman et al. 2009). This is particularly important at elevations >1,000 m (~3,000 ft).

Tools necessary for safe and professional immobilization include a pulse oximeter. This tool continuously measures both heart rate and SpO_2 (blood oxygen level) and costs <$100. Monitoring SpO_2 is better than counting breaths per minute (bpm) because SpO_2 provides a direct measure of the critical function of respiration – the amount of oxygen in the bloodstream. By 'automating' the taking of heart and respiration rate, the pulse oximeter is also much more convenient than repeated counts timed with a watch. In addition, any sudden problems with heart or respiration rate will likely be noticed much more quickly. However, we note that monitoring equipment, like a pulse oximeter, should not replace an educated, vigilant hands-on observer. Monitoring should include evaluation of pulse rate and rhythm, respiratory rate and pattern, jaw tone, eye position and pupil size, palpebral reflex, capillary refill time, and mucus membrane color.

We also recommend a suitable continuous-read thermometer. Ambient temperatures during winter wolverine captures in the field can often be well below freezing. Care should be taken to have materials on hand to warm the animal if necessary. This is particularly true if an abdominal implant is being surgically inserted (see below, although we note that immobilization and surgery at the capture site are not seen as beneficial within this document). Intraperitoneal VHF radio-devices would likely be surgically implanted at the holding facility, and not in the field, although this procedure has been conducted regularly in field conditions with temperatures well below freezing. If wolverines are immobilized in a field setting, every effort should be made to maintain body temperature. To do so, place the wolverine in dorsal recumbency on a thermal bed and modified sleeping bag with hand warmers on the axillas, groin and lumbar areas. The eyes of the wolverine should be covered after inspection and lubrication. Of course, handlers should be familiar with indicators of critical situations such as shock, dehydration, and cardiac depression, and prepared to remedy these situations with the appropriate drugs/tools that are within their expiration dates. This includes reversal drugs.

5.3 Initial Assessment of Suitability for Translocation and Parasite/Disease Treatment

Assuming that the vast majority of captured wolverines would be accepted for translocation, it may be most efficient to allow the trapper to take the animal immediately to a veterinarian (without conducting any immobilization), which would shorten holding time. This can be accomplished with portable traps (e.g., Lofroth et al. 2008) that can be pulled behind a snowmobile. It is also possible with use of a "squeeze box" on the side of a log box trap. The squeeze box is a smaller transport crate placed against a small (12" x 15" or 31 x 38 cm), pre-made door in the log trap that slides vertically. The wolverine is forced into the smaller box which can be more easily transported to the veterinarian. At the veterinary facility, animals would first be anesthetized to allow an assessment to determine the animal's suitability for translocation. If this is a clinic there needs to be strict guidelines for isolation from other animals to prevent pathogen transmission. If animals are deemed unsuitable for translocation, they can be returned to the capture site.

During the preliminary assessment, weight (males generally 25-35 lbs., females generally 18-25 lbs), sex, and general health would be determined. An attempt would also be made to determine reproductive status and age. Because females can be sexually mature but may not have produced a litter, any non-lactating female would be considered for translocation whether or not her teats indicate she bore a litter in previous years. Criteria for rejection can be further refined, but at a minimum should include individuals that are obviously old or in poor health (e.g., combination of bad/missing teeth, emaciated) or have broken digits or limbs.

Wolverines deemed suitable for translocation would be immediately treated for endoparasites (ivermectin and praziquantel) and ectoparasites (carbaryl). Samples to be collected and archived should include fecal, blood (10 ml serum separator tube), and genetic material (plucked hair with roots placed in a dry storage container). Fecal samples must be collected prior to treatment for endoparasites. Blood should be spun down and serum frozen in plastic vials. Ectoparasites can be assessed by combing through the hair (e.g., 10 strokes across the back with a standardized comb and placement of all combed hair in a plastic bag to be frozen). Vaccination of translocated wolverines may include inactivated rabies (Imrab 3, Fort Dodge) and canine distemper (Purevax, Merial). Alternatively, based on level of care available at source site and importation requirements, these treatments and samplings may be postponed until arrival at the relocation area holding facility. The animal would be placed in a suitable transport crate and taken to the transport site accompanied by personnel who would be responsible for the health of the animal in transit. We recommend minimizing the time animals are held in holding crates.

6 TRANSPORTATION, CAPTIVE CARE, AND INSTRUMENTATION

6.1 Logistical Considerations

The U.S. Fish and Wildlife Service (USFWS) has jurisdiction, not the U.S. Immigration and Customs Enforcement. The USFWS requires a Designated Port Exception 3-201 to allow inspection at any port of entry where wolverines may be flown or trucked into the U.S. from Canada. The import destination must be notified at >48 hrs prior to arrival, >24 hrs before arrival, and with a confirmation of impending arrival at >2 hrs. Each animal/container must have a 3-177 Declaration for Importation or Exportation of Fish or Wildlife. Also required is a veterinary inspection at point of export for animal health requirements and to confirm compliance with importing agency requirements (toes, teeth, limbs, age, sex, etc.). An international health certificate is required for importation of animals into the U.S.; a certificate of veterinary inspection prepared by an accredited veterinarian is required for interstate movement of animals within the U.S.

Airlines (Alaska Airlines, Air Canada, United, Air North, Northwest) must have a live-animal cargo hold, and a charge account must be established along with space reserved before each shipment. The exporter (State or Provincial agency or trapper) must confirm loading and departure. Any over-night stay requires the assistance of an animal care facility to take the animal away from airport, secure and care for the animal, and return it to the airport (e.g., Mid Forwarding Inc./Worldwide Animal Travel).

The International Air Transport Association has shipping container requirements for live animals. The aluminum boxes used in the lynx reintroduction project by Colorado Parks and Wildlife were also designed to accommodate wolverines. Wolverines have been shipped in large PVC pipe sections modified for ventilation, drainage, bedding, locking, food and water. Other alternatives are using flat bottomed shipping containers for animal stability. Each container must have a paperwork folder with permits, export permit, declared value, 3 copies of "invoice," shipping labels, and emergency contacts. Written justification must be included that allows these animals to be exposed to temperatures outside of normal airplane cabin temperatures. Containers must be shipped to area of capture (via UPS, Airlines, etc.) in preparation for the capture season.

Personnel must pick up animals at the airport and transport them to a holding/handling area. Purchase orders and personal services agreements must be properly in place. Border brokerage firms (e.g., UPS Supply) must be arranged when animals are trucked in.

6.2 Transportation of Wolverines to Relocation Area Holding Facility

As soon as possible upon capture and veterinary examination, animals accepted for reintroduction should be transported to the nearest airport, along with all required permits and certificates, and flown to the major airport nearest to the selected release area holding facility. Immediately prior to departure, and on arrival, the wolverines should be inspected by personnel trained to evaluate the condition of the animal. On arrival, wolverines should be immediately transported from the airport to a suitable holding/transfer facility. A potential alternative for transport may be the use of private aircraft and pilots, facilitating use of smaller airports at the source sites and also closer to the release area holding facility. The general condition of the wolverines, such as hydration and stress level during ground and after air transportation, should be monitored. Signs that animals are experiencing unexpectedly high stress during transportation should compel review of protocol and may lead to modifications of transport crates, sedation methods, or other aspects that could help reduce transport stress. Sedation could be used if necessary during initial instances should they occur.

A somewhat spacious transport box is believed to be less stressful. As an example, boxes could be constructed of aluminum with minimum dimensions of 24” x 24” x 36” (61 cm x 61 cm x 92 cm). We recommend 3/16” (5 mm) wall thickness and 1/4" (7 mm) thickness for sliding door. Transport boxes should be vented on at least 3 sides with ventilation holes not to exceed ½" (13 mm) diameter to prevent animals from getting their feet or mouth through the hole to minimize injury. A water tray, or a bottle similar to that used in rabbit cages (but obviously more durable), must be provided. A double floor for commercial transport includes a solid bottom floor to prevent leakage and an elevated second floor to allow separation of fluids from the animal. Clean dry bedding (straw, recycled paper, hardwood shavings) must be provided. Animals should be transported in a cool transport vehicle with good ventilation. These cages are designed to attach to another transport cage, squeeze cage, or nest barrel/box via brackets to make a larger cage if necessary (e.g., for changing bedding).

6.3 Care of Captive Wolverines at the Reintroduction Area Holding Facility

Personnel at the holding facility would be responsible for monitoring captive wolverines for stress and health problems, and fulfilling all other animal care requirements. A veterinarian should be on call while wolverines are in the holding facility in case of emergency. While at this facility, wolverines should be fed a variety of items *ad libitum* that will likely comprise their main food in the release area. During winter, captive male wolverines with food available on a daily basis consumed an average of 33 oz (~1 kg) of food (C. Long, unpublished data). The range of male food consumption was 20–57 oz (~0.5–1.5 kg). Females consumed slightly less, averaging 21 oz (~0.5 kg) and ranging from 14–34 oz (~0.3–1 kg). Holding facility pens should be approximately 7’ H x 8’ W x 16’ L (2.5 m x 2.5 m x 6 m; other configurations might be equally satisfactory), and capable of being connected to provide more space for individual animals. The walls and roof of the pens should be constructed of 9-gauge chain link fencing with 1” mesh. The roof should be solid and the floor concrete. Covering the floor with straw of woodchips is not recommended unless there is an unusual case of foot abrasion. Keeping the floor clean of feces, urine, and food, etc., becomes more difficult with straw or chips, and once it becomes wet, it can become a frozen mass of all of the above. Firmly secured climbing platforms, climbing logs and water dishes should be available in each pen and a nest box should be provided. Wolverines should be held solitary in individual pens. Those slated to be released to the same area should be held in adjacent pens at the holding facility but physically separated, i.e., unable to contact each other. Habituation to human contact at the pens (visual, auditory and olfactory) should be minimized. Contact with domestic animals (especially felids and canids) should be prevented.

Time at the holding facility should be minimized. Tasks that must occur at the holding facility include equipping each individual with telemetry equipment, conditioning the animals for release, and monitoring health. All individuals should be examined and observed for a sufficient period to ensure they have no injuries that might impair their ability to function normally in typical habitat. All individuals should be eating and drinking by release time, preferably feeding on ungulate carcasses as these would be distributed across the landscape.

6.4 Instrumentation and Marking

We recommend immobilizing wolverines within 5 days after arrival at the holding facility for examination by a veterinarian for health and disease issues and to fit and implant collars and transmitters. In the case of animals with severe injuries or health issues that are likely to result in long-term pain or suffering or inability to hunt and survive after release, we recommend considering euthanasia. Any necessary biological sample collection or treatment not administered at the capture location would be completed at this time. The recommendations for monitoring transmitters below are based on contemporary equipment and experience. Of course as improved technology becomes available, it should be used.

The primary data needed to assess reintroduction success and make any adaptations necessary are frequent (daily, if possible) checks of status (alive/mortality) and general location. In North America, Argos Satellite collars appear to be the best method available at present to efficiently record these data for wolverines. This is because sufficient location and regular mortality information may be remotely obtained. VHF implant transmitters require aerial searches which would be difficult and inefficient given the frequent inclement weather in the mountainous terrain where wolverines live and the ability of wolverines to quickly move long distances. GPS collars of suitable size for wolverines, at present, are unable to provide regular mortality signals or sufficient duration of monitoring needed for translocation efforts. The Argos transmitter would be the primary means for monitoring individuals during the first year post-release when mortality and large movements would be most likely. A VHF implant is necessary as a backup because wolverines can slip collars over their heads. Implants would allow the wolverines to be monitored over a multi-year period.

The lightest collar available (<200g) should be used to maximize comfort for the wolverines and lessen the chance that they would remove it. Currently, the Sirtrack KS303 equipped with an activity sensor (which can help indicate mortality) and modified for wolverines is considered to be the best performing and most reliable. These collars can be programmed to collect locations for a 12+ month period and should be equipped with a drop-off device timed to release within 6 months after the anticipated end of collar battery life.

A sterile (e.g., autoclaved and placed in a sealed package) intraperitoneal VHF radio-transmitter should also be surgically implanted into each wolverine by a veterinarian using aseptic technique (Arnemo and Fahlman 2007). Hair removal at the surgical site should be large enough to insert the radio-transmitter, prevent inadvertent contamination of the sterile surgical field during the procedure, but hair clipping kept conservative for an animal that will later be exposed to cold weather conditions. We recommend use of ATS M1250B implants for females (battery life of 2-3 years) and M1255B for males (battery life of 5-7 years). Implants made of a smooth and hard acrylic exterior are less conducive to abdominal tissues "attaching" to the surface (vs. implants with a wax exterior).

The following procedure has been used successfully in the field to radio-implant wolverines. With the patient in dorsal recumbency, make a ventral midline skin incision ~1cm caudal from the umbilicus. Tent the abdominal wall and make a sharp incision into the linea alba with a scalpel blade. Using scissors extend the incision cranially and caudally just large enough to insert one end of the sterile transmitter (approximately 2 inches). Insert the transmitter into the peritoneal cavity loosely. Closure of the abdominal wall must be secure therefore absorbable suture material with interrupted patterns are required. Closure of the subcuticular layer also requires absorbable suture material. Skin closure is done with tissue adhesive (n-butyl cyanoacrylate) rather than skin suture to avoid self-trauma to the surgical site post-operatively. Post-operative care includes reversal of anesthetic agent, direct observation of recovery, and ensuring safe delivery to secure, clean, warm and dry environment. Noise should be kept to a minimum. Secure crates and transport crates must be properly disinfected between patients.

It is important to consider during the time of surgery that the incision leads to significant heat loss, and the animal may need to be warmed to keep body temperature at a suitable level. This is particularly true of surgeries conducted in field settings. Commonly used tools to warm wolverines include modified sleeping bags, hot water bottles filled with water brought to the site in a thermos, chemically-activated hand warmers, etc. VHF intraperitoneal implants should also be kept warm prior to insertion. If an implant at ambient outdoor temperature is placed in the abdomen, it can lower body temperature significantly. Perioperative antibiotics and pain relief would be administered as prescribed by the attending veterinarian.

Both the Argos collar and VHF implant should be activated and tested immediately prior to fitting, thereby eliminating the need for an additional sedation to initiate or test the functioning of the transmitters before release. Putting the collar on at the holding facility will insure that it fits properly and will remain on the wolverine without causing any physical problems. Effective monitoring requires that we strive to minimize the probability that the animal can slip its collar after release. A PIT tag should be placed subcutaneously between the shoulder blades. Wolverines can often be distinguished by distinct white markings on the head body, chest, and feet (Magoun et al. 2011a, Magoun et al. 2011b), so photographs of these markings should be taken and archived while wolverines are anesthetized. Photos taken at the captive facility while the wolverines are in natural stances may also prove valuable as they could better resemble photos made after release. The animal's weight and body condition would be measured, and, if not collected previously, blood samples would be collected for genetics and archiving.

7 SITE SELECTION FOR RELEASE LOCATIONS

The main causes of wolverine decline by the early 1900s in the contiguous U.S. are thought to have been intentional human-caused mortality - the widespread use of poison baits for predators and unregulated trapping and killing (Aubry et al. 2007). These factors were greatly reduced or eliminated over most or all of the wolverines historical range in the contiguous U.S. and wolverine populations seem to have recovered significantly thereafter in the northern tier of states where suitable habitat is relatively contiguous with larger populations in Canada (Newby and Wright 1955, Newby and McDougal 1964, Aubry et al. 2007). Therefore the previous causes of decline are not likely to impact reintroduction efforts within the areas of historical range that have not yet been reoccupied by wolverine populations.

Food is obviously a major factor in habitat suitability for wolverines. The species is a relative generalist in terms of prey. Wolverines scavenge ungulate remains regularly but also use a wide range of foods opportunistically. Foods include caribou/reindeer, moose, mountain goat, bighorn sheep, elk, beaver, marmots, ground squirrels, voles, lemmings, hares, porcupine, birds, bird eggs, insect larva, amphibians, and berries (Magoun 1987, Copeland and Whitman 2003, Lofroth et al. 2007, Packila et al. 2007, van Dijk et al. 2008, Dalerum et al. 2009, Mattisson et al. 2011b). Ungulate carrion, neonatal ungulates, and small prey may all be important for successful wolverine reproduction (Inman et al. 2012b). Some combination of these food resources must be present. Interestingly, wolverines appear to be adapted to take advantage of areas where overall food resources are sparse (Inman et al. 2012a), therefore the abundance of competitors and potential mortality sources (larger carnivores) could play a role in habitat suitability.

Wolverines do not appear to be habitat specialists, other than their need for cold, snow covered areas that are fundamental to their niche (Copeland et al. 2010, Inman et al. 2012a, Inman et al. 2012b). Steep, rocky terrain is also a common feature of wolverine habitat within the contiguous U.S. (Hornocker and Hash 1981, Copeland et al. 2007, Inman 2013). Den sites are located on north slopes, under snow and boulders or avalanche debris (Magoun and Copeland 1998, Inman et al. 2007b). Given that these general characteristics are prevalent within the areas of historical distribution that wolverines have not reoccupied (Inman 2013), perhaps the most important characteristic is simply the presence of large areas of cold, rocky habitat where deep snow cover exists during winter. These large areas of habitat are a necessity because of the large territorial requirements of individual wolverines and the resulting low densities. Of course, the larger these general areas of habitat, the more potential for wolverine capacity, as long as there are adequate food resources within. An estimate of potential population capacity along with the relative abundance of higher quality "maternal" habitats (areas used by females with young) is available for the contiguous U.S. and can help prioritize potential release sites (see Inman 2013 Paper III, Table S3). Suitability assessments for mustelids can also provide important information (Lewis and Hayes 2004, Callas and Figura 2008, Garcelon et al. 2009).

8 POST-RELEASE MONITORING

The primary function of a post-release monitoring program is to assess and modify reintroduction protocols if necessary to ensure the highest probability of survival and site fidelity for released individuals. The next step in determining the long-term success of the reintroduction consists of monitoring wolverines for a multi-year period to estimate population trajectory and/or habitat occupancy. Long-term, monitoring of translocated wolverines to estimate survival, site fidelity, reproduction, recruitment, and/or habitat occupancy is critical to inform future reintroduction efforts by understanding why the project ultimately succeeded or failed. Monitoring of released wolverines can occur through radio and satellite telemetry and also non-invasive techniques (cameras, snow tracking, hair snares, etc.). Unique pelage patterns allow individual identification of photographed wolverines and hair snares can also provide genetic samples sufficient for individual identification (Magoun et al. 2011a, Magoun et al. 2011b). We provide recommendations here based on current technology. Of course technological innovations occur rapidly and can result in great improvements and the best available tools and technology at the time of release should be used.

8.1 Monitoring Survival to Adapt Release Protocols If Needed

To assess initial survival and specific mortality factors, reintroduced wolverines should be monitored using a combination of satellite and VHF telemetry. Satellite collars would be the primary short-term means of determining if the wolverines are still alive. Satellite collars suitable for wolverines are capable of sending a location and alive/mortality signal on a daily basis for at least several months (~6-12+). VHF implants/collars are not as reliable for these important initial data because they require flights in small fixed-wing aircraft, and there will be many days where weather conditions in high alpine environments, especially during winter, will not permit flights. Also, VHF ground tracking of wolverines is extremely difficult and typically unproductive in mountainous habitats because of the large movements wolverines make thorough extremely rugged terrain. VHF implants are also needed though. This is because satellite collars can be "slipped" over the head and lost which would result in loss of contact with the wolverine and no information on its survival and site fidelity. In addition, battery life of satellite collars limit their use to a relatively short-term, and while this is the most critical period for monitoring, longer-term information is also needed and could be obtained with a VHF implant. Implants can transmit for up to 7 years. While data will be less abundant due to limitations on flights, contact can be maintained over a multi-year period. If satellite transmitters fail, flights to obtain VHF locations should be conducted as often as budgets and weather conditions allow.

It is very important that all mortality signals be investigated on the ground as soon as possible to determine cause of death. This is because determining cause of mortality, especially during the early stages of release, is critical to permit modification of release procedures if needed. Carcasses should be retrieved using safe work practices and personal protective equipment. Documentation and evidence collection (with appropriate maintenance of chain of custody) should be conducted onsite as necessary. Carcasses should be submitted to a board certified veterinary pathologist for postmortem examination and diagnostic sampling.

If sample sizes are sufficient, multi-state mark-recapture models also should be developed and used to incorporate telemetry data to estimate monthly mortality (Devineau et al. 2010). This approach accommodates missing data and allows for exploration of factors possibly affecting wolverines survival. Many factors could influence survival. Source area, because of similarities or differences in prey and potential mortality sources, should be paid close attention. All factors that might influence wolverine survival should be documented throughout the process so that analyses are as informed as possible. Additional factors of note include capture method, weight at capture, parasite load, injuries (natural or capture related), body condition, pelage condition, foot size, sex, age, genetic factors, pregnancy status, time spent in pre-release captivity, changes in weight/condition during captivity, proximity to other released wolverines, and habitat features within the area of use. Considerable effort should be made prior to initiation of reintroduction to assess all possible factors that may influence survival and incorporate the necessary data collection throughout the effort so that adjustments can be made.

8.2 Monitoring Site Fidelity to Adapt Release Protocols If Needed

Site fidelity is also key to a successful reintroduction. In this case, site fidelity should be defined as “remaining within the broad area where a population is desired” and not strict adherence to the specific drainage or even mountain range where an individual is released into the wild. The tools described above for monitoring survival should also be adequate to monitor site fidelity. Again, satellite collars with frequent (daily) locations would provide sufficient data in the earliest and most critical stage of release, and VHF implants can serve as a backup for the early stages in addition to providing more long-term data. GPS collar data, while potentially more intensive and accurate than satellite or VHF data, do not improve the ability to determine survival or basic site fidelity over the other technologies; in fact, GPS collars for wolverines, at this point in time, require intermittent flights to download data (which would not allow identification of mortality in time to determine cause of death), can be slipped like any collar, and generally provide short-term (although intensive) data.

Similar to the assessment process for factors influencing survival, data relevant to successful site fidelity should be collected at all points though the translocation and assessed for its influence. Potential factors influencing site fidelity include pregnancy status, presence/absence of a litter, time of release prior to or after parturition, date of release, time between release and marmot emergence, amount of food provisioned at the release site, amount of food provisioned at later dates, relative ungulate diversity and density in release/home range area, days between capture and release, days at captive facility in release area, age, body condition, similarity of prey and mortality sources between source and release site, road density, human activity levels, proximity to other released wolverines, presence of opposite sex in release area, and presence of (intentionally placed) scats of same or opposite sex in release area. Other factors should be considered also. Because wolverines are capable of ranging widely and translocations have not been attempted previously, these data on site fidelity (and survival) are critical for learning and adapting to improve success within initial and subsequent attempts.

8.3 Other Important Monitoring Data

Because reintroduction areas are unlikely to have had wolverines in the recent past, knowledge of specific habitat use will be unavailable. Other basic information such as home range size and food habits will also be lacking. As such, these data should be collected to develop a fundamental understanding of whether any locally-specific resources appear critical in the release area or if resources are either more lacking (e.g., larger than expected home ranges) or super-abundant (smaller than expected home ranges). Developing models of local habitat suitability will improve accuracy of expectations for carrying capacity of the reintroduction site. This will in turn be useful for decisions on the amount of time until habitats could be expected to be saturated and whether additional releases are warranted or not. Habitat-use data could also be used to modify and improve criteria for selecting future release locations in the present area or other target areas of similar habitat composition. Annual home ranges will provide information on site fidelity, persistence, and how individuals are distributed in relation to other released individuals. This information could be used to prioritize subsequent release locations in an effort to assist with establishment of mating pairs. Habitat and home range information could likely be obtained without additional effort or expense above the basic monitoring for survival and site fidelity.

Winter diet could be estimated by documenting items found at scavenging or kill sites through snow-tracking and/or scat analysis. Scat samples could be collected wherever found and labeled with location and individual wolverine's identification. Only part of the scat should be collected (approximately 75%); the remainder should be left in place in the event that the scat was being used by the animal as a territory mark. Food habits data might also be used in analyses that examine factors influencing survival and site fidelity. Determining use or lack thereof for provisioned carcasses would provide information to aid in determining how long and where provisioning is effective, and when it should be concluded.

Because very little wolverine research has been conducted relative to many wildlife species, it should be recognized that any radio-marked sample represents an opportunity to significantly improve our understanding of the species in many ways. Beyond the new information to be gained about the specific release site (e.g., habitat use, food habits, territorial size), the opportunity to improve knowledge relevant to other wolverine populations exists.

8.4 Reproduction

Adequate reproduction is also obviously key to long-term success. Several options exist for identifying wolverine reproduction. These include direct spring/summer observations of VHF radioed females, remote detection of young with cameras (Inman et al. 2008, Magoun et al. 2011b), capture of young at den sites (Persson et al. 2006), and, over a longer-term, genetic sampling. The onset of denning of translocated females could be identified with satellite collar data. Collars could be programmed to collect more intensive locations (2-3/day) between Feb 1-Mar 15, the period during which birth would have occurred in nearly all cases (Inman et al. 2012b). Den establishment typically involves repeated locations at the same site each day for a period of at least 2-3 weeks. Females will only stay entirely within the den site (not leaving) for a few days after or surrounding birth. Within a week, she will begin making movements away from the den and returning each day. Litters are often lost during the first couple of months. This could be due to resorbtion, starvation, infanticide or other unknown factors. Use of dens will cease if this occurs. However it must be noted that females can move young to secondary dens sites within a few weeks after giving birth (Magoun and Copeland 1998, Inman et al. 2012b). Any pattern of repeated visits to a site during February, March, and April should be considered a possible den site. By April/May, once snowmelt of significance is occurring at elevations where dens are located, movement among den and rendezvous sites becomes common. At this time, tracks of young in the snow are easily distinguishable from adults by their size, and reproduction can be confirmed. By May/June, young are moving with the female enough that direct observation of radioed females can confirm reproduction. The Swedish wolverine program focuses its capture efforts during May when females and young can be captured at rendezvous sites. This allows replacement of VHF implants in adult females and installation of a VHF radio in young. Young are then known-age, which is difficult if not impossible to determine otherwise, and this knowledge provides advantages for subsequent derived reproductive data used in population modeling (i.e., age at first reproduction, a critical component).

Using cameras to document reproduction can also be productive. Cameras can be placed near a den/rendezvous site and can confirm reproduction (Inman et al. 2008). Cameras can also be used later in the summer or early fall at bait stations designed to attract wolverines (Magoun et al. 2011).

8.5 Recapture of Injured, Starving, or Widely Dispersed Individuals

Reintroduced wolverines that are injured or otherwise seriously compromised may be recaptured or euthanized on a case-by-case basis if necessary. If an animal has dispersed into poor habitat and/or if neighboring states request removal, the animal may be recaptured for re-release back into more suitable habitat. Such animals could be captured with live-traps or darted using appropriate drug combinations as prescribed.

8.6 Assessing the Need for Additional Releases

Each year after the release phase, results should be analyzed and the population status determined to the extent possible given available data. The number of released wolverines staying in suitable habitat, their locations relative to each other and sex ratio should be determined. This information should be used to assess if the reintroduced population of wolverines is likely to persist based on criteria determined by study cooperators. If not, additional wolverines may be needed to augment the population to achieve success. If it is determined that establishing a viable population is not possible, the translocation project would be terminated.

8.7 Population Monitoring to Assess Viability

To assess potential viability of the wolverine's population and monitor progress toward achieving a reintroduction goal, some form of long-term monitoring would be needed to determine whether recruitment exceeds mortality. As radioed animals become unavailable for monitoring due to failed telemetry collars, death, or movement out of release areas, accurately evaluating the status of the entire wolverine population would become more difficult. Replacing collars as they fail and telemetering wild-born wolverines would be a time consuming and expensive operation since large home ranges may be entirely located within wilderness or other largely inaccessible areas. Alternatively, occupancy modeling using non-invasive techniques may be a feasible alternative for ascertaining trends in population status and form the basis for a large-scale area monitoring program. In order to validate the non-invasive methodology, studies should be conducted while radio collars on wolverines are still active. Reintroduction sites may provide an otherwise unavailable opportunity to do so since they will contain a relatively large number of radio-marked wolverines.

Non-invasive methods may include snow-tracking, hair snares, scat samples and camera surveillance. Identification of individuals would allow determination of the presence, distribution, reproduction, social structure and possibly apparent survival rates. Long-term monitoring would allow evaluation of trends in these demographic parameters which in turn would enable evaluation of the status of the population. Such non-invasive techniques are desirable because they are considered to have a minimal impact on animals and may have the potential to be less expensive. Some information on denning and habitat selection may be generated via telemetry data.

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Appendix 1

Wolverine Immobilization Form

Wolverine Normals: Temperature: 100-102˚ F (Stop other & Warm if <96˚ F; Cool if >104˚ F); **Heart Rate**: 90-120 bpm; **Respiration**: 6-20 bpm

Stage I. Assessment Prior To Initial Immobilization Dose **Date ____/____/____ Animal ID _______**

Data Recorder ___________Observers____
Ambient Temp ______ Wind Speed _____ Estimated Weight _______ Estimated Phys Condition: Excellent / Mod / Poor
Estimated Ageclass_____ Estimated Stress Level: High / Moderate / Low **Other Factors?** __________________________
Will we immobilize: Y or N If no, why? ____

IMMOBILIZATION, ANESTHESIA, AND RECOVERY CHEMICALS

Time (24:00)	Dose	Tech.	Route	Drug	Vial #	Concent	Volume	mg	Delivery Success (%)	Inject. Site	Notes

Time (24:00)	Effect	Notes
		Induction Time __________ (Time from initial dart to recumbancy)

IMMOBILIZATION CHEMICAL EFFECTS

Dose		Technique		Route		Effect	
I:	Immobilizing Dose	C:	CO_2 Dart	IM:	Intramuscular	N:	None
SI:	Supplemental Immobilizing Dose	H:	Handsyringe	SC:	Subcutaneous	S:	Sedation (able to move head/legs, eye blink or toe pinch reflex active)
M:	Maintenance Dose	P:	Polesyringe	IV:	Intravascular	SA:	Surgical Anesthesia (No reflexes)
A:	Antagonist Dose					FR:	Fully Recovered (on 4 legs)

Drug: M+K Carnivore Mix is 5 mg/ml medetomidine and 150 mg/ml ketamine
Adult Male or Unknown Dose: 4 mg medetomidine and 120 mg ketamine (0.8 ml M+K Carnivore Mix)
Adult Female Dose: 3 mg medetomidine and 90 mg ketamine (0.6 ml M+K Carnivore Mix)
Offspring dose: 5-7lbs=0.07ml (7 insulin units) M+K, 8-10lbs=0.11ml (11 insulin units) M+K, 11-15lbs=0.2ml (20 insulin units) M+K, (see chart)
Analgesia: 4 mg/kg caprofen (Rimadyl 50mg/ml) or 0.3 mg/kg meloxicam (Metacam 5 mg/ml)
Reversal(typically 30 min after last Ket): 5 mg antipamazole (Antisedan 5mg/ml) per total mg medetomidine. 1 dose male: 4 ml, 1 dose female 3 ml.
Antibiotic: 100,000 IU/Kg Dual-Pen
Not down within 15 minutes: Another full dose.
Maintenance Dose (M): 25-50% of initial dose

Stage II. Initial Hands-on Assessment

Dart or Needle Removed: Y N Wolverine Actual Weight (scale zeroed): ____________ lbs. Head Downhill **(Emesis) Y N**

Time Reading
_______ **SpO_2** ______% (>90%) **Resp Rate** ______bpm (6-60)
Heart Rate ______bpm (90–120)
Temp ______˚ F (100–102)
Capillary Refill 1) Fast (Instant) 2) Normal (1-2 seconds) 3. Slow (>2 seconds)
Jaw Tone 1) Loose 2) Moderate 3) Tight
Stage of Anesthesia 1) Sedation 2) Surgical Anesthesia
Eyes Clear of Debris Y N **Ears** Clear of Debris Y N **Mouth** Clear of Debris Y N
Bleeding/Injury Y N Bleeding/Injury Y N Bleeding/Injury Y N
Opthal. Ointment Y N **Nose** Clear of Debris Y N
Eyes Covered Y N Bleeding/Injury Y N
Hydration Gums and Lips 1) Moist 2) Moderate 3) Dry/Tacky
Skin Reflex 1) Instant 2) 1-2 Seconds 3) >5 Seconds
Is Animal Dehydrated? Severe Moderate Mild Well Hydrated
Rehydration Attempted Y N Describe____

Stage III. Surgical Decision, Vitals & Anesthesia During Surgery

Is Surgery a Go? Y N Intranasal Oxygen Supplied? Y N
______ **Time Incision Opened** ______ **Time Incision Completely Closed**

Wolverine Normals: Temperature: 100-102˚ F (Stop other & Warm if <96˚ F; Cool if >104˚ F); **Heart Rate**: 90-120 bpm; **Respiration**: 6-20 bpm

Time Reading
________ **SpO_2** ______% (>90%) **Resp Rate** ______bpm (6-60)
Heart Rate ______bpm (90–120)
Temp ______˚ F (100–102)
Capillary Refill 1) Fast (Instant) 2) Normal (1-2 seconds) 3. Slow (>2 seconds)
Jaw Tone 1) Loose 2) Moderate 3) Tight
Stage of Anesthesia 1) Sedation 2) Surgical Anesthesia

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Time Reading
________ **SpO_2** ______% (>90%) **Resp Rate** ______bpm (6-60)
Heart Rate ______bpm (90–120)
Temp ______˚ F (100–102)
Capillary Refill 1) Fast (Instant) 2) Normal (1-2 seconds) 3. Slow (>2 seconds)
Jaw Tone 1) Loose 2) Moderate 3) Tight
Stage of Anesthesia 1) Sedation 2) Surgical Anesthesia

Wolverine Normals: Temperature: 100-102˚ F (Stop other & Warm if <96˚ F; Cool if >104˚ F); **Heart Rate**: 90-120 bpm; **Respiration**: 6-20 bpm

	Respiratory Depression	**Cardiac Depression**
Indicators	Respiration < 6 bpm	Heart Rate < 90 bpm
Causes	Heavily Anesthetized	Heavily Anesthetized
Treatment	Stop Administering Drugs Reverse Drugs Administer **Dopram** Assist Respiration if Needed	Stop Administering Drugs Reverse Drugs Administer **Atropine** Chest Compressions if Needed

	Dehydration	**Shock**
Indicators	Dry/Tacky Mucous Membranes Slow Skin Collapse Severe Dehydration => Shock	Rapid Pulse Slow Capillary Refill Rapid, Shallow Respiration Low Temp
Causes	Fluid Loss via: Highly Active Overheating	Exertion/ Dehydration Stress Blood Loss
Treatment	Administer Fluids Sub-Q or IV 1 liter sterile water/100lbs Sub-Q	Stop Administering Drugs Administer Fluids IV at shock rate Stop Bleeding/Treat Injury Assist Respiration if Needed

	Hypothermia	**Hyperthermia**
Indicators	Temp below 97° F	Temp above 104° F
Causes	Extreme Cold Ambient Temp Loss of Body Heat via Surgery Immobilization Drugs	Highly Active High Stress Level Extreme Warm Ambient Temp
Treatment	Wrap in Space Blanket Warm Body/Heat Packs	Cold Water Enema Apply Water to Skin & Fan Cold Packs

	Aspiration	**Seizure**
Indicators	Gurgling Gasping Pale Mucous Membranes	Muscle Rigidity Muscle Twitch/Convulsions
Causes	Vomiting Foreign Material	Reaction to Drug
Treatment	Clear Airway Endotracheal Tube; prophylactic antibiotics	Stand Back Until First Seizure Stops Administer **Valium (Daizapam)**

Appendix 2

Wolverine Handling/Biological Form

WOLVERINE CAPTURE FORM

Sex M F **ID** _____________ **Capture Area**: ____
Trap UTM-E __________ **UTM-N** ___________
Observers____ **Data Recorder**_________________________

RADIO-TRANSMITTER

New Implant
Frequency ______________ Model __________________ Implant Warmed: Y N Working: Y N

New Collar
Frequency ______________ Model __________________
GPS/SAT Initialize: Y N Schedule ________________
VHF Working: Y N Duty Cycle: Y N Time On ___:___ Time Off ___:___
Release Magnet Off: Y N Scheduled Release Date ____________
Neck circumference: _______cm Describe fit and spacer: ____

Previous Radio-Transmitter (Removed at this Capture)
Implant: Frequency ______________ Working: Y N
Collar: Frequency ______________ Working: Y N
Describe Condition of Wolverine, Transmitter & Spacer in Notes

SEXUAL MATURITY

Female:
Teats(circle): Nulliparous or Previously Reproductive **Teat Pictures**: Y N
Swelling: Y N **Hair matting**: Y N **Lactating**: Y N
Uterus: Previously Reproductive Y N
Fetus Palpated: Y N #_____________

Male:
Testes: Descended Y N

BIOLOGICAL SAMPLES

Ectoparasites: Y N **Abundance**: (1)Rare; (2)Light; (3)Heavy **Sample taken**: Y N
Blood samples: (Indicate # Taken): ____ Purple Tops (Invert) ____ Red Tops
Genetic: **2 Hair samples** (plucked for roots): Y N
Fecal Sample: Y N

NOTES

TOOTH & AGE DATA

	Incisors Middle 4	Incisors Outer 2	Canines	PM1	PM2	PM3	PM4	M1	M2
Eruption	U L	U L	U L	U L	U L	U L	U L	U L	L
Wear	U L	U L	U L	U L	U L	U L	U L	U L	L

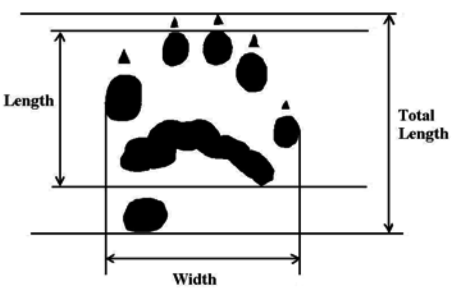
Eruption: (1) not erupted (2) deciduous (3) < ½ erupted (4) > ½ erupted (5) fully erupted
Wear: (1) not flattened (2) slightly flat no dentin showing (3) moderately flat some dentin showing
(4) extremely flat dentin obvious (5) broken (6) missing

TAKE WELL-FOCUSED PHOTOS OF TEETH SHOWING ERUPTION & WEAR

Estimated Birth: March 1, _______ **Estimated Age _____ yrs, _____ mos.** (based on tooth and morphological info)
Estimated Age-Class: JV SA AD
JV = <12 months SA = 13-36 months & no evidence of sexual maturity AD = 37+ months *or* evidence of sexual maturity

MORPHOLOGICAL MEASUREMENTS

Weight (lbs) _____(kg) _____
Chest girth (cm) _______ (behind front legs and around the chest)
Total length (cm) _________ (body contour from tip of nose along backbone to base of tail)
Neck circum. (cm) _______ (around the neck at midpoint between back of skull & front of scapula) HIND FOOT



Hind Foot Width (mm) ________
Hind Foot Length (mm) ________
Hind Foot Total Length (mm)_______

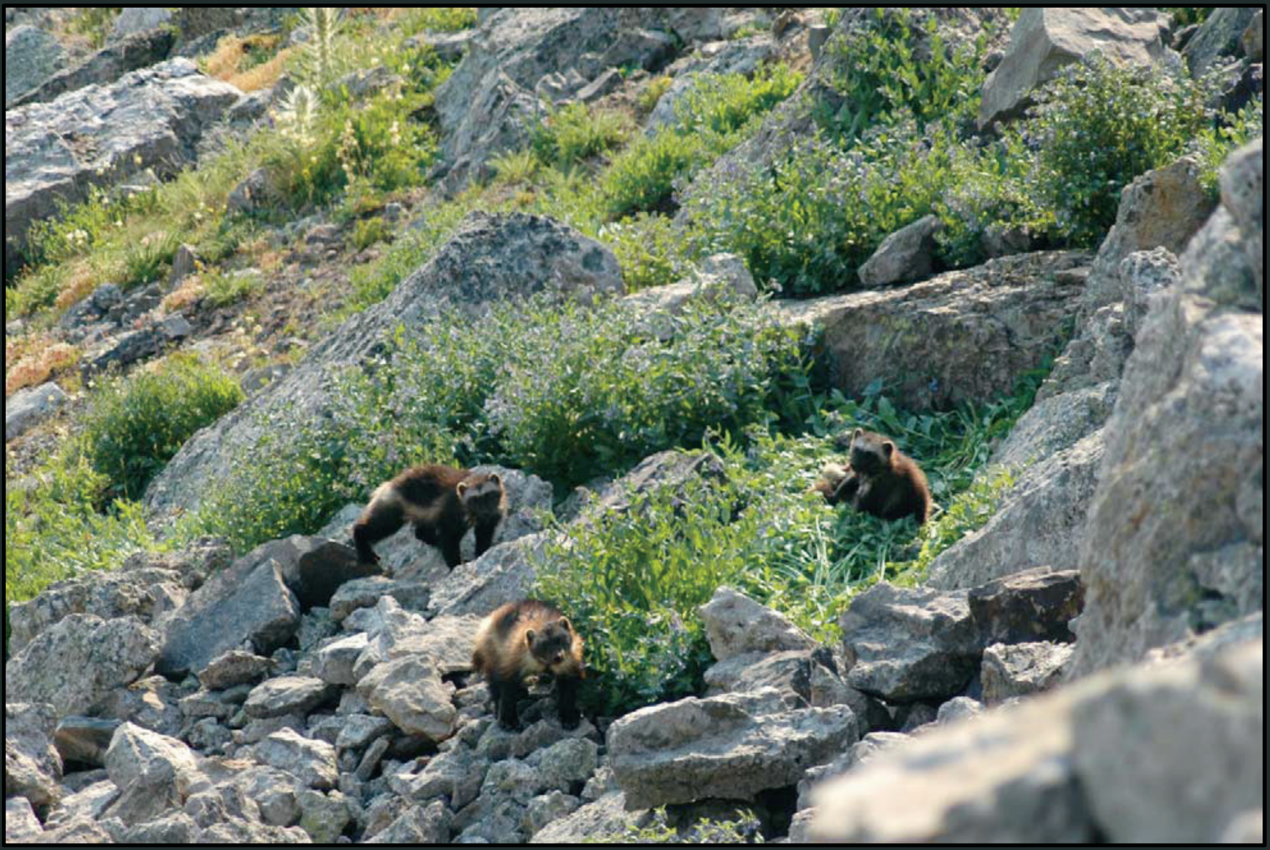
Front Foot Width (mm) _________
Front Foot Length (mm) ________
Front Foot Total Length (mm) _______

PELAGE DATA

Coat condition:	(1)Prime	(2)Shedding	(3)Summer	(4)Mange	(5)Other_______
Overall pelage color:	(1)Pale brown	(2)Dark brown	(3)Black	(4)Blond	
Lateral Stripes:	(1) Well defined	(2) Faint	(3) None		
Chest markings present:	Y N Photos Y				
Throat markings present:	Y N Photos Y				
Markings on Feet/Toes:	Y N Which Foot ______________________________				
Other Markings:	Y N Describe______________________________				
Scars:	Y N Describe______________________________				
Photos of Markings	Y N				

NOTES

Notes:



Female wolverine F121 and two young of the year in the Gravelly Range of southwest Montana, July 2007.
Photo by Mark Packila, WCS Greater Yellowstone Wolverine Program.