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Wildlife Scientists and Wilderness Managers Finding Common Ground with Noninvasive and Nonintrusive Sampling of Wildlife

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Iconic wildlife species such as grizzly bears, wolves, lynx, and wolverines are often associated with wilderness. Wilderness may provide some of the last, and best, remaining places for such species because wilderness can offer long-term legislated protection, relatively large areas, and remoteness (Mattson 1997). Indeed, the word *wilderness* in its original form literally means "place of wild beasts" (Nash 1982). Despite this natural fit between wilderness and wildlife, simply drawing a boundary around an area such as wilderness does not assure the protection and persistence of wildlife either inside the area or across the broader landscape (Landres et al. 1998). Only by understanding where such species occur and how their populations are faring can we know if wilderness is aiding in the role of sustaining wildlife.

Traditionally, wildlife scientists have used tools such as collecting individuals, trapping, and equipping animals with radio collars to understand the distribution, movement patterns, behavior, and abundance of wildlife. These tools, however, may pose a significant problem to wilderness managers because the primary legal mandate in wilderness is preserving wilderness character (Rohlf and Honnold 1988; Scott 2002), and such tools may degrade wilderness character (Landres et al. 2008). For example, we can ask how the perception of natural or untrammeled may be impacted when a visitor to the wilderness sees wildlife wearing a radio collar or tag. Similarly, how does the temporary placement of weather gauges or telemetry stations influence the undeveloped aspect of wilderness? Examples such as these have led to an understandable tension between wildlife scientists and wilderness managers: scientists strive to maximize sample sizes and data quality while minimizing field costs, and managers strive to uphold legal regulations by only allowing research that is necessary to preserve wilderness character and ensure that such work uses only the minimum methods, approaches, and tools (Hendee and Mattson 2002).

This tension between scientists desiring to work in wilderness and managers striving to preserve wilderness character has been a concern for decades. Franklin (1987), Parsons and Graber (1991), Oelfke et al. (2000), and others have explored the concerns and debates about using invasive research tools to understand the dynamics of wildlife populations. However, this philosophical debate extends beyond the conflicting goals of each party. It broadens to the question of permitting activities that may degrade wilderness character in the short term, yet enhance it by providing critical data over the long term. Indeed, there is a paradox that has historically arisen in which wilderness managers are in the position of balancing the preservation of wilderness character while still permitting the science that can either inform or lead to improvements of the very wilderness character they are fostering.

This article discusses relatively new wildlife biology research tools that may help ameliorate this debate. In nearly all scientific disciplines, technological advances are providing a new suite of research tools that can bridge the gap between wildlife researchers and wilderness managers, and reconcile the manager's dilemma of short-term versus long-term preservation of wilderness character. In this article we discuss how the fields of molecular ecology, endocrine biology, and stable isotope analysis can provide high quality data through the use of noninvasively and nonintrusively collected samples. Although these tools are not a panacea to the tensions described above, they are at least an option that can lead to improved communication between managers and scientists. Furthermore, these tools can minimize impacts to wilderness character while providing the information needed to understand the dynamics of wildlife populations and the conditions needed to sustain them.

Noninvasive versus Nonintrusive Sampling

The trend in wildlife science has been to move away from lethal and highly intrusive methods that were commonly used in the mid-19th century, and still prevalent throughout the 20th century. Early scientific expeditions often relied on lethal collecting of specimens. For instance, between 1914 and 1920, Joseph Grinnell, the famed natural historian at the University of California at Berkeley, collected more than 4,000 specimens from a wide variety of species in Yosemite National Park (Moritz et al. 2008). Although this lethal sampling has proven to be enormously useful for answering a variety of modern-day questions (Moritz et al. 2008), it can be argued that nonlethal methods that are available today may offer comparable data. Even some of the most common methods used by today's wildlife ecologists, such as radio and satellite telemetry or "marking" individual animals to understand animal movements, survival, and habitat use, are being questioned on both ethical and data-quality grounds. This is because capturing and handling individuals has been shown to reduce survival and may ultimately reduce the individual's lifetime fitness (Marco et al. 2006; Cattet et al. 2008; McCarthy and Parris 2008). Although these invasive approaches are not casually used by researchers, less invasive approaches have often been sought or at least considered prior to initiation of a project.

Recently, the field of molecular ecology has been leading the way in noninvasive sampling. In molecular ecology, the term *noninvasive sampling* is the collection of samples for genetic analysis where direct contact (physical or even visual) between researchers and animals is avoided (Taberlet et al. 1997; Schwartz et al. 1999). In recent years, noninvasive genetic sampling has produced important data on the population structure, abundance, diet, and genetic connectivity among populations of many elusive species, some that would otherwise be virtually impossible to study (Bergl and Vigilant 2007; Marucco et al. 2009; Valentini et al. 2009).

However, not all noninvasive genetic sampling is nonintrusive. That is, many times noninvasive sampling involves drawing an animal to a device using an attractant or lure, and subsequently inducing the animal to interact with a collection device, such as a piece of double-sided sticky tape or barbed wire (Zielinski et al. 2006; Kendall and McKelvey 2008). Although these methods are noninvasive, they are not nonintrusive.

Here we introduce the term *nonintrusive sampling*. By nonintrusive sampling we mean scientific methods that are used to learn about an animal without perceived manipulation of the behavior of the animal. For instance, in some research circumstances we can track an animal on natural surfaces to find hair or feces (McKelvey et al. 2006; Heinemeyer et al. 2008) or use detector dogs (MacKay et al. 2008) to find feces of a target species that can be used to obtain key genetic material. These approaches offer significant scientific benefits because there is limited observer effect (i.e., the animal is not being drawn to a device), thus allowing inferences about habitat preferences without the scientist influencing the result. In addition, these nonintrusive sampling methods will lower the potential impact on wilderness character.

With this concept, we now have a continuum or gradient of intrusiveness

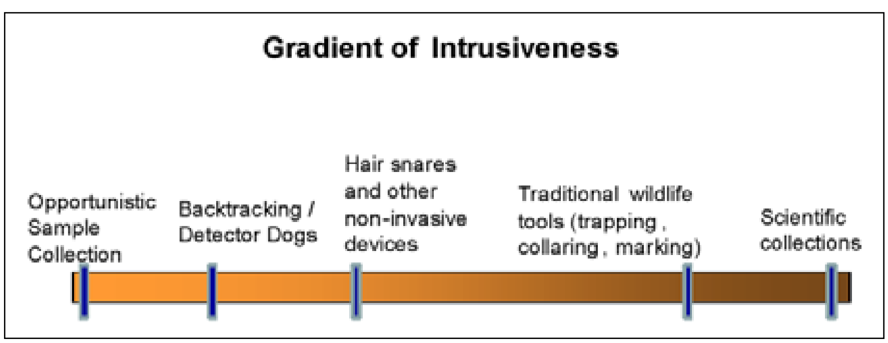

Figure 1—This graphic illustrates a gradient of "intrusiveness" of tools and techniques used by wildlife biologists to collect data. On one end of the spectrum are opportunistic samples collected by field biologists where there is little suspected impact on the individual or population by collecting the sample. On the other end of the spectrum are scientific collections, where lethal means are used to collect samples. This does not imply that data quality is equal across the spectrum, but does suggest that a range of tools that should be evaluated does exist.

for all research approaches (see figure 1), with lethal collection anchoring one side and nonintrusive genetic sampling anchoring the other. Noninvasive genetic sampling would be positioned near the nonintrusive side of the gradient. Techniques such as adding a hair collection device at sites naturally visited by animals, as is being implemented with grizzly bear studies (Kendall et al. 2009), would fall amid noninvasive and nonintrusive sampling (see figure 1). Establishing this framework should facilitate communication between scientists and wilderness managers, and provide new options for studying difficult, rare, and elusive animals in wilderness.

Noninvasive and Nonintrusive Sampling Sometimes Provides Better Data

Historically there has been a trade-off between the level of intrusiveness required and the quality of the data generated (see figure 2). Grinnell and colleagues did not have many options to learn about California wildlife with less invasive methods and thus used lethal methods. Even in the era of radiotelemetry there were few reliable, noninvasive alternatives to the radio collar available for researchers to learn about the secretive nature of their study species. In some cases, scientific and technological advances have now eliminated this trade-off (see figure 2). For example, a recent study by Kendall et al. (2009) collected 20,785 hair samples using hair snares and natural bear rubs to estimate the population of grizzly bears in the Northern Continental Divide Ecosystem. This 31,410 km^2 (12,127 mile^2) study area included the Bob Marshall, Great Bear, Scapegoat, Mission Mountains, and Rattlesnake Wildernesses in Montana. As a result, the authors were able to estimate that 765 bears (with a 95% confidence interval of 715–831 bears) reside in this area, more than initially predicted by managers (Kendall et al. 2009). If these scientists relied on traditional capture-mark-recapture approaches, they would never have been able to produce such a precise population abundance estimate. Here, advances in the field of molecular genetics and noninvasive genetic sampling allowed data quality to *increase* while intrusiveness actually *decreased*. The combination of noninvasive (hair snares) and nonintrusive (natural bear rubs) approaches provided wilderness managers and wildlife scientists a better answer than if traditional sampling approaches were used—a win-win situation.

Other Technological Advances Reduce Intrusiveness: A Wolverine Case Study

Molecular genetics isn't the only field to provide technological advances that reduces intrusiveness. A recent example of a wolverine appearing in California, where the last confirmed animal was documented in 1922, highlights how advances in molecular genetics, remote-camera operation, and stable-isotope analysis can provide answers without invasive methods (Moriarty et al. 2009). In February 2008, a graduate student was working on a marten project in the Sierra Nevada, California. One of her remote camera sets captured a picture of a wolverine. For years, there have been reports of visual observations of wolverines in California, but no supportive evidence. In fact, many noninvasively collected hair and fecal samples have turned out to be from other species such as marmots and bears. This photograph was the first definitive evidence of this species since Joseph Grinnell's era. But this photograph didn't answer other important questions: How did the wolverine get there? Was it from a population that persisted in California undetected for decades? Did it migrate from one of several neighboring populations in the Rocky Mountains or the North Cascades of Washington?

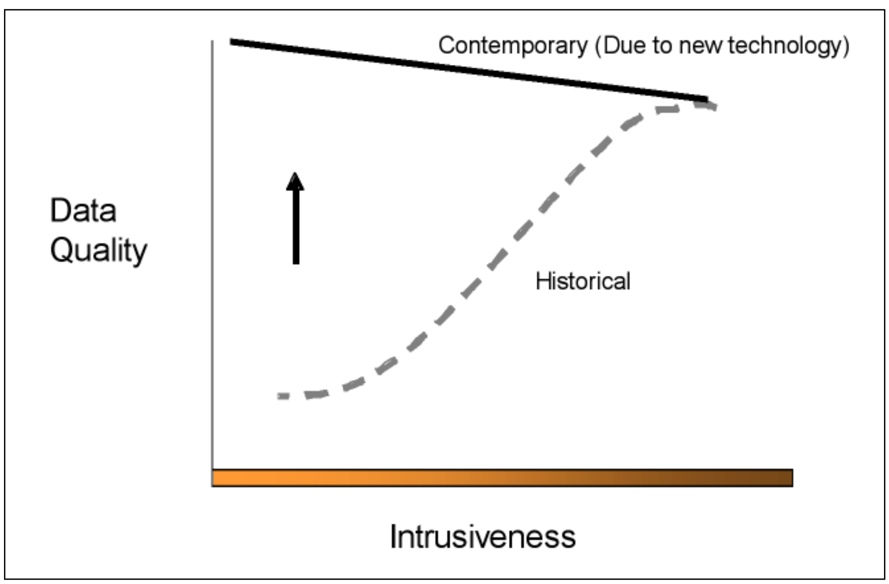

Figure 2—A schematic comparing the level of intrusiveness of a wildlife technique versus data quality. Historically, there was a positive relationship between how intrusive a wildlife biology technique was and the quality of the data obtained (dotted line). Currently, in some cases, data quality can be higher with less intrusive methods due to newer technologies (solid, black line).

Researchers used a combination of baited hair stations (16 stations covering 150 km^2/58 sq. miles), detector dogs (searching over 100 linear km/62 mile), and biologists looking for samples deposited over the snow tracks of the animal to collect 82 noninvasive or nonintrusive fecal and hair samples. Six of these samples positively identified the animal as a wolverine through molecular genetic analyses. Subsequent analysis revealed that this individual initially came from a population in the western portion of the wolverine's geographic range in the Rocky Mountains of Idaho (Moriarty et al. 2009). Most important, using ancient DNA techniques and pieces of historical California wolverine skulls from museums, Schwartz et al. (2007) determined that this individual did not match DNA samples obtained from the California population that persisted in the region in the late 19th and early 20th centuries. Given these data, it is highly unlikely this animal persisted in the California wilderness, undetected for more than 80 years. Stable isotope analysis using carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) confirmed these results. Specifically, two noninvasive hair samples from this California wolverine were compared to reference hair samples from other geographic areas, confirming that this unknown animal came from the Rocky Mountains (Moriarty et al. 2009). Overall, the multiple noninvasive and nonintrusive sampling (camera sets, detector dogs searching for scat, molecular genetic analyses, and stable isotope analyses) allowed us to make inferences that would be unobtainable using traditional approaches. DNA analyses on the hair and fecal samples also determined that the animal was a male, which is the sex that is known for its dispersal capability. Additional endocrine work was not undertaken, but could have been conducted from the fecal samples to evaluate stress and physical condition (Schwartz and Monfort 2008).

. . . wilderness managers needed to balance short-term disruptions to wilderness character with long-term information gains that may preserve or enhance wilderness character.

Conclusions

Historically, a high level of invasiveness and intrusiveness was required to obtain useful data for understanding and ultimately managing wildlife. In wilderness, these methods may lead to conflicts between wildlife researchers and wilderness managers who are respectively trying to maximize data quality and preserve wilderness character. Additionally, wilderness managers needed to balance short-term disruptions to wilderness character with long-term information gains that may preserve or enhance wilderness character. Recent developments in the wildlife sciences provide less invasive and less intrusive approaches that obtain data of equal or higher quality than acquired using traditional approaches. In some situations these newer approaches may be insufficient to understand the distribution and population dynamics of a species, and traditional approaches may still be needed. But in many other situations these newer methods have shown that they can provide better quality and quantity of data to understand the dynamics of wildlife populations with less impact to wilderness character. These new methods should foster better and more informed communication between wilderness managers and wildlife scientists to further their mutual interests in sustaining wildlife and preserving wilderness character.

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