An Assessment of Current Methods for Surveying and Monitoring Wolves

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SUMMARY

Monitoring is of high priority when assessing and managing restoration efforts for imperiled species. Successful recovery strategies cannot be adequately developed without reliable estimates of population size. In Idaho, wolf (*Canis lupus*) monitoring protocols are needed to address management objectives on 2 different levels: (1) short-term documentation of minimum population levels above a federal re-listing threshold to satisfy delisting requirements, and (2) long-term population distribution, status, and trend for effective conservation and management of the species. To date, the Nez Perce Tribe and the United States Fish and Wildlife Service have used radio telemetry as the primary method for monitoring wolves in the northern Rocky Mountains. While this method is reliable and was appropriate for a small, recovering Idaho wolf population, it is too expensive, logistically difficult, intrusive, and unnecessary for long-term statewide conservation and management of a much larger recovered wolf population. Therefore, we assessed the application of existing survey and monitoring methods to Idaho's unique landscapes and potential for methods to meet identified monitoring objectives across the state. Objectives of this effort included (1) synthesizing a worldwide review of existing wolf and other appropriate carnivore survey and monitoring methods by conducting a questionnaire survey and a review of published and gray literature, (2) assessing application of existing methods to Idaho based on established evaluation criteria and Idaho-specific landscape and climate constraints, and (3) recommending monitoring methods with potential application to Idaho for further field testing and evaluation. We reviewed 396 papers related to wolf monitoring and sent questionnaires to 46 individuals responsible for wolf monitoring in their respective districts, including 13 countries. We evaluated 15 monitoring methods; the most common used was territory mapping using radio telemetry (52%). Based on our monitoring objectives and evaluation criteria, we recommend a suite of methods for field-testing and eventual implementation in Idaho.

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INTRODUCTION

The International Union for the Conservation of Nature (IUCN) has identified monitoring as a high priority when assessing and managing restoration efforts for imperiled species (IUCN 1998). Successful recovery strategies cannot be adequately developed without reliable estimates of population size. Additionally, the robustness of delisting criteria for endangered species is being questioned (Cade et al.1997, White et al. 1999, Klavitter et al. 2003). Such criteria should include appropriate and rigorous methods to assess population levels, ensure achievement of recovery goals, and provide for long-term population viability. Better integration of recovery and long-term management objectives with appropriate monitoring methods is needed. This is especially important for high profile species, those with differentially high economic and ecologic impacts, and those that may serve as surrogates for other conservation goals.

One of the most important knowledge gaps affecting our ability to effectively manage wolves (*Canis lupus)* is population assessment (Fuller et al. 2003). Few efficient and reliable methods exist for estimating populations of large carnivores. Fewer still have been formally tested (Wilson and Delahay 2001).

In Idaho, wolf monitoring protocols are needed to address management objectives on 2 different levels: (1) short-term documentation of minimum population levels above the federal re-listing threshold to satisfy delisting requirements, and (2) long-term population distribution, status, and trend for effective conservation and management of the species. The population recovery goal for wolf restoration in the northern Rocky Mountains, as defined by the U. S. Fish and Wildlife Service (USFWS), is to establish and maintain 30 breeding pairs of wolves equitably distributed among Idaho, Montana, and Wyoming for 3 years (E. Bangs, USFWS, personal communication). Upon delisting, the USFWS requires monitoring the Idaho, Montana, and Wyoming wolf population for a 5-year period to verify continued population sustainability at or above an expected relisting threshold of 10-15 breeding pairs (USFWS 1987). Standardized and reliable monitoring protocols will be important in satisfying this federal monitoring requirement. Beyond the 5-year post-delisting period, Idaho and other States will need more rigorous and higher resolution monitoring methods to meet long-term wolf conservation and management objectives, including assessment and management of wolf impacts to livestock and wild prey, and managing a sustainable wolf harvest.

To date, the Nez Perce Tribe and the USFWS have used radio telemetry as the primary method for monitoring wolves in the northern Rocky Mountains. While this method is reliable (Fuller and Snow 1988) and was appropriate for a small, recovering Idaho wolf population, it is too expensive, logistically difficult, intrusive (Bekoff and Jamieson 1996), and unnecessary for long-term statewide conservation and management of a much larger recovered wolf population (Fuller et al. 1992). New and less intensive monitoring methods are needed to address long-term conservation of wolves in Idaho.

Idaho landscape and climate constraints limit application of many existing monitoring methods. For reliable results, many monitoring methods require relatively open landscapes, good access, and snow cover. One or more of these constraints are limiting over much of occupied wolf range in Idaho. Most wolf packs in Idaho currently occupy regions of continuous, dense forest cover that may limit aerial methods. Past experience conducting radio telemetry flights in Idaho indicates that wolves and tracks are rarely observed in the heavily forested areas where > 50% of wolf territories are located. Snow cover is often not adequate for tracking in more open landscapes across much of southern Idaho and on many lower-elevation ungulate wintering areas. Large wilderness and other remote areas in Central Idaho limit ground access required by several methods. Although >80% of known wolf territories have some level of road access, most access is limited (low road densities) from a monitoring standpoint (C. Mack, Nez Perce Tribe, personal communication). In addition, most (63%) known wolf pack territories have limited (low road or snowmobile trail densities) or no winter access. Idaho landscape and climate constraints may preclude statewide application of a single method, and may require developing a suite of coordinated methods dovetailed together for effective statewide monitoring.

To address these changing monitoring needs and realities, and logistical challenges, the Nez Perce Tribe is interested in working with the Idaho Department of Fish and Game (IDFG), USFWS, and others responsible for wolf management, to develop more cost-effective, efficient, and reliable methods that are more appropriate for long-term conservation and management of wolves in Idaho. Information gathered during this effort may also benefit Montana, Wyoming, and other western States to monitor wolves within the northern Rocky Mountains.

Goals and Objectives

Our goal was to assess the suitability of applying existing survey and monitoring methods to Idaho's landscapes and their potential for meeting identified objectives for monitoring wolves across the state. Objectives included (1) synthesizing a worldwide review of existing wolf and other appropriate carnivore survey and monitoring methods by conducting a questionnaire survey and a review of published and gray literature, (2) assessing application of existing methods to Idaho based on established evaluation criteria and Idaho-specific landscape and climate constraints (e.g., access, forest cover, snow cover), and (3) recommending monitoring methods with potential application to Idaho for further field testing and evaluation.

METHODS

Questionnaire

We developed a questionnaire to solicit unpublished information from managers currently monitoring wolves (Appendix A). A questionnaire recipient list was developed from attendees at the 2003 International Wolf Conference in Banff, Alberta; members of the IUCN

wolf specialist group; and discussions with colleagues. We categorized the various methods in use and identified factors related to their selection and incorporated this information into our assessment of methods.

Literature Review

We assessed methods used to monitor wolves by reviewing pertinent literature. We selected more recent papers that were (1) most representative or thorough in outlining methods, (2) described original applications of the techniques, and (3) provided an evaluation of techniques. Our review focused primarily on wolves, however, we also reviewed monitoring methods for species with ecological and landscape use characteristics similar to wolves, including other carnivores and medium-sized and large mammals. We believed a broader review would serve biologists working on these species and help to develop more efficient multi-species monitoring methods. A multi-species approach is important as conservation and management challenges increase and resources become more limited.

We searched electronic databases, the primary literature on wolves with which we were already familiar, and citations provided to us by biologists who received our questionnaire. We compiled results of the literature review into a separate annotated bibliography of monitoring techniques for wolves and other carnivores (Kunkel et al. 2005). The annotated bibliography follows the outline and organization of the monitoring techniques found in this report so that each can be cross-referenced. Further details on how the annotated bibliography was arranged may be found in Kunkel et al. (2005).

Evaluation of Monitoring Methods

Methods that had the most application to wolves and were more appropriate for long-term conservation and management were evaluated according to (1) their ability to address identified Idaho monitoring objectives, (2) their potential application to Idaho landscape and climate constraints, (3) level of data resolution and precision, (4) required sampling effort, (5) method assumptions, (6) advantages and disadvantages, (7) field constraints, and (8) costs.

To help with our evaluation, we identified important wolf management and monitoring objectives for Idaho. Objectives are based on federal monitoring requirements and long-term conservation and management needs for wolves in Idaho. In formulating these objectives, we also considered federal recovery goals and delisting criteria for the northern Rocky Mountains (USFWS 1987), and management goals identified in State and Tribal wolf management plans developed for the northern Rocky Mountains (Idaho Legislative Wolf Oversight Committee 2002; Montana Fish, Wildlife and Parks 2003; Wyoming Game and Fish Department 2003; Nez Perce Tribe 2004).

The identified overall management goal for wolves in Idaho is to ensure a viable, self-sustaining wolf population while effectively addressing and minimizing conflicts between wolves and human activities (Idaho Legislative Wolf Oversight Committee 2002, Nez Perce Tribe 2004). Management goals identified in state and tribal plans include (1) maintain a

minimum wolf population above the federal relisting threshold to ensure long-term conservation of wolves in the state; (2) manage wolves in concert with other wildlife values, addressing potential impact of wolf predation on ungulate populations; (3) effectively address and resolve conflicts arising from wolf-livestock interactions; (4) effectively address wolf-human safety concerns; (5) provide for regulated sport and treaty harvest of wolves; (6) provide for and maintain connectivity between wolf populations in Idaho, Montana, and Wyoming; and (7) establish a strong public education program emphasizing, wolf ecology, population status, and management.

Management and monitoring are interactive processes. Management goals drive information and data needs and, in turn, determine monitoring objectives and methods required. We identified 4 primary monitoring objectives for Idaho that are important in addressing the above 7 management goals. Some of these monitoring objectives were taken directly from state and tribal wolf management plans (Idaho Legislative Wolf Oversight Committee 2002, Nez Perce Tribe 2004) while others were developed to reflect management needs identified in those plans. Primary monitoring objectives include (1) document a minimum population of 20 wolf packs statewide to satisfy federal monitoring requirements for the first 5 years after delisting, (2) estimate wolf population trend with a 90% CI ($\alpha = 0.10$) and 80% power to detect a 30-40% change in population status annually for long-term monitoring, (3) estimate wolf population size and density once every 5 years, and (4) estimate occupied wolf range (distribution) annually. Methods were evaluated according to their ability to address these identified monitoring objectives for Idaho. The level of monitoring effort necessary to meet management objectives will likely differ regionally for wolves and by the level of confidence required by managers.

Application to Idaho landscape and climate constraints was evaluated based on ease of implementation relative to access, forest cover, and snow cover. Levels of data resolution were categorized as (1) determining presence, absence, and distribution; (2) estimating relative abundance using direct and indirect indices; (3) estimating absolute abundance; and (4) estimating population demography. When possible, the level of precision, measured in terms of confidence intervals (CI) around the estimate, was evaluated.

Methods that seemed promising were assessed in more detail and when available, case studies were outlined. There is no best or absolute way to definitively compare methods, as selection of appropriate methods is driven by many factors. Therefore, we provided a summary of important evaluation criteria to assist in comparing methods (Appendix B). For any reader interested in putting a particular method to use, it is essential that they read some of the primary literature referred to here, and adapt it to their own conditions and requirements (statistical, logistical, political, and ecological). Finally, we developed recommendations for a suite of monitoring methods that provide potential for application in Idaho and best meet identified monitoring objectives.

Statistical Concepts Related to Population Monitoring

Our assessment of existing survey and monitoring methods and final recommendations for Idaho considered basic statistical concepts related to population monitoring; appropriate monitoring methods reflecting identified management objectives; and principles of wolf ecology, conservation status, and management that influence selection of appropriate monitoring methods. When possible, we evaluated and compared the statistical robustness of assessed methods. In the report, we included statistical detail used by cited authors if we felt it helped to understand the suitability of a monitoring method. A brief summary of relevant statistical principles is provided below to help define some of the terms and concepts used to evaluate different methods.

Estimates derived from different monitoring methods can be in error in 2 general ways, referred to as Type I and Type II errors. A Type I error is the probability of rejecting a null hypothesis (no change or status quo) when it is in fact true. For example, a Type I error would occur if results of a monitoring method indicated a population change when, in fact, it had not. The probability of making a Type I error is called alpha (α), and it can be adjusted by setting different levels of α, usually between 0.10 – 0.05. An α level of 0.10 indicates a 10% probability while an α level of 0.05 indicates a 5% probability of making a Type I error. A Type II error is the inverse of a Type I error, the probability of accepting the null hypothesis when it is in fact false. For example, a Type II error would occur if results of a monitoring method indicated no population change when in fact there was one; or more simply, failing to detect a population change. The probability of making a Type II error is called beta (β). Alpha and beta are inversely related such that, by setting or accepting a higher α level, β is reduced and visa versa.

Power of a test or method ($1 - \beta$) is the probability of correctly rejecting the null hypothesis when it is in fact false and should be rejected; or more simply, correctly detecting a population change. Power is also related to α in that accepting a higher probability of making a Type I error (setting $\alpha = 0.10$ instead of 0.05) reduces the probability of making a Type II error, which increases the probability of correctly rejecting the null hypothesis. Power of a test or method can be increased by setting higher α levels and/or increasing sample sizes. When managing small and threatened populations, consequences of committing a Type I error (incorrectly concluding that a population has declined) are less severe than a Type II error (failure to detect a change), and therefore, power should be maximized (Taylor and Gerrodette 1993). Because few researchers have assessed power for those methods we reviewed, we relied primarily on the relative level of precision related to Type I errors when assessing survey methods.

Accuracy of an estimator relates to how close it is to the true, but unknown, value of the population parameter being estimated. Because the true value of the population parameter is usually unknown (except for controlled situations), we rarely know how accurate an estimate is. However, it is, possible to measure the precision of an estimator. Precision relates to repeatability of an estimator, or the range of results obtained when a method is repeated multiple times. A monitoring method that produces a narrow range of estimates when repeated multiple times is said to be more precise than a method that produces a wide range

of results when repeated multiple times. Precision of an estimate can be measured by constructing CIs around that estimate. Wider CIs indicate lower precision while narrower CIs indicate higher precision. Monitoring methods that are capable of producing more precise estimates are preferred, however, they are generally more intensive and expensive to implement. When available and appropriate, we indicate reported confidence intervals for methods evaluated.

RESULTS

Questionnaire

We sent questionnaires to 46 individuals responsible for wolf monitoring in their respective state, province, or nation (district), including 13 countries. We received 28 individual responses from 8 countries.

Wolves were classified by districts as furbearers (57%), threatened species (26%), endangered species (13%), and other (4%; includes species not classified as furbearer, threatened, or endangered). Most respondents indicated they conducted surveys for wolves (74%), and most (67%) used more than 1 method to monitor wolves. Methods used by respondents to monitor wolves were grouped into 11 broad survey categories (Table 1). The most common wolf monitoring methods used were territory mapping using radio telemetry (52%) track/sign surveys (30%), harvest data (30%), and demographic parameters (30%). Of respondents using wolf track surveys, most (60%) used this method to map wolf territories and produce minimum counts rather than to calculate a population index (40%). Few respondents indicated they used mark-recapture techniques (4%) and few used a sampling design for aerial surveys (2%). Monitoring was done from the air (61%), on foot (22%), or by road (17%). Respondents used several monitoring methods to produce minimum counts (34%), density estimates (24%), estimates of relative abundance (21%), presence/absence data (17%), and other population data (3%). Most respondents (53%) did not produce CIs around their estimates. Of those that did, about half reported CIs of less than ± 20%.

The most common monitoring objectives were to manage harvest (26%); produce population models (23%); support delisting (17%); and assess habitat relations, wolf impacts, and address other management objectives (12%). More respondents (57%) surveyed every survey unit rather than subsets of units within their district.

Most respondents (86%) conducted surveys annually, primarily in winter (52%), but also during fall (24%), summer (19%), and year-round (5%). A majority of respondents (88%) indicated survey methods they used were adequate for their needs, however, over 47% indicated they planned to change methods in the future. Reliability (50%) and cost (41%) were cited as reasons for selecting survey methods. A majority of respondents (57%) indicated that they combined wolf surveys with surveys for other species. Half (50%) of the respondents in those districts that classified wolves as threatened or endangered indicated they used radio telemetry for territory mapping.

Table 1. Methods used for counting and estimating wolf population size based on responses to a questionnaire survey.

Method Used	Respondent[1]	Percent of Respondents
Territory mapping with telemetry	2, 3, 4, 5, 7, 8, 10, 15, 17, 18, 20, 23	52
Track/sign surveys	2, 4, 6, 9, 14, 18, 23	30
Demographic parameters	2, 4, 5, 7, 8, 15, 18	30
Harvest data	4, 6, 8, 13, 15, 17, 21	30
Habitat/prey-based potential	1, 4, 14, 17	17
Howling surveys	4, 9, 10, 18	17
Research extrapolation	4, 8, 13, 14	17
Biologist reports/interviews	4, 10, 13, 14	17
Hunter reports/interviews	3, 4, 10, 13	17
Subunit Probability Estimator (SUPE)	4, 6, 13	13
Mark-recapture	9	4
No monitoring done	11, 12, 16, 19, 22	22

[1] Primary natural resource government organization unless otherwise noted:

1. Saskatchewan, Canada
2. Michigan, USA
3. Quebec, Canada
4. Minnesota, USA
5. Yellowstone National Park, USA
6. Alaska Department of Fish and Game – Anchorage, USA
7. Yukon Charley National Park, Canada
8. Northwest Territories, Canada
9. France
10. Glacier National Park, USA
11. Italy
12. Ontario, Canada
13. Alaska Department of Fish and Game – Fairbanks, USA
14. British Columbia coast – University, Canada
15. British Columbia. Canada
16. Romania
17. Alaska Department of Fish and Game – Juneau, USA
18. Mexican Wolf Project – USFWS, USA
19. Nunavut
20. Kenai National Wildlife Refuge, Alaska, USA
21. Labrador and New Foundland, Canada
22. Alberta, Canada
23. Wisconsin, USA

Literature Review

We reviewed 396 papers related to wolf monitoring, but include only 133 (32% on wolves) that related most directly to our objectives. This information was compiled separately as an annotated bibliography (Kunkel et al. 2005). The majority of the work on monitoring wolves has been conducted in North America. The primary objective of many of these papers was to estimate wolf density as part of a larger research project on wolf ecology. The most common method reported for monitoring wolves was using radio-collared wolves for territory mapping to produce minimum population counts (Table 2).

Evaluating Monitoring Methods

Selected methods were assessed and compared according to our established evaluation criteria, landscape and climate constraints, and identified monitoring objectives. This information is displayed in Appendix B.

<u>Methods not Requiring Original Fieldwork</u>
Methods in this category are generally the least intensive to implement, but often produce lower levels of data resolution such as presence/absence, general distribution, indices of relative abundance, and in rare occasions, indices of absolute abundance. In most cases, statistical estimates of precision are not obtainable. We evaluated 4 different methods within this category, including assessment of questionnaires and observations from the public, review of livestock depredation reports, analysis of harvest data, and habitat evaluation.

1. Questionnaires
Questionnaires and reports from the public are the simplest level of data collection. These methods have been widely used in Europe and North America (e.g., Kolstad et al. 1986, Blanco et al. 1992, Fuller et al. 1992).

Questionnaires targeted towards persons with intimate knowledge of an area and who spend considerable time in the field (e.g., trappers, conservation officers, rangers, guides, and outfitters) may provide data on species range and status (Kaufman et al. 1976, Fuller et al. 1992) and a subjective estimate of abundance (Allen and Sargeant 1975, Harris 1981). Many natural resource agencies use this method to compile species status reports that include relative abundance, distribution, and indicators of population trend, particularly in countries that are unable to invest the resources more accurate population assessments require (Fanshawe et al. 1997).

Crete and Messier (1987) tested reliability of hunter questionnaire surveys in a 6,400-km^2 study area of hardwood-conifer forest in southwestern Quebec. Hunters were asked at check stations how many wolves they saw, how often they heard howling, and if they saw scats or tracks. Questionnaire responses were used to calculate numbers of wolves observed/100 hunting days, number of days wolves were heard howling/100 hunting days, percentage of hunting trips with scats observed, and percentage of hunting trips with tracks observed. Indices were regressed against known wolf densities of 6-15 wolves/1,000 km^2 based on

Table 2. Examples of the most commonly used methods reported for counting and estimating the size of wolf populations in North America and Europe, based on a literature review.

Method[1]	Survey Category[2]	Study Location (size)	Reference
MAP	MC	Alaska (10,000 km^2)	Adams et al. 1995
GTS	MC	Poland (520 km^2)	Smietana and Wajda 1997
GTS	MC	Poland (1500 km^2)	Jedrzejewska et al. 1996
GTS	MC	Minnesota (74,000 km^2)	Fuller et al. 1992
GTS	MC	Michigan (42,000 km^2)	D. Beyers, Mich. D.N.R., unpub. report
GTS	MC	Wisconsin (68,400 km^2)	Wydeven et al. 2004
GTS	MC	Sweden/Norway (837,000 km^2)	Wabakken et al. 2001
ARS	MC	Alaska (8,300 km^2)	E. Jozwiak, Kenai National Wildlife Refuge, unpub. report
ARS	MC	Alaska (17,060 km^2)	Gasaway et al. 1983
ARS + MAP	MC	Alaska (13,000 km^2)	Gasaway et al. 1992
ARS (T)[3]	MC	Minnesota (839 km^2)	Fuller 1989
MAP + extrapolation of home range size to study area (T)	MC	Alaska (61,600 km^2)	Ballard et al. 1987
MAP	MC	Alaska (26,600 km^2)	Peterson et al. 1984
MAP + ARS + extrapolation of home range size (T)	MC	Alaska (12,280 km^2)	Ballard et al. 1997
MAP	MC	Minnesota (2,700 km^2)	Fritts and Mech 1981
MAP	MC	Alaska (30,000 km^2)	Dale et al. 1994
MAP	MC	Quebec (1,667 km^2)	Potvin 1987
MAP	MC	Quebec (6,400 km^2)	Messier 1985
MAP	MC	Montana (3,000 km^2)	Pletscher et al. 1997
MAP	MC	Ontario (7,571 km^2)	Forbes and Theberge 1996
MAP + extrapolation of home range size (T)	MC	Alberta (25,000 km^2)	Fuller and Keith 1980
ARS	MC	British Columbia (13,200 km^2)	Bergerud and Elliot 1986
MAP + ARS (T)	MC	Alaska (17,000 km^2)	Boertje et al. 1996
ARS	MC	Michigan (520 km^2)	Peterson 1977
MAP + ARS (T)	MC	Minnesota (2,060 km^2)	Mech 1986
Extrapolation of home range size + Number of wolves seen per hour of flying (T)	MC/SS	Alberta (9,000 km^2)	Carbyn et al. 1993
TIP (T)	PE	Alaska (6,464 km^2)	Ballard et al. 1995
TIP (T)	PE	Alaska (5,011 km^2)	Ballard et al. 1995

[1]Methods include:
GTS = Ground Tracking Survey
ARS = Aerial Reconnaissance Survey
TIP = Track Intercept Probability estimator
MAP = Territory mapping using radio telemetry

[2]Survey Categories include:
MC = Minimum Count
PE = Population Estimate without recognizable individuals
SS = Sign Survey

[3]Methods augmented with radio telemetry are indicated by "(T)"

radio telemetry. Indices of wolf observations (r^2 = 0.87; 90% CI = ± 30%), wolf howling (r^2 = 0.81; 90% CI = ± 37%), wolf scat observations (r^2 = 0.87; 90% CI = ± 30%), and wolf track observations (r^2 = 0.89; 90% CI = ± 28%) were related to wolf density. However, predictive ability of regression equations for all indices was relatively weak due to small sample sizes. Variance in wolf observations was large because wolf sightings were rare and the authors suggested that >1,500 interviews would be required to assess this index with a CI of ± 20. The authors further stated that 150-375 interviews using indices based on wolf howling, and 100 interviews using indices based on scat or tracks would be required to gain the same level of precision. The authors noted that larger sample sizes would be easier to obtain in areas with denser wolf populations (>10 wolves/1,000 km^2). Length of hunter trips appeared to have little influence on track and scat indices because if wolves were present; sign was noticed quickly; and if they were absent, more time did not increase chances of seeing sign.

Results from Crete and Messier (1987) showed the potential for using hunter questionnaires as indices of relative wolf density; however, they suggested that hunters should be queried as soon as possible after hunts. The authors also advocated the use of hunter surveys for financial reasons. This method has been employed by the government of Quebec to monitor wolf harvest and is considered to be efficient because hunting areas have tightly controlled access and gate personnel can present the questionnaires to hunters (Lariviere et al. 2000; H. Jolicoeur, Societe de la Faune et des Parcs du Quebec, personal communication). Nonetheless, before field application, indices need to be tested in other regions with differing wolf densities, access, and hunter methods and experience.

Questionnaires have also been used for other large carnivores. Gros et al. (1996) found that, of the 4 indirect methods tested, densities of cheetah (*Acinonyx jubatus*) estimated in national parks of east Africa from interviews of visitors, farmers, and biologists were closest to estimates produced by a direct method of estimating baseline demographic data. Estimates derived from the indirect method based on interviews deviated 12%, on average, from the direct method. The interview method performed very well for small, highly visited national parks and in areas with highly visible cheetahs.

Although using questionnaires and reports of observations from the public are tempting in their simplicity, there are several problems which may cause under-, or over-estimation of true numbers, including (1) many people misidentify sign and sightings because of lack of experience (Van Dyke and Brocke 1987*a*,*b*; Smallwood and Fitzhugh 1995); (2) some segments of the public may have vested interests in over- or under-representing carnivore numbers, and reliability cannot be assumed; (3) people may be more likely to report sightings in areas where carnivores are not common (novelty value), and therefore the frequency of reporting may not reflect the frequency of occurrence; and (4) low densities of carnivores yield low frequencies of reporting.

At a minimum, information from the public provides a starting point to plan more intensive surveys and confirmed observations should be recorded. If a large number of observations can be regularly collected, it may be possible to produce minimum counts, provided strict protocols are applied (see below, Knight et al. 1995).

Evaluation: With recognized statistical and reliability limitations, hunter questionnaires show promise for application in Idaho. This method could be applied at low cost statewide and is not generally affected by landscape and weather constraints. This method stands out from the others in this category as it has the potential to provide estimates of absolute abundance and could potentially address all identified monitoring objectives. However, because of the difficulties of confirming the accuracy of information collected using this method, it would more appropriately be used as a supporting, rather than primary, monitoring method.

2. Review of Livestock Depredation Reports

Where large carnivores overlap with livestock, depredations will occur (Bangs et al. 1998, Fritts et al. 2003). When compensation is paid for livestock losses, cause of death is usually verified, allowing for consistent data gathering (Fritts et al. 2003, USFWS 2004). If all reports of livestock depredations are recorded, a map of minimum carnivore distribution across livestock grazing areas can be developed. Large changes in the distribution and number of depredations can be used to gain a first approximation of changes in carnivore numbers and/or distribution (Torres et al. 1996, Mech 1998, Aune et al. 2002).

Wolf depredation trends in Minnesota over the last 25 years have tracked estimated wolf population trends (J. Erb, Minnesota Department of Natural Resources, unpublished data). From 1996-2003, wolf depredation rates on cattle in the northern Rocky Mountains of Idaho, Wyoming, and Montana were significantly correlated with wolf population trends ($r^2 = 0.97$, USFWS 2004). However, depredation rates on cattle in Idaho alone were not correlated with number of wolves ($r^2 = 0.40$, $P = 0.09$; USFWS 2004). Wolf depredations on sheep appear to be much more volatile than on cattle, and trends are less strongly correlated with wolf numbers.

The relationship between livestock depredation and number of wolves may be confounded by livestock husbandry practices, weather, and the numbers of livestock present (Fritts et al. 2003). Population trend indices derived from depredation rates are sensitive to reporting rates, a parameter which is rarely known. This index yields a point estimate with unknown variance and risk of Type I and Type II errors. Therefore, the value of livestock depredation reports as a method for monitoring wolves is questionable.

Evaluation: Records of wolf depredation on livestock provide valuable information on wolf depredation patterns useful for effectively addressing and resolving conflicts arising from wolf-livestock interactions, and supporting information for estimating occupied wolf range. This method, however, shows limited promise for monitoring wolf population status and trends in Idaho. Although these data can be collected with little cost and effort, no measures of precision are available and the information is limited in resolution. Additionally, this method cannot be used to adequately address most Idaho monitoring objectives and is only applicable to areas where wolves and livestock overlap.

3. Analysis of Harvest Data

Where large carnivores are harvested or killed in response to depredation on livestock or nuisance behavior, carcasses can provide valuable information. Changes in hunter success

can reflect changes in carnivore populations, although it is important to control for confounding factors such as quota size, weather, and the economic value of the species (Myrberget 1988). In addition, a measurement of hunter effort is very important to correctly interpret results. Sex, age, and allometric data can be collected by the hunter immediately after making a kill. Carcasses can be examined for reproductive history if the whole carcass, or at least some teeth and reproductive organs, can be collected for laboratory analysis and age determination (Coy and Garshelis 1992). Many attempts have been made to model bear (*Ursus* spp.) population structure and trend from harvest data (Harris and Metzgar 1987, Miller 1990, Mano 1995). The methods used have become increasingly complex, involving detailed demographic models, and are beyond the scope of this review. However, there are several problems frequently encountered when using harvest data:

1. Sample sizes are often small.
2. Animals in different age, sex, and reproductive classes are rarely equally vulnerable to harvest or capture (Miller 1990, Landa and Skogland 1995, Huber et al. 1996), and there may be important individual differences in vulnerability (Noyce et al. 2001) resulting in a non-random sample of the population, which confounds the use of life table analyses.
3. Harvest reporting rates can vary at unknown levels (E. Jozwiak, Kenai National Wildlife Refuge, unpublished data).
4. Harvest is sensitive to hunting and trapping effort, which varies due to changing conditions, therefore, use of harvest data alone to estimate population trends is not recommended (E. Jozwiak, Kenai National Wildlife Refuge, unpublished data; M. McNay, Alaska Department of Fish and Game, personal communication).
5. Any given harvest structure can often be interpreted in many different ways (Miller and Miller 1990, Garshelis 1993).

The basis for harvest statistics used for monitoring population status is not well documented and appears imprecise and unreliable (Harris and Metzgar 1987). In areas where unreported harvest is large, reported harvest may not be representative of harvest mortality, and as a result, problems associated with use of harvest data for assessing population trends may be insurmountable.

Despite these problems, harvest data are useful to assess extent and location of harvested animals. Also, continuous monitoring of harvest allows detection of changes in the composition of the harvest, which may indicate changes in population structure (Anderson 2003). Further research is required to extract more useful information from harvest data. Two promising research areas include combining harvest data with independent estimates of trend (e.g., open population mark-recapture models (McDonald and Amstrup 2001, Boulanger et al. 2002), and using harvest data to determine spatial structure and distribution of populations (Swenson et al. 1998).

<u>Evaluation</u>: Wolf harvest data should be collected to assist with managing regulated sport and treaty harvest of wolves, and to provide supporting information when estimating occupied wolf range and determining harvestable surplus. Although these data can be collected statewide with minimal cost and effort, the unreliability of the information and unknown relationship between harvest and population density precludes application of this method for monitoring wolf population status and trend in Idaho.

4. Habitat Evaluation

Habitat suitability models have been developed for many carnivore species. With the continued development of satellite imagery, remote sensing, and Geographic Information Systems, areas containing suitable habitat for a particular species can be identified, increasing efficiency of survey efforts and/or predictions of species abundance. Several habitat models have been developed to determine landscape factors selected by wolves and to predict areas of wolf recolonization (Mladenoff and Sickley 1998, Mladenoff et al. 1999, Oakleaf 2003). Oakleaf (2003) developed a map of wolf occupancy probability throughout Idaho that could be used to focus survey efforts. He also found that demographic rates of wolves were related to the home range quality of recolonizing wolves.

Demographic parameters and habitat selection factors can be extrapolated throughout the state to estimate potential relative densities and persistence of wolves. As wolf recolonization continues in Idaho, these models can be further tested and refined (Mladenoff and Sickley 1998).

Relationships between prey density (the main indicator of habitat quality for wolves) and carnivore density have been used to extrapolate carnivore distribution and density (e.g., Fuller 1989, Messier 1995, Gros et al 1996, Fuller and Murray 1998, Fuller and Sievert 2001; (But see Mills and Gorman (1997) for an important exception). In Minnesota, Fuller et al. (1992) used the equations from Fuller (1989) and Fuller and Murray (1998), documenting the relationship between wolf density and prey density, to estimate the number of wolves present in areas with estimated prey but unknown wolf densities. The estimate produced by this method (90% CI = 1,020 – 2,400 wolves or ± 40%) was similar to the estimate produced from collating reports of wolf numbers and distribution collected from natural resource professionals across the state (90% CI = 1,338 – 1,762 or 14%). Karanth et al. (2004) estimated prey densities for tigers (*Panthera tigris*) for 11 sites across India and found model predictions of tiger density based on prey density were reasonably consistent with known tiger densities. Gros et al. (1996) found that using prey biomass to estimate cheetah density deviated 37% from estimates produced by a direct method of estimating baseline demographic data. Messier (1985), however, believed that local ecological conditions will make extrapolations problematic.

As for any population estimate based on modeling or extrapolation, caution is necessary and limitations need to be recognized. When habitat quality and/or prey density are the primarily limiting factors of carnivore abundance, then extrapolations of carnivore numbers based on those parameters may provide an estimate of potential carnivore numbers present. However, most large carnivore species are exposed to legal and/or illegal harvest that is often a primary factor determining abundance (Knight et al. 1988, Kenney et al. 1995, Fuller et al. 2003). Carnivore estimates based on habitat quality are more applicable in areas where human harvest is minimal, such as inaccessible and protected areas.

<u>Evaluation</u>: Although habitat modeling may assist in identifying potential areas of wolf presence and relative abundance at a given point in time, this method is not appropriate for monitoring changes in population trend. Developing an index of wolf density based on prey density shows some promise in areas where human-caused mortality of wolves is low and

prey densities are monitored regularly. This method may be useful, when combined with other information, to estimate occupied wolf range.

Sign Survey Methods

Sign surveys are commonly used methods for monitoring relative abundance of large carnivores (Van Dyke et al. 1986, Jackson et al. 1997, Smallwood and Fitzhugh 1995). These methods require some level of fieldwork, including searching transects and identifying sign of un-recognizable individuals, such as tracks, scats, scrape marks, or any other sign of a passing carnivore. An underlying assumption is that higher carnivore densities will result in more sign on more transects.

These methods can be labor intensive to ensure sufficient sample sizes. Data collected using sign surveys provide presence, absence, and distribution data; and indirect indices of relative abundance. Statistical procedures are available to calculate precision of estimates, but large sample sizes are required.

Sign survey indices can be used to obtain population estimates if the relationship between the index of relative abundance and actual density is known. This relationship can be determined through intensive field research repeatedly applying sign surveys in areas of varying and known animal density, usually determined by radio telemetry. Regression analysis is then used to evaluate the relationship between the index and actual density. Once the relationship is determined through field research, resulting regression equations, describing this relationship, can be applied to results of sign surveys to extrapolate population estimates from the indices. Studies evaluating this approach have shown that indices obtained through sign surveys can provide reasonable precise population estimates given sufficient sample sizes (Crete and Messier 1987, Lariviere et al. 2000). We evaluated 3 different commonly used sign surveys for carnivores, including scent stations, scat surveys, and track surveys.

1. Scent Stations

Scent stations typically depend on using food, urine, or chemicals to attract a carnivore to a station with a prepared substrate that facilitates the recording and identification of tracks and other carnivore sign left behind. The most common design for meso-carnivores is to space stations along a line at a predetermined interval along roads or trails and then visit these transects for 3-4 consecutive nights to record new tracks (Linhart and Knowlton 1975, Roughton and Sweeney 1982, Sargeant et al. 2003).

Stations can be positioned to meet the needs of survey design and reduce accessibility problems, offering managers more control over study design and data collection. Distance between stations should be great enough to reduce the likelihood of visits by one animal to multiple stations. Sargeant et al. (1998) concluded that the problem of multiple visits can be reduced by documenting trends over transects rather than over individual stations. The authors found this analysis was robust to biases of multiple visits and differing distances between stations among areas. The authors noted, however, that a larger sample of transects is required for this analysis. Sergeant et al. (2003) reviewed sampling designs for scent-station surveys using red fox (*Vulpes vulpes*) and striped skunk (*Mephitis mephitis*) data from

surveys in Minnesota and offered procedures and a formula for determining appropriate sample design. These authors identified several cautions when interpreting results from scent stations, especially when visitation and sample sizes are low. They concluded that small-scale scent-station surveys are not a reliable basis for inference or action, especially if visitation rates are <10%.

Although several studies have found that visitation rates broadly reflect changes or differences in population density (Conner et al. 1983, Diefenbach et al. 1994), there are clearly problems in detecting small changes in population density using this method. Large numbers of stations and replicated surveys may be needed to detect changes in population size of 10-20 %, particularly when applied to large carnivores occurring at lower densities (Diefenbach et al. 1994). Using this method for large carnivores will result in a high proportion of zero values (no visitations at a station), greatly reducing the power to detect changes in population density. Further variation caused by seasonal and annual variation in response to the attractant need to be taken into account (Lindzey et al. 1977). Seasonal changes in habitat use can contribute to invalid correlations of animal density and visitation rates. This variation leads to uncertainty in the relationship between visitation rate and population density. Few studies have tested this relationship.

Diefenbach et al. (1994) found agreement between an index of visitation and actual density of bobcats (*Lynx rufus*) in Georgia. Schauster et al. (2002) also reported a positive correlation (R = 0.61) between scent-mark station estimates and swift fox (*V. velox*) density in Colorado. While some biologists reported that scent-station surveys reflect changes in raccoon (*Procyon lotor*) abundance, Smith et al. (1994) found no association between visitation rates and density of raccoons. Knowlton (1984) found a positive correlation (r^2 = 0.79) between scent-station indices and coyote (*C. latrans*) density. In summary, misidentification of tracks, weather (wind and precipitation), wariness of animals, and intensity of effort are items to address when considering scent-station surveys.

The activity index, a variation of the scent-station method, has been used to index dingo (*C. familiaris dingo*) populations (Engeman et al. 2000, Engeman et al 2002). This modification uses a sifted dirt area on a road without any scent or lure to attract animals. The number of track-sets crossing the sifted area is used to assess relative abundance and calculate an estimate of variance.

The Minnesota Department of Natural Resources uses 175 (1/500 km^2) scent-station survey routes distributed statewide to calculate an index of wolf population trend (Berg and Benson 1999). An index is computed as the proportion of stations with track presence, and bootstrapping statistical methods are used to calculate CIs for the indices. This method relies on the untested assumption of constant detection probability across years. Wolf population trends over the past 25 years, based on scent stations, were similar to wolf population trends determined from snow-track surveys and statewide population estimates (95% CI = ± 42%; J. Erb, Minnesota Department of Natural Resources, unpublished data).

<u>Evaluation</u>: This method appears to be more applicable to smaller, higher density meso-carnivores. Because relatively low wolf densities and large territory sizes would require

large sample sizes to measure even large changes in population status, this method shows little application for wolves in Idaho. Analysis of trends from these data over shorter periods is questionable. Also, given statistical and sample size issues and added field effort (creating and clearing tracking substrates and baiting), this method is less attractive than other indices. Although this method could provide information useful for estimating occupied wolf range, the extensive level of field effort, large samples sizes required, low level of resolution of data obtained, and inability to address other identified monitoring objectives preclude this method from consideration in Idaho.

2. Scat Surveys

Scat deposition along roadways or trails has been used to estimate relative abundance of some canid species (Clark 1972, Davison 1980, Andelt and Andelt 1984). This method establishes transects from which all scats are cleared. After a standard deposition period, transects are surveyed and all scats collected. A scat index is computed as number of scats collected/transect/deposition period (Davison 1980). If transect length or deposition period vary, then the index can be standardized to the number of scats/km/day.

Knowlton (1984) found that scat deposition rates were correlated ($r^2 = 0.97$) with estimates of coyote density derived from mark-recapture techniques using radioisotope tagging of feces. Schauster et al. (2002) found that scat deposition rates were correlated ($r^2 = 0.70$) with swift fox density estimated from intensive trapping and performed almost as well as a mark-recapture estimator.

Several factors should be considered in scat survey design. For long-term monitoring, scat transects should be conducted along the same routes at the same time of year to avoid introducing biases associated with differential prey digestibility (hence differential scat deposition rates) and seasonal changes in prey items consumed (Andelt and Andelt 1984). Misidentification of scats and heavy vehicle traffic on roadways can also be problematic when using scat surveys. Use of DNA techniques for identifying species and individuals from scats may alleviate the problems of misidentification (Foran et al. 1997*a,b*), and could potentially be used to estimate populations (Paxinos et al. 1997, Kohn et al. 1999).

Crete and Messier (1987) tested scat surveys as an index of wolf population trend by comparing derived scat indices to estimated wolf densities based on radio telemetry. These authors made weekly counts of scats observed on forest roads in July. Surveys were repeated from 6-10 times/year over a 4-year period. They defined suitable roads within their study area as those with minimal traffic where scats could remain undisturbed for 1 week. Suitable road segments had an average length of 6.9 km. They randomly selected a subset of suitable roads to form 2 48-km survey circuits within the study area. Two observers on motorcycles traveling at 20 km/hr collected all scats along the roads. The annual number of scats/100 km/week was calculated as the index. The wolf scat index was related to wolf density ($r^2 = 0.90$; CI = ± 22%) and had the best precision of 5 indices examined. Similar to other indices they tested, however, the predictive ability of the regression equation was relatively weak due to limited sample sizes. Variance of the index was relatively large, requiring 70-80 sampling weeks to assess this index with a CI of ± 20%, although the authors noted that variance could be reduced using longer transects. While reliable, the technique requires

substantial effort. Crete and Messier (1987) were able to cover 30-40 km of randomly selected roads daily. No significant change in deposition rates was detected from early July to mid August so data were pooled over this interval. Also, scats collected when a rendezvous site was located on or near a transect were not included in the analysis as scats became much more numerous then. Regression equations from Crete and Messier (1987) may be valid for other areas, but field testing for specific areas is needed as type of road systems (level of traffic affecting wolf use and scats persistence and detection) and wolf density may significantly affect results.

Evaluation: This method could potentially address all identified monitoring objectives, including estimating population size and density. Population size and density could be estimated based on field-testing correlations between indices and real population estimates based on radio telemetry or other methods (Lariviere et al. 2000). This method, however, requires substantial cost and effort to produce precise estimates, and would be difficult to apply in remote areas with limited road access.

3. Track Surveys

The sign survey method most tested for carnivores is the track survey used for monitoring cougar (*Puma concolor*) populations in the western United States (Van Dyke et al. 1986, Smallwood and Fitzhugh 1995, Beier and Cunningham 1996). Transects along sandy, dusty, or snow-covered roads or trails are covered on foot, horseback, or from a motorcycle. The incidence of tracks, scats, and scrapes are recorded, usually as the number of sign/km/day of accumulation. Consistent methodology has been proposed to maximize detection and recording sign (Smallwood and Fitzhugh 1993, 1995; Smallwood 1997). Van Dyke et al. (1986) reported that differences in observed track abundance among regions were closely related to documented differences in density as determined by radio telemetry.

Because large carnivores typically occur at low densities, tracks and other sign are not found on many transects. Therefore, a large number of transects are required to statistically detect changes in the index. Carnivores commonly favor certain travel routes and the probability of detecting their presence can be increased by placing transects along these favored routes (Jackson and Hunter 1995, Smallwood and Fitzhugh 1995, Beier and Cunningham 1996). Whereas this method may increase the number of tracks detected, comparisons between regions become more difficult with non-standardized placement of transects. Smallwood and Fitzhugh (1995) suggested locating transects throughout an area used by the target species and avoid placing transects only in areas with highest abundance. These authors argued that sampling marginal habitats would increase the ability to detect changes in population trend sooner. Such an effort, however, would have lower than expected power. As with scent stations, transects should be separated by distances great enough to minimize the probability of recording the same individual on >1 transect (Smallwood and Fitzhugh 1995).

Beier and Cunningham (1996) examined track survey designs that would have 80% power to detect a 30% or 50% change in cougar track abundance between 2 survey periods. They used data from track transects in southeastern Arizona to evaluate survey designs for 8-km transects in first- and second-order dry washes. Twenty-eight dry washes within a 4,035-km^2 study area were surveyed during 4 periods over 2 years. Track surveys had low power to

detect increases in track density (e.g., about 190 transects would be needed to detect a 30% increase with 80% power and $\alpha = 0.05$), but somewhat more power to detect decreases (about 140 transects would detect a 30% decrease with 80% power and $\alpha = 0.05$). They indicated the power of surveys could be increased, or fewer transects would need to be surveyed, by accepting a higher probability of a Type I error ($\alpha = 0.10 - 0.20$). To detect a 30% change with 80% power, about 110 transects would be needed at α=0.10, and 85 transects at α=0.20. The authors also noted that to detect a 50% decrease in population density with 80% power about 50 transects would be needed at $\alpha = 0.05$, and 30 transects would be needed at $\alpha = 0.20$. Most power curves they generated had an inflection point at 75-90% power, indicating that large increases in the number of transects were necessary to make small gains in power beyond that level. Track surveys usually will not detect small annual changes, but may reveal large changes more efficiently than other methods.

Smallwood and Fitzhugh (1995) reported that 44 quadrats each with 2-3 11.3-km transects could be used to monitor the statewide trend of cougars in California. They divided California into 50-km^{2}quadrats and randomly selected survey units. They excluded areas that were not considered cougar habitat. Local biologists chose transects in the quadrats. Quadrats contained up to 3 11.3-km road transects >16 straight-line km apart, unless they were separated by deep canyons or urban areas that prevented cougar movements between transects. Establishing 3 transects within each quadrat ensured good distribution and provided flexibility to ensure road access if conditions changed in some parts of the quadrat. Dust ratings were collected at the beginning, middle, and end of transects, and surveyors were required to trace on paper at least 1 track identified as cougar. Survey data were used to determine an optimum sample size using a general formula for sampling contagious distributions (Eberhardt 1978). Counts of track sets gave consistent, reliable information at low cost. Tracks were found on 55% of surveyed quadrats. Local biologists misidentified 10% of tracks sketched. The least costly (<$5,000) survey was done by an individual on a motorcycle surveying all quadrats. Using local biologists only increased the cost by approximately $1,500. The authors estimated that surveying 37 quadrats would produce an estimate within 40% of the mean with 95% CI and surveying 52 quadrats would increase the precision to 30% of the mean. The survey was easy to administer and flexible to changes in road conditions and personnel. Quadrats could be surveyed in a day. Dust rating had no relation to tracking success. Cost and effort could be reduced by selecting transects with topographic and habitat features most likely traveled by cougars.

The Minnesota Department of Natural Resources uses winter track survey routes to monitor wolf trends annually (J. Erb, Minnesota Department of Natural Resources, unpublished data). Fifty track routes are followed each winter throughout wolf range. Each 16-km route is divided into 20 0.8-km segments and surveyed by mid-January, following a fresh snowfall. Indices are computed as the proportion of segments with tracks and tracks observed/mile. The method relies on the untested assumption of a constant detection probability across years. Track routes were established along secondary roads and trails for convenient sampling and even transect distribution within the survey area. Trends observed over the last 10-20 years based on track surveys were similar to trends in the wolf population based on other indicators.

Correlations between track counts and animal abundance have also been reported for other carnivores. Stander (1998) found that track counts of lions (*Panthera leo*), leopards (*Panthera pardus*) and hunting dogs (*Lycaon pictus*) along road transects were a function of true density as determined by radio telemetry. He sampled 20 roads over 6 months 821 times covering 3,089 km. Accuracy stabilized and precision reached an asymptote as they reached a sample size of 30 track counts of leopards along 1,200 km of roads.

Canada lynx (*L. canadensis*) and coyote tracks were recorded along 25-km transects in the Yukon Territory, Canada, each day after snowfall from October-April 1986-1995 (O'Donoghue et al. 1997). Trends in the track index were highly correlated with population estimates based on other methods, including radio telemetry. A similar method has been used in Alaska with poorer correlations, but unlike in the Yukon Territory, sample sizes were small (2-5 weeks of transects; 542 km) and covariates were not controlled for (Ward and Krebs 1985).

Crete and Messier (1987) tested use of aircraft to record tracks along survey routes. In forested regions, they found the technique unworkable due to high costs and a high occurrence of misidentified tracks.

Power tests of existing data sets consistently confirm the ability of track surveys to detect larger changes in population trends over extended periods, but an inability to detect small annual changes (Kendall et al. 1992, Beier and Cunningham 1996, Zielinski and Stauffer 1996). It is, therefore, vital to carry out a pilot study within a proposed study area to determine which density and configuration of transects will be required to provide adequate power for the area-specific management purposes. Finally, it is important to remember that the relationship between the index and real density is largely untested and may depend on habitat, climate, detectability of sign, time of year, prey density, and social structure of the carnivore population (Thompson et al. 1989).

Evaluation: Similar to scat surveys, track surveys could be used to address all identified monitoring objectives, including estimating population size and density. Population size and density could be estimated based on field testing correlations between indices and real population estimates based on radio telemetry or other methods (Lariviere et al. 2000). This method however requires substantial cost and effort to produce precise estimates. This method would be difficult to apply in remote areas with limited road access and in areas with unreliable snow cover.

Minimum Count Methods without Recognizable Individuals

Methods for obtaining minimum or unduplicated counts are the most widespread for estimating absolute abundance of carnivores. Minimum counts are usually expressed as minimum densities. However, no measures of precision are available for these methods. These methods are appropriate when individual animals can be identified, but need not be recognized. Methods in this category use a variety of techniques to sum all individual animals detected within a known survey area. Standardized protocols are used to avoid double counting (Knight et al. 1995). For wolves, which are territorial and pack-living carnivores, this is an obvious and intuitive approach to estimating numbers and is similar to

the territory-mapping method used for songbirds (Baillie 1991). Although minimum counts may be robust, in many cases there is no objective way of knowing how many animals were undetected. This problem may be of less concern with wolves, if the primary interest is enumerating numbers of packs rather than all individuals. Although rules can be used to estimate the number of animals that were present but not detected, no statistical measure of the error associated with animals missed is usually obtained making it difficult to statistically detect changes in population density (Mattson 1997). Although unknown precision introduces uncertainties about the estimate, by nature minimum counts will always be conservative.

For all of these methods it is important that double counting be minimized. Rules used to separate distinct individuals or groups based on distance and time should be verified using radio telemetry or other data representative for the area and species being counted. If reports from the public are used, it cannot be assumed that all observations and reports are correct. Therefore, only verified or documented observations from the public and those made by trained or experienced personnel should be used. We evaluated 3 different monitoring methods within this category, including howling survey, Aerial Reconnaissance Survey (ARS), and Ground Tracking Survey (GTS).

ARS and GTS assume that (1) all tracks are visible, (2) all tracks are detected, and (3) tracks can be attributed to different individuals when there is no connection between sets of tracks. These assumptions can be hard to satisfy. Tracks can be destroyed by wind, snow falling from trees, or other animals. In addition, carnivores often walk in ungulate tracks, along plowed roads, and other areas of poor track detection. Finally, it is very easy to miss tracks entering or leaving a plowed road where snow is banked on the sides. To assign tracks to distinct animals, a protocol is often established that requires at least 1 transect without tracks between transects with tracks.

1. Howling Surveys

Eliciting a howling response by either broadcasting a recorded howl or simulating a howl with the human voice can often document presence of canids. Time of year, time of day, and carnivore group composition will affect natural frequency of howling and response rate (Harrington and Mech 1982, Jaeger et al. 1996). The distance sound carries and the ability to hear or detect a response varies due to many environmental factors, with upper limits of about 3 km (Harrington and Mech 1982, Mills 1996). Consequently, a large number of broadcast sites are required to cover a survey area. Fuller and Sampson (1988) found this method gave poor estimates of population size with wide CIs for wolves in Minnesota. Although this method is more applicable for documenting presence within a small sampling area, this method has been used with some success to survey spotted hyenas (*Crocuta crocuta*) over large areas in Africa (Mills 1996).

In their comparison of wolf monitoring methods, Crete and Messier (1987) tested the howling survey design recommended by Harrington and Mech (1982). They found that wolf responses to tape recordings were sporadic, ranging from 0-4 responses during 60 night-stations. No groups of pups were located during 6 full nights of surveying. Based on the response rate they observed, 940 stations (20 stations could be run per night by 1 person)

would be required to produce an estimate with a 90% CI = ± 20%. Assuming a 1.5 km radius of coverage per station (Harrington and Mech 1982), about 30-50 stations (2-3 days of work) would be required to survey a single 300-500 km^2 wolf territory. Crete and Messier (1987) indicated that pups were likely to use areas farther from roads, making howling surveys more difficult. For these reasons, and because it required considerable work and expense, these authors did not recommend this technique.

Evaluation: Although this method could be used to address all identified monitoring objectives, the large sample size and extensive field effort required for statewide coverage and to achieve precise estimates preclude this as an applicable method for monitoring wolves in Idaho. Howling surveys would be appropriate and productive for documenting presence of wolves in local areas of suspected wolf activity and in determining reproductive status of known or suspected individual wolf packs.

2. Aerial Reconnaissance Surveys (ARS)

The ARS has been the most widespread method used to census wolves in northern North America (Mech 1966, Petersen 1977, Stephenson 1978, Gasaway et al. 1983, Bergerud and Elliot 1986, Boertje et al. 1996). Using this method, a study area is surveyed by aircraft when snow-tracking conditions are optimal. Search intensity for tracks is highest in area most likely used by wolves (e.g., ridges, shorelines, and streams). All encountered wolf tracks are followed until the pack is located and the pack size determined. The process is repeated until the entire study area has been covered and all packs present have been detected. This method requires good tracking conditions and experienced observers and pilots to be able to follow a wolf track from the air. In areas of high ungulate densities, ungulate tracks can obscure wolf tracks. One disadvantage of this method is that single wolves are rarely detected.

At least 2 experienced pilots and observers are required in study areas of closed canopy forest that are >1,300 km^2 to ensure the area can be covered in 1-2 days of good snow conditions and bright tracking light (Stephenson 1978). Of the survey methods examined for large areas, Crete and Messier (1987) recommended extrapolating abundances from small areas (<2,000 km^2) using ARS. This technique provides a minimum count because some wolves may be missed when study packs are on extra-territorial forays outside of the study area during the survey, or when survey boundaries straddle pack territories. The technique can only be used in areas with good snow cover and in habitats with good visibility. E. Jozwiak, Kenai National Wildlife Refuge, personal communication indicated the technique was not possible in the closed forest of the Kenai National Wildlife Refuge in south-central Alaska.

Evaluation: Although the ARS method could be used to address all of the identified monitoring objectives, its applicability is limited compared to other, more recent aerial methods developed. The inability to calculate a measure of precision, and limited application to good snow cover and open country preclude the use of ARS as a primary monitoring tool for wolves in Idaho. This method may hold promise for remote wilderness areas where access and forest cover are limited.

3. Ground Tracking Surveys (GTS)

Ground tracking surveys involving searching for tracks in the snow using a network of roads, paths, or transects, can produce minimum counts of wolves. Assumptions are that all packs have a high probability of being detected, and double counting can be avoided. Double counting is avoided by either back-tracking all tracks encountered or by ensuring that 1 or more transects without tracks lie between 2 transects with observed tracks. Although animals tend to move greater distances and are easier to detect with increasing days after snowfall, the resulting abundance of tracks can also make back-tracking and separation of individuals more difficult. Accurate minimum numbers are also more difficult to obtain in areas of higher carnivore densities, as the greater number of tracks observed would complicate interpretation.

Wisconsin Department of Natural Resources (WDNR) personnel and volunteer trackers used snow-tracking surveys to obtain counts of wolves in packs without radio-collared individuals or to supplement counts for radio-collared packs with few observations (Wydeven et al. 1995). Forested areas of the state were subdivided into 132 survey blocks, averaging about 200 square miles each (Wydeven et al. 2004). During 2003, WDNR personnel and volunteers examined 117 survey blocks. Snow-tracking surveys were conducted in 90 of the 117 blocks examined. Blocks monitored by aerial radio telemetry and blocks with little potential for having wolf packs were not surveyed. Volunteers were asked to conduct at least 3 "good" surveys per block, and cover about 96-160 km of road. All volunteers were required to attend weekend wolf ecology courses and day-long track-training programs. Volunteers detected 137-147 wolves along 6,091km surveyed, and WDNR personnel detected 203-221 wolves along 4,619 km surveyed. Volunteers conducted, on average, 4.3 surveys covering 132 km/survey and spent an average of 15.4 hours surveying per block. Use of volunteers expanded coverage and opportunity to detect wolves in Wisconsin.

Applying the GTS technique to wolves in Upper Michigan, Beyer et al. (2004) created 7 survey zones. Surveys in adjacent zones were coordinated in space and time along zone boundaries to avoid duplicate counting of wolves whose home ranges overlapped those boundaries. Wolf sign was searched for by traveling roads and trails at 5-24km/hr in a truck or snowmobile. An extensive network of local contacts, including loggers, hunters, trappers, and farmers, was developed to aid in the effort. When wolf tracks were found, pack size was estimated by following the tracks as far as practical (typically at least 200 m), searching for distinct trails of individual animals. Track size, stride, age of tracks, and time of last snowfall were recorded. Scent marks and blood in urine were used to identify territorial pairs and breeding activity.

Beyer et al. (2004) developed protocols to avoid double counting wolves. Movements of radio-collared wolves helped to separate packs, pairs, and lone wolves. Identification of different packs relied on finding fresh tracks in adjacent areas with no movement between the 2 areas. Historical knowledge of wolf territories, locations of den sites, and fresh tracks going in opposite directions also aided in separating packs. Repeated surveys of an area were often needed to determine that wolf sign located in 2 adjacent areas was made by distinct

groups of wolves. Coordinated searches using several trackers were sometimes needed in areas of high wolf density. GTS may only be applicable in areas of Idaho with good road access.

Potvin et al. (In Press) assessed the Michigan track survey efforts and investigated the performance (bias, CI coverage, and mean % error) of various sampling-based estimators as a means of reducing monitoring costs. They divided upper Michigan into 22 sampling units separated by major roads. They tested 2000-2002 population estimates to evaluate the performance of 3 probability-sampling designs, including simple random sampling, stratified random sampling, and a hybrid design wherein some sampling units were monitored every year and combined with a random sample of other units. Low, medium, and high wolf density strata were established for the area. The researchers found that stratification was effective in reducing mean percent error when compared to simple random sampling. Stratified sampling using proportional allocation performed best, resulting in a 10% mean error and CI coverage of 95%. Sampling even 50% of upper Michigan yielded population estimates with mean percent errors of about 20%. They suggested a complete census could be conducted every 5 years with sampling conducted in between. One problem with this sampling technique is assigning a pack to a single sampling unit. They assigned packs to the sampling unit that contained the majority of the territory. This required intensive tracking of some packs. If determination still could not be made, the authors suggested using a randomization procedure.

Minnesota has, at approximately 10-year intervals, used a hybrid approach, combining a GTS with other data sources, to estimate a minimum count of wolves. Track surveys are used to determine occupied wolf range. Survey instructions and maps are sent to several hundred natural resource professionals throughout the state. They are asked to record all wolf sign observed throughout the winter during their normal work activities. Occupied wolf range is calculated by including all townships where wolf packs were detected from this survey. Once occupied wolf range is delineated, a population estimate is derived by: (1) computing average territory and pack size, using information from radio-collared wolf packs, and then increasing results by 37% to account for interstitial space between wolf territories (Fuller et al. 1992); (2) estimating the number of packs by dividing occupied range by the mean territory size of known wolf packs; (3) multiplying estimated number of packs by mean pack size; (4) increasing the population estimate by 15% to account for lone wolves (Fuller et al. 1992); and (5) generating CIs for population estimates using bootstrap resampling of territory and pack size. The GTS method as applied in Minnesota does not account for all the variation associated with the estimate because variance of some parameters (1-4) cannot be estimated (Becker et al. 1998).

<u>Evaluation</u>: Standardized protocols used by Michigan, Wisconsin, and Minnesota for GTS methods appear rigorous. The GTS method shows promise to address all identified monitoring objectives for Idaho and could be applied at a reasonable cost and effort over much of the state. This method would be difficult to apply in remote areas with limited winter access and with unreliable snow cover. As with all minimum-count methods, the inability to calculate a statistical estimate of error is of concern.

Population Estimate Methods without Recognizable Individuals

One disadvantage of minimum counts is the lack of a statistical estimate of error. Estimates of error become especially important when trying to determine the accuracy of an estimate of population trend. We evaluated 2 methods that provide estimates of absolute abundance and for which estimates of precision are possible. As with minimum counts, these 2 methods are appropriate when individuals can be identified, but need not be recognized. Although these methods provide a high level of data resolution, they are also very intensive to implement. Methods in this category include the Track Intercept Probability Estimator (TIP) and Subunit Probability Estimator (SUPE).

1. Track Intercept Probability Estimator (TIP)

The TIP method was developed in Alaska for Canada lynx and wolverines (*Gulo gulo*) (Schwartz et al. 1988). This method uses a series of parallel randomly-spaced transects which are surveyed (flown or skied) when snow-tracking conditions are favorable. All tracks intercepted are back-tracked to their beginning point and forward-tracked to their present location to enumerate individuals. The minimum number of animals detected is determined by counting all tracks intercepted from different individuals. The distance moved by tracked animals perpendicular to the orientation of the transect route allows the probability of undetected animals to be estimated (Becker 1991). As a result, an estimate with statistical error is obtained for that population. This technique is currently being used for wolves, Canada lynx, wolverines (Becker 1991, Ballard et al. 1995, Patterson et al. 2004), and cougars (Van Sickle and Lindzey 1991, Anderson 2003). Assumptions include (1) all tracks that cross a transect route are detected, and (2) tracks can be back- and forward-tracked.

Six different applications of the TIP procedure conducted in Alaska between 1990 and 1992 produced wolf population estimates with 80% CIs that averaged ± 40% of the estimates (range ± 22% to ± 56%). This range was not precise enough to meet the Alaska Department of Fish and Game wolf management objectives (McNay 1993). In addition, the method had rigorous assumptions and was found by experienced wolf survey pilots to be inefficient.

Evaluation: The TIP method is not recommended for Idaho as this method has been recently modified and improved by the SUPE, which addresses many of the shortcomings of the TIP (see below).

2. Subunit Probability Estimator (SUPE)

Recognizing the limitations of the TIP method, Becker et al. (1998) designed a subunit probability estimator procedure for probability sampling of tracks occurring in a network of blocks surveyed by aircraft. The SUPE procedure uses aerial searches for tracks in areas of likely travel by wolves within a block or sample unit (SU) rather than along a transect route, and a stratified sampling approach that is based on whether a pilot and observer team, flying over a particular SU, has a high, medium, or low probability of spotting a fresh wolf track. The estimator and variance are based on probability sampling in the network (Horvitz-Thompson probability estimator). Becker et al. (1998) described the SUPE procedure as a combination of the best aspects of the TIP estimator and the traditional ARS method (Stephenson 1978). The idea of using probability sampling to make inferences about the area of interest comes from TIP, while the use of the travel-route concept comes from the

traditional ARS method. Travel routes and other areas thought to be highly likely to contain fresh wolf tracks are assigned to the high probability category. The study area is partitioned into SUs (1.4 – 41.4 km^2) that are grouped into strata for sampling. A greater proportion of high-probability SUs are sampled. Lower-probability SUs include areas not normally searched for wolves, such as marginal habitats, that may contain lone wolves. A simple random sample of SUs from each stratum is flown 24-36 hours after fresh snow. Similar to ARS, when tracks are located they are back- and forward-tracked, mapped, and the number of wolves making the tracks is determined. Size of the study area and sampling intensity should be large enough so that >8 groups are encountered.

SUPE provided much improved precision (80% CI averaging ± 13%) of the estimated population in 3 applications from 1993-94 (range ± 8% to ± 15%) (E. F. Becker, Alaska Department of Fish and Game, unpublished data). The SUPE method was better accepted by experienced wolf survey pilots and has less rigorous assumptions than TIP. The SUPE procedure works well anywhere that favorable snow-tracking conditions exist in open canopy habitats, or in closed canopy areas with large and frequent breaks. Because the SUPE procedure provides CIs, it can be used to monitor trends in population and density, assuming that the methods are followed as consistently as possible between years. Composition data (adults vs. pups) may also be obtained if observers are briefed on classification methods.

The following assumptions are pertinent when using SUPE: (1) all animals of interest move during the survey, (2) tracks are readily recognizable from aircraft, (3) tracks are continuous, (4) movements are independent of the sampling process, (5) tracks made within and outside of the sampling window (pre- and post-snowfall) can be distinguished, (6) "fresh" tracks in sampling units are not missed, (7) tracks can be followed forward and backwards to determine all sample units containing those tracks, (8) group size is correctly enumerated, and (9) no animals were double counted by moving among sample units on subsequent days. Using concurrently collected radio-telemetry data on 9 wolf packs in their study area, Becker et al. (1998) did not detect any violations of these assumptions. Although promising, successful application of this method in densely forested habitats is uncertain.

Patterson et al. (2004) tested the SUPE method for a forested study area in Ontario, Canada. Sample units (25 km^2) were surveyed using a Bell 206 B Jet-ranger helicopter with a 4-person crew (including the pilot). Observations resulted in an estimate of 87 wolves in the 3,425-km^2 study area (90% CI = 2.5 ± 0.5 wolves/100 km^2). Patterson et al. (2004) reported that the assumption that all tracks are continuous was usually met, even though they occasionally lost tracks in patches of thick conifer cover. When this occurred, they searched the perimeter of the timbered patch until they found the track again or determined the wolves had not exited the patch. Thus, even though they occasionally missed segments of the entire track network left by wolves, they clearly established a 1-to-1 correspondence between all track segments and the animals that made them. Becker (1991) demonstrated that an unbiased estimate could still be made provided that such a 1-to-1 correspondence could be demonstrated.

Given the close correspondence between their SUPE and radio telemetry-based population estimates, and that the statistical assumptions of the SUPE method were met, Patterson et al.

(2004) believed that the SUPE method can provide useful, relatively accurate, and precise estimates of wolf density in forested areas. However, owing to greater forest cover throughout much of their study area, the average length of time to complete each SU using a helicopter was 46 min (range = 23–132 min, n = 45), including time to follow track segments, which was considerably greater than required to survey even larger (41 km^2) SUs from an airplane in Alaska (12–33 min/SU) (Becker et al. 1998). A helicopter will probably be required for inexperienced observers to continuously follow wolf tracks in heavily forested areas. However, there are professional wolf trackers in both the Yukon Territory and Alaska who have demonstrated the ability to efficiently follow wolf tracks through dense cover using airplanes (E. F. Becker, Alaska Department of Fish and Game, personal communication). Using such trackers could increase survey efficiency.

Patterson et al. (2004) noted the cost of deploying radio collars and radio tracking wolves within their census area (2,338 km^2) during winter 2003 was approximately 25% higher than the cost of applying the SUPE method. Because other ecological objectives can be pursued simultaneously with radio-collared wolves, Patterson et al. (2004) could not recommend the SUPE survey method on a cost-savings basis alone. Nonetheless, the SUPE method provided an objective, seemingly accurate, and repeatable means of estimating wolf density with an associated measure of precision. The SUPE method can be employed in some forested areas and may be useful in areas where a non-invasive survey method is required.

E. Jozwiak (Kenai National Wildlife Refuge, unpublished data) concluded that while the SUPE method is cost effective, the technique would not work well in the lowland boreal, closed-canopy forests (white and black spruce forests) on the northern portion of the Kenai Peninsula. In habitats dominated by closed-canopy forests with few openings, aerial snow-track survey procedures are not feasible, and intensive radio telemetry appears to be the only practical means of obtaining reliable wolf population estimates Peterson et al. (1984).

Gratson et al. (2000) applied SUPE in the forested Lochsa and Clearwater regions of central Idaho to estimate cougar numbers. They divided a game management unit into 42 SUs of approximately 20 km^2 each and assigned SUs into 4 probability classes based on distribution and number of elk (*Cervus elaphus*). They flew subunits using a helicopter 48 hours after snowfall. Each SU took 10-12 minutes to fly. They followed cougar tracks until they lost them in the timber at which point they assumed was the cougar location. Forty-two SUs were flown over 2 days. Five cougar groups were detected producing an estimate of 76 cougars with a 90% CI of 8 – 163 cougars or ± 90%. Low precision was related to low sampling effort (10%). Gratson et al. (2000) recommended increased sampling effort and testing the method further.

Anderson (2003) used records of cougar track sets from GPS collars in southeast Wyoming to evaluate accuracy and precision of TIP and SUPE methods from spatial simulations of varying cougar densities, sampling efforts, and number of track-set nights. Interestingly, estimates using the TIP method consistently provided improved accuracy, precision, and reliability over the SUPE method, and the results of simulations suggested cougar population changes of 15-30% could be detected from TIP surveys. Additionally, results of TIP simulations suggested reliable cougar population estimates could be obtained from surveys of

varying degrees of effort (the number of transects and number of times they are run), regardless of cougar density or number of track-set nights. However, time and costs increase with intensity.

Evaluation: Although this method provides high-level resolution data and would address all of the identified monitoring objectives, the intensive field effort required and associated high costs probably make using the SUPE method unrealistic for long-term monitoring of wolves. While this method may not be applicable to areas of dense forested canopies found across much of Idaho, it may be useful in more open landscapes with adequate snow cover.

Minimum Count Methods with Recognizable Individuals

The most accurate density estimates of large carnivore populations are obtained when individuals can be recognized either through natural markings or unnatural marking such as ear tags or radio collars. Statistical methods can be used under these circumstances to provide greater precision and accuracy. These methods provide high-level data resolution and precision, but require intensive field efforts. We evaluated 2 methods in this category, including territory mapping using radio telemetry and genetic analysis.

1. Territory Mapping Using Radio Telemetry

Territory mapping using radio telemetry can be used as a minimum count method with recognizable individuals. Through time, researchers acquire an estimate of the number of recognizable (marked) and unrecognizable (unmarked) animals that inhabit a study area. Presence of unmarked animals is easier to assess with territorial species (Mech 1986, Garshelis 1993). A minimum count population estimate can be calculated as the sum of all marked or recognizable individuals plus those unmarked animals that are known to exist. Although this method is difficult to evaluate because the percentage of animals "missed" (lone wolves) is unknown and no measures of precision are available (but see Fuller et al. 2001), it is widely used in radio telemetry-based research projects for species like black bears *(U. americanus*) (Garshelis 1993), grizzly bears (*U. arctos*; McLellan 1989), wolves (Mech 1986, Ballard et al. 1997), cougars (Lindzey et al. 1992), and Eurasian lynx (*L. lynx*; Breitenmoser et al. 1993). Because many of these research projects have used intensive trapping methods and conducted intensive fieldwork, these estimates are probably the most reliable of any method used.

Because wolf packs are territorial, determining pack size and numbers of packs over a given area provides nearly a total count of wolves; only the number of lone wolves remains unknown. Not surprising then, the most used, tested, and reliable way of estimating wolf density is by capturing and radio collaring members of every pack present in the census region, summing estimates of pack sizes, adding estimates of lone wolves in the area, and dividing by the area of the census region (Peterson et al. 1984, Mech 1986, Ballard et al. 1987, Fuller and Snow 1988, Fuller 1989, Ballard et al. 1997, Kunkel and Pletscher 1999). Although lone wolves may comprise up to 30% of a winter population, some researchers have ignored them (Fritts and Mech 1981, Peterson et al. 1984, Mech 1986). Although this technique is the most reliable for estimating wolf density, it is relatively expensive, invasive, and difficult to apply over a large area (Dale et al. 1995)

Methods for estimating wolf populations over large areas using radio telemetry are available. Large areas can be stratified into low, medium, and high strata of relative wolf densities based on a combination of known relative wolf densities, estimates of prey density, and human density (Fuller and Snow 1988). Strata can then be subdivided into quadrats large enough to include a minimum of 4-5 wolf packs, ≥ 2 sample quadrats can be selected randomly within each stratum, and ≥ 2 wolves marked in each pack within the selected quadrats (Fuller and Snow 1988). Strata boundaries are defined by pack territory boundaries, and densities are estimated from minimum counts of pack sizes. Different sampling designs using this method can then be tested for statistical efficiency (i.e., determining the minimum number of marked packs needed to document population changes of a given magnitude). If areas between radio-collared packs are large enough to contain wolf packs, ground and aerial checks can be used to determine if an unmarked pack is present. Fuller and Snow (1988) indicated that 30-35 radiolocations annually should be enough to determine pack size and territory boundaries. Once again, the cost of an aircraft to delineate territories is a major constraint (Burch 2001).

Estimating wolf numbers using the territory mapping method is problematic when wolf populations fluctuate and large areas of unknown wolf pack status exist. Population fluctuations can occur when wolves are recolonizing new areas or when wolf pack turnover is high (short pack persistence) due to disease, removal through management actions, or other reasons.

Although several authors have expressed confidence in their estimates (e.g., Mech 1977, Fuller 1989, Hayes and Harestad 2000), it remains difficult to statistically quantify the uncertainty surrounding radio telemetry-based population estimates. Underestimating territory size will result in biased high density estimates (Fuller and Snow 1988). Potvin et al. (In Press) indicate that home ranges based on 30 radio locations underestimate actual territory size by 100% and concluded that 126 radio locations were required for estimating 80% of the year-round territory size. Using satellite collars in Alaska, (Ballard et al. 1998) also found that techniques employed in most studies grossly underestimate the extent of pack territories. Fritts and Mech (1981) reported that a mean of 80 radiolocations was required to describe territories of an expanding wolf population in Minnesota. Potvin et al. (In Press) estimated territory size for radio-collared wolf packs based on calculating asymptotes for observation/area curves used by Ballard et al. (1998). This technique avoids the need to adjust for interstitial space between territories. On average, territory size determined by this method was 20% larger than determined by other statistical methods using radio telemetry data.

Burch (2001) assessed the effects of radiolocation sample size on estimated wolf density in Denali National Park, Alaska, using the territory mapping method. He found that low numbers of radiolocations could result in significantly higher wolf density estimates. This effect was reduced if more packs were monitored. Burch (2001) estimated that at least 6 adjacent wolf packs should be monitored to adequately determine density. Simulation results showed that increasing annual radiolocations from 30 to 40 per pack produced a 3% increase in population area for 11 packs monitored and a 5% increase for 5 packs monitored. Monitoring effort should increase by ≥ 5 radiolocations per year per pack for every pack

below 6 being monitored. Because it can be expensive to obtain adequate sample sizes annually, it may be necessary to combine data over multiple years. Burch (2001) recommended maintaining consistent radiolocation effort among years. If this is not possible and density estimates are significantly correlated with radiolocation effort, then regression results may be useful to standardize density estimates to a common level of radio tracking. Finally, when reporting wolf densities, Burch (2001) suggested thoroughly describing methods, assumptions, and radiolocation efforts so others can evaluate the results. It is important to report the number of radio locations/pack, the number of packs involved, and a thorough description of methods and assumptions for estimating the population.

Evaluation: Territory mapping using radio telemetry is one of the most effective ways to monitor wolf populations. In addition, it has benefits in providing useful ancillary ecological data for wolf management. However, as previously mentioned, required field effort and associated costs of this method are not realistic for statewide, long-term wolf monitoring.

2. Genetic Analysis

Recently developed methods allow DNA to be extracted from hair and scat (Taberlet and Bouvet 1992, Wasser et al. 1997). Extracted DNA can be used to determine species, sex, and individual identity of animals (Taberlet and Bouvet 1992, Foran et al. 1997*a,b*; Paxinos et al. 1997, Kohn et al. 1999). Because individuals can be identified, population size can be estimated based on minimum counts and mark-recapture methods (Kohn et al. 1999, Woods et al. 1999).

By back-tracking wolves during winter, Lucchini et al. (2002) collected scats from wolves in the Italian Alps. Based on spatial and temporal locations of individual genotypes and kinship analyses, they determined that 2 distinct packs of closely related wolves, plus some unrelated individuals, ranged in the study areas. These results were in agreement with field observations. They recommended scats be collected in winter so the samples are better preserved for analysis. Additionally, scats collected in summer, primarily from roads and trails, were largely only from dominant pack members.

Kohn et al. (1999) collected 651 coyote scats during a 2-week period along 6 transects in a 15-km^2 area in California. They randomly drew scats from this sample for genotyping until 30 consecutively analyzed scats yielded only 1 new genotype. They projected the coyote population size as the asymptote of the function $y = (ax)/(b + x)$, where "y" equals the cumulative number of unique genotypes, "x" is the number of scats sampled, and "b" is the rate of decline in the value of the slope. Iterative nonlinear regression was used to estimate 95% CIs. Forty-eight percent of the 238 scats randomly selected were successfully typed. They estimated the population as 38 (95% CI = 36-40 coyotes, or ± 5%). They also used a mark-recapture estimator for the same collection of scats and produced a population estimate of 42 coyotes (95% CI = 38-45 coyotes, or ± 9%).

Kohn et al. (1999) concluded that the collection and genotyping of scats allowed a relatively instantaneous point count because scats decay rapidly. The sampling effort was lower than for trapping and radio collaring efforts and provided detection of a larger fraction of the population than obtained from trapping or remote cameras. More coyotes were detected by

scats than by trapping, probably due to the large turnover in the exploited coyote population and the difficulty of capturing coyotes. Their results suggested that 67% of the coyote population might have been missed by their long-term ecological surveys based on trapping. The DNA methods they used to estimate population numbers (mark-recapture and asymptote), however, assumes equal defecation rates among sex and age classes, an assumption that does not appear to hold for wolves (Lucchini et al. 2002). This assumption is less important if packs rather than number of individual wolves are enumerated.

Bellemain et al. (2005) used hunters to collect brown bear scat in a 39,000-km^2 area of Sweden. Hunters collected 800–1,000 scats each year of which 70-80% could be amplified**.** Depending on the estimator used, population estimates (for each year and by sex) ranged from 150-350 bears and 95% CIs ranged from ±33% - 50%.

Primary disadvantages of genetic sampling are (1) high cost, (2) significant field effort, and (3) genotyping errors that require more expensive methods (Waits et al. 2001). In the past, a lab artifact called allelic dropout has limited this technique. Allelic dropout is caused by low quality and low quantity DNA extracted from hair and scat, however, it can be controlled by either repeating the sample multiple times, quantifying the DNA prior to use, or, if multiple samples are available per individual, using several computer-based algorithms to identify samples with potential dropout (M. Schwartz, U.S. Forest Service, personal communication). Costs will vary depending on sampling scheme, allelic dropout rates, and monitoring objectives. A method for using DNA to estimate minimum counts of wolves would reduce needed sample sizes and costs. A sampling design aimed at enumerating packs rather than individuals would further reduce required sampling effort and cost.

Evaluation: This method shows promise for increasing the precision and level of resolution of estimates obtained from scat surveys to fully address monitoring objectives. Field logistical constraints previously identified for scat surveys also apply to this method. Cost of DNA analysis applied statewide may be a limiting constraint and further research is needed to assess sampling designs and efficiency of the method. To date, this technique has only been tested over relatively small areas. If large samples of scats can be collected along roads, however, the technique holds potential to work over larger, accessible areas.

Demography

Measuring population demographics such as survival, reproduction, emigration, and immigration, provides managers with information needed to assess causes of observed population trends. In combination with methods that estimate absolute abundance, demographic information provides the most useful and precise information for population size, trends, and understanding reasons for observed trends. However, measuring population demographics is also the most intensive approach and is realistically only feasible for research-oriented efforts applied over a small area. The most commonly used method for obtaining these types of data is radio telemetry.

The ultimate goal of population management is to implement effective management strategies in response to observed trends. Determining population density and trend alone does not provide information about the causes of observed trends. Estimates of population

demographic parameters are the most difficult to obtain, but also the most useful. When estimates of reproduction rates are combined with cause-specific mortality rates (e.g., from a sample of radio-collared animals) population trend can be modeled and factors affecting trends can be determined (Eberhardt et al. 1994, Wydeven et al. 1995, Pletscher et al. 1997, Kunkel and Pletscher 1999).

Knowing why populations are increasing or decreasing allows managers to apply the appropriate management prescriptions. Estimating population parameters using a demographic approach is suitable when the primary management objective is to determine cause-and-effect relationships in population trends to facilitate effective population management (Eberhardt et al. 1986, Eberhardt and Knight 1996). Such approaches have been used for bear populations, perhaps because bear populations are so hard to enumerate using other methods (Garshelis 1991, Hovey and McLellan 1996, Saether et al 1998). This method may require years of intensive data collection to accurately determine population trend.

1. Measuring Population Demographics Using Radio Telemetry

Pletscher et al. (1997) conducted intensive radio telemetry efforts on a population of recolonizing wolves in northwest Montana from 1984-1995 and estimated rates of wolf survival, reproduction, emigration, and population trend. The wolf population consisted of 3-4 packs in a 3,000-km^2 study area. Continuous annual trapping efforts were employed through summer to maintain 2-3 instrumented individuals in each pack. Pup production estimates averaged 4.5 ± 0.5 pups. Overall 95% CIs for survival rate estimates were 73-87% based on 52 radio-collared wolves and 29 radio-collared wolf mortalities over approximately 46,000 radio-location days. Cause-specific mortality rates (95% CIs) varied at most by 5%. Based on these rates, they estimated lambda (finite rate of change) at 1.20. These demographic estimates allowed the authors to demonstrate that human-caused mortality was not limiting wolf recovery in northwest Montana, as long as some wolves were protected in core areas. Smith et al. (2004) have done similar work in the Greater Yellowstone Area and recently these data have been incorporated into a region-wide estimate of wolf survival (D. Murray, Trent University, unpublished data). Such studies have determined that human-caused mortality is the primary mortality factor for wolves in the Northern Rocky Mountains.

<u>Evaluation</u>: This method is cost prohibitive for a long-term conservation and management framework and is not practical for statewide, long-term monitoring of wolves. This approach may be applied in a research context to address local management concerns.

<u>Monitoring Methods not Evaluated in Detail</u>

We did not evaluate some methods found in the literature because they had limited application to wolves. These methods are briefly summarized below.

1. Thermal Infrared Imagery

While thermal infrared imagery (Havens and Sharp 1998) appears to have promise for some species, the technology is currently not developed enough to apply over large areas.

2. Catch-Per-Unit-Effort
Catch-per-unit-effort does not appear useful for wolves because standardization of capture procedures and variation among individual trappers would cause problems in interpreting results. Expected small sample sizes would also be problematic. This method was poorly correlated with density for swift fox, even when large sample sizes were obtained (Schauster et al. 2002). We are not aware of cases where this method has been applied to wolves.

3. Den Counts
Wolf dens are usually too difficult to find systematically in most habitats.

4. Aerial Line Transects
Aerial line transect methods require open regions like the arctic, and even there, these methods were problematic for wolves (Miller and Russell 1977).

5. Mark-Recapture
We are not aware of cases where mark-recapture methods have been successfully applied to wolves. Wolves have no natural definitive markings, thus requiring capture and handling to mark individuals (e.g., ear tags or radio collars). Additionally, mark-recapture is less efficient than other methods for territorial and pack animals where enumeration of individuals is less important. Because wolves use roads and trails, remote cameras used for "recaptures" could be placed along wolf travel routes with baits or lures, similar to methods used for trapping. Using remote cameras could determine territory size, however, wolves would initially need to be trapped and marked so that individuals could be identified. And, once wolves are captured, it would be easier to radio collar them and use the territory mapping method to estimate populations.

6. Bio-Markers
Tetracycline can be used as a bio-marker because it binds to bones and teeth and is visible under ultraviolet light for several years after being administered (Garshelis and Visser 1997). The disadvantage is that the animal must be dead before it can be examined. This method is currently being tested in Idaho for black bears and it may have application to wolves, but only after populations are large enough to sustain harvest.

DISCUSSION

Monitoring wolf population status, trend, and distribution will be an important part of a successful Idaho wolf management program. Monitoring will be particularly important to address identified management goals and objectives, including ensuring that minimum population levels are maintained, addressing wolf-ungulate interactions, , and regulating the harvest of wolves. Developing an effective wolf monitoring program will be a challenge as it must reflect wolf management goals, provide for appropriate levels of information needs, be tailored to unique ecological and management aspects of wolves, and address Idaho landscape and climate constraints.

Management Goals and Levels of Information Needs

An effective monitoring program should be based on identified management goals. In addition, objectives of a successful monitoring program must be clearly identified to facilitate appropriate selection and application of monitoring methods (Goldsmith 1991, Noss and Cooperrider 1994, Sutherland 1996, Linnell et al. 1998, Gese 2001, Karanth and Nichols 2002). Because management goals dictate information needs (e.g., required level of data resolution and precision of estimates) they drive selection of appropriate monitoring methods. Appropriate monitoring methods, in turn, dictate required levels of monitoring intensity (operational requirements in terms of logistics, cost, effort, and time). In general, information needs requiring higher levels of data resolution and precision require monitoring methods that are more intensive. Levels of resolution include (in ascending order of precision and monitoring intensity): (1) determining presence, absence, and distribution; (2) estimating relative abundance using direct and indirect indices; (3) estimating absolute abundance; and (4) estimating population demography. Often times, the monitoring method and level of data resolution required to meet objectives must be balanced against realistic considerations of implementation cost and field effort.

Information needs vary for Idaho monitoring objectives. The State of Idaho and the Nez Perce Tribe anticipate that appropriate management goals and direction for long-term conservation of wolves will likely change through time, according to the conservation status of wolves. Management direction should reflect the current status of the wolf population, being more conservative at lower population levels approaching the minimum relisting threshold, and more liberal at higher population levels to effectively address social concerns. Less intensive methods may be used to document population levels above the minimum relisting threshold, while more intensive methods will be necessary to determine annual population trends and 5-year population estimates. Our recommendations for potentially applicable monitoring methods reflect the range of information needs for identified monitoring objectives.

Appropriate levels for alpha, power, precision, sample size requirements, survey design, and statistical assumptions of each survey method should be considered before implementing a monitoring program (Lancia et al. 1996, Reed and Blaustein 1997, Van Strien et al. 1997). We used information from Beier and Cunningham (1996) and Zielinski and Stauffer (1996) to establish recommended levels of alpha, power, and precision for meeting the identified monitoring objective of determining annual wolf population trends in Idaho.

Intrinsic ecological parameters, such as population viability, level of resilience, and population threats can influence the appropriate levels of data resolution, precision, and monitoring intensity needed. For example, small populations have lower resilience and impacts of potential threats (e.g., exploitation, human disturbance, loss of habitat) have greater consequences, increasing the need for monitoring methods that provide higher levels of data resolution and precision to detect population declines in time for corrective management. In such cases reducing the probability of a Type II error (failing to detect a change) is paramount and power of selected methods should be maximized. However, consequences of a Type I error still remain important, even as wolf populations increase. It

is important to implement statistically rigorous monitoring methods to ensure responsible management of wolves, reduce conflict, and maintain credibility with affected publics. We adopted Beier and Cunningham's (1996) recommendation of setting α at 0.10 as an appropriate acceptance level of a Type I error.

In assessing feasibility of using track surveys for monitoring trend in cougar populations (a common predator in Idaho), Beier and Cunningham (1996) believed that, in general, 80% power is a reasonable goal for managers. These authors further reasoned that because surveys designed to detect small changes (10-20%) would be prohibitively expensive, and because management actions are unlikely unless larger changes occur, monitoring methods that are able to detect changes in the range of 30-50% were reasonable for cougars. Although wolves are resilient (Weaver et al. 1996), because of their conservation status and the political nature of wolf management**,** we contend a more conservative goal to detect population changes would be appropriate.

Zielinski and Stauffer (1996) concluded that for fishers (*Martes pennanti*), a relatively rare forest carnivore in California, surveys that could detect a 20% change with 80% power were optimal. Lower power would result in real changes going undetected, while increases in power above 80% are gained at high costs. Considering these authors' recommendations and the management needs for wolves, we concluded that being able to detect a 30-40% change with 80% power would be appropriate for wolves in Idaho.

Ecological and Management Aspects of Wolves

Wolves inherently occur at relatively low densities. This implies that sample units established for monitoring populations must be relatively large so they contain individuals, or sign left by individuals, at the time of the survey. Even then, there will be many zero values and low absolute values, factors that introduce large variances into estimates of abundance. Carnivore density may also vary greatly across relatively small distances, for example across a recolonization front of an expanding species (Swenson et al. 1998), making the choice of sampling area crucial (Smallwood and Schonewald 1998**,** Smallwood 1997). Idaho's rugged terrain, forested cover, and difficult access will compound these inherent problems, increasing the difficulty of developing reliable, efficient, and inexpensive population monitoring methods.

While large carnivores, as a group, are relatively difficult to monitor, wolf social structure and territorial behavior make this species one of the easiest of this group to monitor. Because wolves live in packs of several animals, are territorial, and travel widely, their presence is readily detected through sign including scats, tracks, and howling. Packs, rather than individuals, are the functional ecological unit at which estimators should be aimed; and enumerating packs is easier than enumerating individuals. The territorial nature of wolves facilitates delineation of distribution, which can remain relatively constant over time. Territoriality results in a clumped wolf distribution, so once a pack's territories is identified, there is no need for additional survey work throughout that territory.

Wolves are probably the most resilient of the large carnivores because of their high reproductive and dispersal rates (Weaver et al. 1996). Wolf populations can withstand high levels of annual mortality, ranging from 20-50% without decline, reducing the need for precision in population monitoring (Fuller et al. 2003). Wolves can generally recover quickly from population declines, depending on the initial population level.

Wherever wolves have been studied, the primary limiting factor has been human-caused mortality resulting from lethal wolf control, and legal and illegal harvest (Pletscher et al. 1997, Fuller et al 2003, Mack and Holyan 2004, USFWS 2004). Therefore, intensive research aimed at examining cause-specific mortality rates, or other demographic parameters, may not be generally needed to determine the remedy for a decline in wolf numbers. Reducing human-caused mortality to the extent possible may be the best management direction for addressing a declining trend in wolf numbers. This may mean that wolf managers become more conservative in lethal removal of wolves to address wolf-livestock conflicts and become more aggressive in public education to increase tolerance for wolves. A secondary limiting factor can be prey density (Fuller et al. 2003), and significant prey declines may also influence wolf populations. Therefore, assessment of prey abundance and trends yields much information on potential wolf populations and trends.

Because hunters have the ability to dramatically reduce large carnivore populations (Swenson et al. 1994; Breitenmoser 1998), more precise monitoring information is needed when large carnivores are harvested, controlled for livestock depredations, and/or illegally killed at high rates, than when they are protected. Large carnivore harvest requires careful monitoring if carnivore populations are low and quotas (hunting quotas or determination of maximum allowable total mortality) are to be sustainable. Effective quota setting can be achieved in 2 ways. First, if precise population estimates exist, and population dynamics are understood such that the harvestable portion of the population can be calculated, an appropriate harvestable quota can be calculated. Second, if population estimates are lacking, an acceptable quota can be set through a process of trial and error by monitoring the response of an abundance index to various quotas (Logan and Sweanor 2001). Preferably, both methods would be used to support each other. Because our knowledge of large carnivore population dynamics and resilience is limited (Weaver et al. 1996), we must use caution. The closer a quota is set to the maximum sustainable yield, the more precise the information must be to prevent over-harvest. In Idaho, more precise and reliable information beyond basic trend will be required to determine whether harvest can be initiated, if and how wolves are affecting prey, and what management should be taken in response.

Required precision decreases greatly if effective refuge areas exist (areas with little or no harvest). Refugia act as “reservoirs” providing a source of dispersing animals. Animals dispersing from refugia recolonize areas of extirpation, either naturally or with human assistance, increasing overall population stability. Refuge areas have been advocated on a theoretical basis in recent years (McCullough 1996), and are used for managing black bears and Canada lynx in some parts of North America (e.g., Powell et al. 1996, Slough and Mowat 1996). Because carnivores generally have large territories and reside at low densities, these refuges need to be very large (Woodroffe and Ginsberg 1998).

Idaho Landscape and Climate Constraints

Our analysis indicated that, for Idaho, it is likely that no one monitoring method will be applicable statewide across all landscapes. Aerial methods may be limited over much of Idaho's densely forested regions. Large inaccessible and forested wilderness areas may be difficult to survey from the ground or air. In addition, inconsistent snow cover on many of Idaho's low elevation ungulate wintering areas may preclude winter survey methods. These unique and varied landscape and climate constraints will add to the challenges of developing an effective monitoring program.

Developing standardized protocols and obtaining monitoring data of equal data resolution and precision statewide may not be feasible. More intensive methods, providing higher levels of data resolution and precision, may only be feasible in more open and accessible landscapes and/or in small regional areas with heightened management concerns. In inaccessible wilderness areas, less intensive methods, providing lower levels of data resolution and precision, may be the only option. Fortunately, since potential for conflict is lower in wilderness areas, management information needs may not be as great as for other areas across the state.

Based on our assessment of monitoring methods and considering management, statistical, ecological, and landscape factors unique to Idaho, we have concluded that a coordinated package of methods used in combination is the best approach for monitoring wolves across Idaho. We recommend a suite of methods for each identified monitoring objective that we feel holds the best promise for addressing that objectives across Idaho's varied landscape.

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

The best overall method for monitoring wolves remains the territory mapping method using radio telemetry (Mech 1986, Fuller and Snow 1988). Advantages of this method include (1) it addresses all identified monitoring objectives for Idaho; (2) it increases monitoring effectiveness by taking advantage of biological characteristics of wolves (territoriality and pack social organization); (3) complete counts of packs in a project area can be obtained; (4) data on wolf demography (e.g. survival, reproduction, etc) and factors affecting demography can be obtained simultaneously; (5) it facilitates research on ecological relationships, including affects of wolves on prey; (6) it facilitates managing wolf-livestock conflicts, determining and addressing illegal take of wolves, and documenting connectivity between the northern Rocky Mountain region; and (7) it is not limited by snow, terrain, land cover, or access concerns.

As indicated in the justification for our review however, this method is not cost-effective for statewide long-term monitoring of wolves in Idaho, so other methods are needed. An appropriate selection of monitoring method(s) will depend on (1) current status of wolves, (2) monitoring objectives identified, and (3) landscape and climate constraints unique to Idaho.

At low wolf population levels approaching the relisting threshold, monitoring techniques and level of management will need to intensify. Methods should be used that provide greater precision and higher levels of resolution needed to detect small and immediate changes in population status to avoid population relisting. At higher population levels, monitoring precision and resolution can be relaxed as larger long-term trends or changes in population levels are more of interest.

Monitoring objectives we identified for Idaho can be addressed using a variety of methods. Additionally, some short-term objectives, such as documenting annual population distribution and minimum population threshold levels, require less intensive methods than other objectives such as detecting population trend or estimating wolf population size. Population simulations similar to those done by Beier and Cunningham (1996) should be conducted for various survey methods for wolves in Idaho.

Idaho landscape and climate constraints will limit the application of methods. The varied terrain, land status, access, and snow cover across Idaho precludes statewide application of most methods, and will influence the geographic area of application and precision of results for methods evaluated. The combination of low access and heavy forest cover across much of Idaho is most problematic.

Because no single method, outside of radio telemetry, will (1) remain applicable in the face of changing wolf population status and monitoring needs, (2) address all identified monitoring objectives, or (3) be applicable statewide, an effective wolf monitoring program in Idaho should consist of a suite of different and integrated methods. For example, minimum counts may be much more useful for detecting trends if they are supported by an independent index. An index, such as track counts, will provide a robust indication of the trend of the population, while the supporting minimum count will provide an indication of the actual number of individuals. Although some indices may have a large degree of variation, if several indices indicate the same trend, it is likely that the trend is real. If a suite of monitoring methods are carefully designed and integrated, it should be possible to use available information in several ways to provide robust data on population distribution, size, and trend.

Maintaining management databases are also important for effectively monitoring wolves. Collected information on cause-specific wolf mortality, wolf depredations, wolf harvest, wolf reports from the public, and pack histories will help to identify patterns of concern and support management decisions. Information contained in management databases can also be used to augment population trend information.

Recommendations for Monitoring at Low Population Levels

Tribal and State (Idaho and Montana) wolf management plans identify the need to ensure a minimum wolf population above a relisting threshold–that population level below which the wolf population may again be considered endangered and relisted under the protection of the Endangered Species Act. Minimum population levels have been variously defined between 15 and 25 wolf packs (Idaho Legislative Wolf Oversight Committee 2002, Montana Fish,

Wildlife and Parks 2003, Nez Perce Tribe 2004). At population levels approaching minimum threshold levels, we recommend that territory mapping using radio telemetry be the primary method for monitoring wolves in Idaho. Use of radio telemetry is the only way to detect and identify causes of small changes in time for corrective action to ensure population viability.

Recommendations for Addressing Primary Monitoring Objectives

Objective 1. Maintain Minimum Population Level above Federal Relisting Threshold
The USFWS requires monitoring the wolf population in Idaho for 5 years after delisting to ensure that state and tribal wolf management will maintain wolf populations above an anticipated minimum relisting threshold of 10 wolf packs (Idaho Legislative Wolf Oversight Committee 2002). At population levels well above the relisting threshold, monitoring can be accomplished using a variety of low effort methods, as complete population counts or estimates are not needed. Low effort methods can be as simple as conducting howling or reproductive surveys in areas of suspected or known wolf pack territories, or otherwise verifying information received from questionnaire results, reports from the public, wolf depredation incidents, and incidental observations by agency biologists through the year. Information needed to address this objective will likely be collected during ongoing wolf management activities requiring little additional specific effort. For populations well above the relisting threshold, no additional specific recommendations are included here, as methods employed to address more intensive monitoring objectives will also serve to address the minimum population objective.

Objective 2. Estimate Annual Wolf Population Trend
Estimating annual changes in population trend is central to responsible and responsive wolf management. Population trend information will be important to facilitate appropriate management direction and decisions regarding regulating wolf harvest, addressing wolf-ungulate concerns, reducing wolf-livestock conflicts, and long-term wolf conservation.

Documenting annual trends in population numbers will require implementing statistically rigorous monitoring methods employing standardized and statewide protocols. In addition, no single monitoring method appears to be applicable across all Idaho landscapes and under existing weather constraints, requiring a suite of coordinated methods or hybrids of methods to assess statewide trends.

We recommend evaluating 3 different index methods to address our proposed objective of detecting a 30-40% population change with 80% power at the 90% CI level ($\alpha = 0.10$). In priority order they are: (1) hunter questionnaire, (2) winter track survey, and (3) summer scat survey. These combined methods were, in part, recommended because overlapping methodology, particularly between scat and track surveys, facilitates simultaneous evaluation of these methods, and results from these indices may be used to obtain population estimates when correlated to known densities of wolves.

1. Hunter Questionnaire

We recommend developing a questionnaire that solicits input from big game hunters, hound hunters, and outfitters and guides. This method is recommended because it has been found to be precise for detecting trends, it can be used to obtain minimum count population estimates if relationship between index and wolf density is determined, it is relatively cheap to implement, and it can be applied statewide (Crete and Messier 1987). Information from hunter questionnaires can also support determination of wolf distribution and occupied range and help focus more field intensive efforts such as documenting pack presence and status. The state of Idaho currently administers a mandatory statewide reporting program for all hunters holding Idaho big game and trophy tags, and a hunter survey specific to wolves could be incorporated into this program.

While testing the reliability of this method, Crete and Messier (1987) found hunter questionnaires could provide an index of trend within a level of precision of < ± 40%. Precision could be increased through a partnership with outfitters and guides, providing training to correctly identify, record, and report wolf sign. Questionnaires could also be expanded to other user groups, such as backpackers, to supplement data gathering in geographic areas of low hunter use.

Crete and Messier (1987) also showed that this method could be used as a population estimator when the relationship between the index and population density was determined through regression analysis. The resulting regression equations provided reasonably precise (< ± 40%) population estimates when compared to known densities of wolves determined by radio telemetry methods. We recommend using an approach similar to Crete and Messier (1987) to evaluate the potential for using hunter surveys as a secondary population estimator method.

2. Winter Track Survey

We recommend developing and evaluating the potential for using track surveys focused on ungulate winter ranges. During winter, ungulates concentrate in low elevation wintering areas comprising a small percentage of their annual range. Wolves also concentrate their activities within these wintering areas, reducing the geographic area required to survey. Wintering areas can be surveyed with track searches from the ground or air, possibly in conjunction with IDFG winter ungulate surveys. Number of tracks at adjacent winter ranges can be compared following rules of Potvin et al. (In Press) and Wydeven et al. (2004) to enumerate packs. Depending on initial tests of this method, it may provide an index, minimum counts, or density estimates. When conducted aerially in inaccessible areas of the state, this method may only serve as an index, although we recommend testing whether wolf tracks could be backtracked from the air to obtain minimum counts. In remote areas where cover proves limiting for aerial methods, wolves could be backtracked on the ground using intensive short-term field efforts with a team of trackers flown into remote winter ranges. Once territories become known, surveys become more efficient.

This method is recommended because it meets our precision criteria for this objective, may be used to obtain population estimates if the relationship between index and wolf density is determined, and it is relatively cheap to implement. However, cost and sampling effort are

higher compared to implementing hunter surveys. In addition, this method requires adequate snow cover on wintering areas and will be more difficult to apply in remote and inaccessible areas.

3. Summer Scat Survey

We recommend developing and evaluating a scat survey method because it provides precise estimates of trend, may be used to obtain population estimates if the relationship between index and wolf density is determined, it provides a data collection protocol for other potential population estimation methods such as DNA analysis**,** has low implementation costs, and has broad geographic application. Crete and Messier (1987) have shown that, given substantial field effort, this method could provide trend information with sufficient precision to meet our requirements. Enlisting volunteers and adjusting acceptable levels of precision could help to address added field efforts required by this method. As with track surveys, summer scat surveys may be used to obtain population estimates if the relationship between index and wolf density is determined.

Crete and Messier (1987) found that a scat index had the best precision of 5 indices examined when related to known wolf density ($r^2 = 0.90$; CI = ± 22%). As with all indices, however, large sample sizes were needed for reliable and precise estimates. We recommend using an approach similar to Crete and Messier (1987) to evaluate the potential for using scat surveys as a secondary population estimator for Idaho. In addition, collecting samples of scats observed during surveys could be used for DNA analysis to facilitate minimum counts and open mark-recapture methods by identifying individuals and pack affiliations. Hunters have been used effectively to collect scat samples over large areas for DNA analysis (Bellemain et al. 2005).

While implementation cost and field effort for this method are relatively low compared to many other methods evaluated, this method involves substantial field effort with higher costs and sampling effort compared to track surveys or hunter surveys. And, although geographic application is broader than some methods evaluated, application is limited in remote inaccessible areas.

4. Implementation

Each method selected for evaluation has unique application limitations, requiring a combination of coordinated methods to provide statewide population trend information. Although the hunter survey method can provide close to statewide application, the inability to verify authenticity of reports and resulting unknown bias of the estimate precludes use of hunter surveys as a primary method. Although both track survey and scat survey methods are capable of producing high precision information, both have application limitations related to landscape and weather constraints. Winter track surveys are best applied in areas of good winter access and require consistent snow cover with good tracking conditions. Unfortunately, many low-elevation ungulate wintering areas in Idaho are located in remote, inaccessible areas and lack the optimum snow conditions required of this method. Although summer scat surveys are not as affected by weather constraints and generally have potential for broader geographic application than track surveys, they are still limited by access and require substantial field effort.

To determine the most applicable and efficient combination of methods to obtain statewide wolf trend information, we recommend first evaluating winter track and summer scat surveys for precision, cost, and geographic application in Idaho. Once the evaluation is completed, a determination can be made as to which method(s) is most appropriate as a primary index to annual population trend. Concurrently, we recommend developing and evaluating a statewide hunter survey as a secondary population trend index. Validation and calibration of bias associated with the hunter survey can be done by comparing hunter survey results with sign surveys results in areas where both methods are being evaluated. Finally, evaluate application of calibrated hunter surveys to geographic areas not covered by primary index or indices.

Objective 3. Estimate Wolf Population Size on a 5-Year Basis

Estimating wolf population size is the most important monitoring objective to address identified management goals and ensure continued effective conservation and management of wolves in Idaho. Unfortunately, population estimation methods are effort-intensive and expensive. Implementing these methods on an annual basis is probably cost prohibitive for most monitoring programs. Therefore, we recommend estimating wolf population size once every 3-5 years (more often at low population levels near the relisting threshold), coupled with annual trend indices as outlined above, to reduce costs. Periodic population estimates can validate observed trends in annual indices, while annual indices will provide important trend information between population estimation intervals. This approach will provide wolf managers with frequent high-resolution data required for responsive management decisions.

Because of landscape and weather constraints in Idaho, population estimate techniques, alone or in combination, may only be partially applicable or not applicable at all. A hybrid approach including a suite of other non-population estimate methods maybe needed to develop a reliable statewide population estimate protocol, similar to the method used in Minnesota (Fuller et al. 1992).

We recommend evaluating 3 population estimation methods, including GTS, ARS, and SUPE, although we recognize that aerial survey methods such as ARS and SUPE may have limited application in Idaho. Again, we recommend evaluating a hybrid approach as is done in Minnesota (Fuller et al. 1992).

1. GTS

We recommend evaluating the application of a GTS method focused on ungulate wintering areas. This method has the potential to meet this monitoring objective, and has been proven efficient and successful in the Midwestern U.S. However, this method does not provide a measure of precision when used alone and may be limited in remote areas with limited snow cover. We recommend testing and comparing the efficiencies between statewide sampling versus stratified sampling similar to Michigan's approach (Potvin et al. In Press). We also recommend determining the most efficient monitoring period (e.g., annual, biannual). The Minnesota method is less field intensive than the Wisconsin method because it relies on extrapolations based on occupied range rather than identifying individual territories. Identifying individual territories often requires repeated survey efforts to confirm territories. Such intensive efforts are difficult in remote areas of Idaho and where territories are large.

Lack of snow cover in the southern portions of the state, and access and forest cover in large wilderness areas may challenge application of this method. Where snow cover is limiting, timing of surveys may help resolve problems, or other non-snow dependent methods (e.g., scat surveys [collecting scats for genetic analysis], howling surveys) may help to supplement this method.

Where access is limiting, supplemental short-term, field-intensive ground efforts, combined with aerial efforts and a sampling approach, could be tested. Habitat evaluation, aerial searches, and information obtained from guides and hunters during hunting season might provide indications of where to focus intensive ground search efforts during winter. Intensive ground tracking efforts could include volunteers, hunters, and professional resource agency staff to reduce implementation costs and increase the area surveyed. Should ground or aerial efforts not prove feasible in wilderness areas, wolf density in these areas may have to be extrapolated, based on territories derived from radio telemetry data and habitat evaluation in the remainder of the state (Fuller and Snow 1988, Fuller et al. 1992). This method becomes even more efficient if wolf territories are known and can be rechecked in following years. Visits to these territories in subsequent years may quickly indicate if packs are still present and the percentage of territories still occupied could be developed into a long-term monitoring index.

2. ARS and SUPE

We recommend conducting pilot studies to test the feasibility of using the ARS and SUPE methods for monitoring wolves in both open- and closed-canopy landscapes. These methods meet our population estimate objective, produce high precision estimates, and could be applicable in wilderness areas with difficult ground access. However, these methods are more costly than GTS to implement and require further field testing for application in Idaho. Before committing to extensive field evaluation efforts, we recommend consulting professionals with prior experience employing these methods in forested mountainous terrain, including pilots from Alaska and biologists from Alberta, Minnesota, and Ontario. By comparing Idaho's landscapes with those they are familiar with, these experienced professionals will provide a good first-step evaluation for potential application of these methods to Idaho. Depending on the results of an initial evaluation by experienced professionals, limited field testing of these methods in more favorable areas of Idaho may help determine overall potential for statewide application. Limited testing of SUPE for cougars in heavily forested areas of central Idaho (Gratson et al. 2000) indicated the method may hold promise for wolves. Placing GPS collars on wolves and intensively mapping their tracks in various habitats may help determine if these methods can be applied in Idaho (Anderson 2003).

3. Hybrid Approach

In the event that no single or combination of standard methods described above prove applicable to Idaho, a hybrid approach, combining different types of survey and non-survey data from multiple sources, may be the only practical means of estimating wolf populations. We recommend developing and evaluating a hybrid approach similar to that employed by Minnesota (Fuller et al. 1992) that relies on different techniques depending on regional access, snow cover and forest cover.

Objective 4. Estimate Occupied Wolf Range

No specific additional methods need to be implemented to address this objective. Summarizing annual results of population trend indices, primarily hunter surveys, combined with information contained in management databases (see below), primarily livestock depredation, wolf harvest, and wolf observation reports databases, will provide a good estimate of occupied wolf range in Idaho. Habitat evaluation methods may be employed to predict potential occupied wolf range and to focus field efforts in areas of unknown wolf activity.

Recommendations for Supplementing Primary Monitoring Methods

The following methods require relatively little cost and field effort to employ and could supplement recommended primary methods to increase monitoring effectiveness. These trend indicators should be validated periodically against population estimation results.

Review of Livestock Depredation Reports

We recommend establishing and maintaining a livestock depredation database. This database can be used to monitor gross changes in distribution and wolf trends in areas where wolves and livestock overlap. These data would also be helpful in furthering our understanding of wolf-livestock interactions and managing wolf-livestock conflicts. Although the relationship between carnivore density, livestock density, and depredation rate is unknown, further study may help clarify this relationship allowing this method to serve as an indirect trend index.

Analysis of Harvest Data

We recommend establishing and maintaining a wolf harvest database incorporating a mandatory reporting and tagging program. Carcasses collected from hunters and Wildlife Services during control actions should be examined for age, sex, and reproductive parameters. We also recommend collecting genetic samples to test the potential for using open population mark-recapture models to monitor abundance (McDonald and Amstrup 2001, Boulanger et al. 2002).

Habitat Evaluation

We recommend comparing area-specific wolf density estimates with prey densities, using regression analysis, to test the application of applying prey abundance as an index of wolf abundance, similar to that done by Fuller et al. (1992) and Karanth et al. (2004). Human-caused wolf mortality can affect wolf-prey density relationships. Area-specific wolf mortality rates based on radio-collared wolves could be incorporated into the analysis to account for the affects of human-caused wolf mortality. Estimates may be more valid in remote inaccessible areas where lower human-caused wolf mortality will have a smaller influence on wolf-prey density relationships. Combining such an approach with modeling efforts like those of Oakleaf (2003) and Mladenoff et al. (1999) may be useful for estimating wolf abundance and trend in remote, heavily forested areas, problematic for other methods. Estimates based on habitat evaluations may, at the very least, help focus survey efforts in remote areas and, at best, provide sound estimates of wolf abundance.

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APPENDIX A

Cover Letter and Questionnaire Used for Soliciting Information About Wolf Monitoring and Survey Methods

Dear:

The Nez Perce Tribe, Idaho Fish and Game Department, U.S. Fish and Wildlife Service, University of Idaho, and Montana State University are cooperating to review wolf (*Canis lupus*) abundance survey methods and protocols. We are assessing the techniques available, their costs, and their reliability as we work to develop survey methods for wolves in the northern Rocky Mountains. This information will be important for all the states in the region as wolves are delisted and states develop management plans. The review and assessment of monitoring protocols should be valuable for any organization looking to assess and develop surveys.

We are interested in, 1) the methodology your organization uses to survey wolves, 2) knowing the primary reasons you selected the particular method, 3) the costs of your current method, and 4) your assessment of your method's performance. We will gladly provide you a copy of the results of this work. The following questionnaire should only take a few minutes to fill out and would provide us with valuable information to compare survey methods in the western states, Canada, and worldwide. If you have the time, we would very much appreciate a more detailed description of methods, assumptions, rationale, and results of your wolf survey work. If possible, we would appreciate any documentation that you could provide, including copies of your survey study plan and progress reports outlining methodologies and results, and any references to literature you used to develop your technique. We would also like to learn of other reports/papers you relied on to develop your survey. Please let us know of others you may know that are monitoring wolves so we can contact them. Also, if you are not the right contact for this questionnaire in your agency please forward to appropriate person.

Please contact Kyran Kunkel, Montana State University (406-763-4109/kyran@montana.net) if you have any questions. Thank you for taking the time to help in this review.

Sincerely,

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Moscow, ID 83844

Wolf Monitoring and Surveying Questionnaire

We would very much appreciate as much detail to all these responses that you can provide, so please add more sheets to respond if needed.

1. What is the status/classification of wolves in your area?

☐ endangered
☐ threatened
☐ furbearer/game animal
☐ other, please list

_____
_____
_____
_____

2. Do you survey/monitor/research wolves in your state/province/country?

☐ Yes ☐ No

If "no", please briefly indicate why not and then please go to question 33.

_____
_____
_____
_____

3. How do you currently survey/monitor wolves? (check multiple boxes if necessary)

☐ line intercept
☐ howling surveys
☐ Sample unit probability estimator (SUPE)
☐ mark-resight
☐ track/sign surveys
☐ harvest success
☐ biologist reports/interviews
☐ hunter reports/interviews
☐ territory mapping with telemetry
☐ monitor survival rates with telemetry
☐ habitat/prey-based potential
☐ research project extrapolations

If other, please briefly explain your method here:

_____
_____
_____
_____

4. Which of the following methods do you use to survey wolves?

☐ aircraft primarily
☐ foot and/or horse surveys
☐ road surveys
☐ varies among management unit
Other_____
_____
_____
_____

5. If you use track/sign surveys, what technique(s) do you use?

☐ scat deposition rate
☐ scent station
☐ ground track searches and mapping
☐ track transect trends
Other_____
_____
_____
_____

6. If you use mark re-sight techniques, how are wolves marked?

☐ DNA scat sampling ☐ radio collars
☐ DNA hair sampling ☐ tags
Other_____
_____
_____
_____

7. If you use mark re-sight techniques, how are wolves re-sighted

☐ hair snags ☐ aerial/ground searches
☐ camera ☐ scats

8. Regarding aerial survey specifically, do you use any of the techniques below?

☐ visibility bias correction
☐ distance sampling (e.g., program transect)
☐ double counts
☐ remote sensing (e.g., infrared)
☐ not applicable (don't use aerial surveys for wolves)
Other_____
_____
_____
_____

9. What design do you use to select survey sampling units?

☐ no sampling design
☐ simple random sampling
☐ stratified sampling
☐ double or two-stage sampling
☐ sample in proportion to size
☐ opportunistic or subjective choice
Other_____
_____
_____
_____

10. What parameters do you estimate from collected survey data?

☐ minimum numbers
☐ relative abundance for trend
☐ density
☐ presence/absence - distribution
☐ additional parameters, list:
_____
_____
_____
_____

11. What are the primary assumptions of your method?

_____
_____
_____
_____
_____
_____
_____
_____

12. What is the general confidence interval of obtained estimates?

☐ <± 10%
☐ ± 10-20%
☐ ± 20-40%
☐ >40%
☐ no estimate

13. What do you do with the data you collect and the parameters you estimate?

☐ develop habitat management recommendations
☐ make harvest recommendations
☐ generate population models
☐ estimate impacts to prey/livestock
☐ monitor for delisting
Other_____
_____
_____
_____
_____

14. On what scale do you conduct wolf surveys?

☐ we survey by each and every management unit in the state/province/region/country
☐ we conduct surveys on a subset of management units
☐ we pool data from multiple management units
Other_____
_____
_____
_____
_____

15. Who conducts your wolf surveys?

☐ contractors
☐ agency personnel do the surveys
☐ we use a combination of contractors and agency personnel
Other_____
_____
_____
_____
_____

16. How often do you survey wolves?

☐ every year
☐ every _____ years
Other (please explain)_____
_____
_____
_____
_____

17. In what month do you survey wolves? If you survey >once/year, please indicate all survey times.
Months_____
_____
_____

18. Describe generally the geographic area you are surveying (e.g. west half of Glacier National Park). Please send us a survey area map if possible.
_____
_____
_____
_____

19. What bioregion do you conduct surveys in?
☐ tundra
☐ taiga
☐ temperate coniferous forest
☐ grasslands
☐ shrublands
☐ temperate broadleaf/mixed forests
Other_____
_____

20. What is the topography of the area?
☐ rugged mountains
☐ mountains/hills
☐ rolling
☐ primarily flatlands

21. What is the dominant habitat?
☐ dense forests
☐ open forest
☐ forest/grasslands
☐ grasslands/tundra
☐ dense shrublands
☐ open shrublands

22. What is the average snow cover in the area?
☐ dependable winter long and annually
☐ sporadic throughout winter and annually
☐ >½ the winter and occurring most years
☐ complete cover is rare

23. What is the size of your survey area?

_____
_____
_____

24. What type of access is available in your survey area?

☐ air access only
☐ few roads and trails
☐ moderate road and trail access
☐ numerous roads and trails

25. Do you think your wolf survey data are adequate to meet your current management needs?

☐ more than adequate
☐ adequate
☐ inadequate

26. What was the primary reason for your survey choice?

☐ reliability of estimate
☐ cost
☐ ease of application
Other_____
_____
_____
_____

27. What are the main advantages/power of this methodology?

_____
_____
_____
_____
_____
_____

28. What are the main disadvantages/limitations of this methodology?

_____
_____
_____
_____
_____
_____

29. We all know that survey methods can be improved. Are you considering changing wolf survey methods in the near future? If so, what method (s) are you considering?

_____

_____
_____
_____
_____
_____

30. Do you combine wolf surveys with surveys for any other species? (Please list)

_____
_____
_____
_____
_____
_____

31. Approximately how much do you spend per year to survey wolves in your state/region/province?

$_____
_____

32. Has any of your survey data been recently challenged by any of the following groups?

☐ other resource management agencies
☐ sportsman groups
☐ environmental groups
Other_____
_____

33. Are you or your colleagues conducting survey for other wildlife that you feel may benefit our effort to develop a wolf survey method. If so, please briefly describe.

_____
_____
_____
_____
_____
_____

We would very much appreciate copies of study plans, progress reports, papers, or citations from your work or work of others that you used.

Thank you for taking time to help in this review. Please check ( ) if you would like a copy of the results.

Agency:_____
_____

Contact
Person:_____

Address:_____
_____
_____
_____

Phone: (_____)_____

Email:_____

Please return completed survey to:

Kyran Kunkel
Montana State University
1875 Gateway S.
Gallatin Gateway, MT 59730
Fax (406) 763-4109 (please call first)

ADDITIONAL SPACE FOR RESPONSES FOLLOWS:

APPENDIX B

Comparison of Evaluation Criteria Among Methods for Monitoring Wolves and Associated Species

Appendix B. Comparison of evaluation criteria among methods for monitoring wolves and associated species. See text for additional details.

			Evaluation Criteria							
Method	**Level of Resolution***	**Application**	**Objectives Addressed****	**Level of Precision**	**Sampling Effort**	**Assumptions**	**Advantages**	**Disadvantages**	**Field Constraints**	**Cost**
No Original Field Work										
Questionnaires	1 – 3***	Statewide	1 - 4***	Medium	Very low	Consistent and accurate reports	Hunter involvement; low field effort	Unknown reliability of reports	Hunter density low in remote areas resulting in small sample sizes	Very low
Case Study[1]		*6,400 Km^2*		*90% CI=± 28-37%*	*214-374 interviews annually*					
Livestock Depredation Reports	1, 2	Statewide (in range of livestock)	6	No measure of precision	Very low	Consistent and accurate reports	Low field effort	Confounding variables; unverified relationship with population trend	Livestock must be present	Very low
Case Sudy[2]				r^2=0.97	*8 reports annually*					
Harvest Data	1, possibly 2	Statewide	4 (minimally)	No reported estimates	Very Low	Consistent and accurate reports	Low field effort	Confounding variables; unverified relationship with population trend; unknown rate of reporting	Hunter density low in remote areas resulting in small sample sizes	Very low
Habitat Evaluation	1, possibly 2	Statewide	4 (when combined with other methods and assumptions)	Low	Very low	Reliable correlation with wolf density	Low field effort, may work in remote areas	Estimates potential population; does not account for human-caused wolf mortality	Prey abundance estimates are often difficult to obtain	Very low
Case Study[3]				*90% CI= ± 42%*						

Appendix B (cont…). Comparison of evaluation criteria among methods for monitoring wolves and associated species. See text for additional details.

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Method	**Level of Resolution***	**Application**	**Objectives Addressed****	**Level of Precision**	**Sampling Effort**	**Assumptions**	**Advantages**	**Disadvantages**	**Field Constraints**	**Cost**
Sign Surveys										
Scent-Stations	1 - 3***	Statewide	1 - 4***	Low	Medium	Visitation rates reflect abund ance	Monitor other species at same time	Confounding variables; unverified relationship with population trend; low sample size; not feasible in remote areas	Roads or trails required	Low
Case Study[4]				*95% CI=± 42%*	*175 stations*					
Scat Surveys	1 - 3***	Regional	1 - 4***	High	Medium	Scat abundance reflects animal abundance	Scats easy to find, identify, and collect	High field effort in remote areas	Roads or trails required	Low
Case Study[1]		*6,400 km*^{2}		*90% CI= ± 22%*	*72-85 sampling weeks*					
Track Surveys	1 - 3***	Statewide	1-4***	Medium	Medium	Track abundance reflects animal abundance	Allows simultaneous monitoring of other species	Medium field effort in remote areas	Roads or trails or tracking snow required	Low
Case Study[5]				*90% CI= ± 30%*	*44 50 km*^{2} *quadrats with 2-3 11 km routes*					*$6,500*
Minimum Counts – Non Recognizable Individuals										
Howling Surveys	1 - 3	Statewide	1 - 4	Very low	Medium	Response rate reflects animal abundance	May involve biologists and citizens	High field effort especially in remote areas; low sample size; variable response rate	Roads or trails required	Low to medium
Case Study[6]		*1,400 km*^{2}		*90% CI= ± 67%*	*55 sites over 45 nights*					

Appendix B (cont…). Comparison of evaluation criteria among methods for monitoring wolves and associated species. See text for additional detail.

			Evaluation Criteria							
Method	**Level of Resolution***	**Application**	**Objectives Addressed****	**Level of Precision**	**Sampling Effort**	**Assumptions**	**Advantages**	**Disadvantages**	**Field Constraints**	**Cost**
Aerial Reconnaissance Surveys (ARS)	1 - 3	Regional	1 - 5	No measure of precision	Medium	Tracks from all packs located; no double counts	Allows estimates from remote areas	Safety	Observer and pilot experience; snow; semi-open habitat required	Medium
Case Study[7]		*8,300 km*^{2}			*6 hours/2,500 km*^{2}					*$0.47/km*^{2}
Ground Tracking Surveys (GTS)	1 - 3	Statewide	1 - 5	Very high****	Medium	Tracks form all packs located; no double counts	May involve biologists and citizens	Requires coordinated field effort	Tracking snow and access required	Very low
Case Study[3,8]				*90% CI= ± 12%*[3]	*Several hundred observers throughout winter*[3]*; 2,385 hrs on 13,123 km of roads/trails*[8]					
Pop. Estimation – Non Recognizable Individuals										
Transect Intercept Probability Estimator (TIP)	1 - 3	Statewide	1 - 5	Medium	Medium	All tracks detected and followed	Objective and reliable measure or precision	Need experienced people; many assumptions; safety	Semi-open habitat, tracking snow, and good weather required	Medium
Case Study[7,9]		*6,464 km*^{2} [9]		*90% CI=± 31-34%*[9]	*7 hours*[9]					*$0.65/km2*[9]
Subunit Probability Estimator (SUPE)	1 - 3	Statewide	1 - 5	Very high	Medium	All tracks detected and followed	Objective and reliable measure or precision	Need experienced people; many assumptions; safety	Semi-open habitat, tracking snow, and good weather required	Medium
Case Study[7,9]		*31,373 km*^{2} [10]		*90% CI=± 11%*[10]	*47 hours*[10]					*$1.55/km2*[7]

Appendix B (cont…). Comparison of evaluation criteria among methods for monitoring wolves and associated species. See text for additional detail.

			Evaluation Criteria							
Method	**Level of Resolution***	**Application**	**Objectives Addressed****	**Level of Precision**	**Sampling Effort**	**Assumptions**	**Advantages**	**Disadvantages**	**Field Constraints**	**Cost**
Minimum Counts – With Recognizable Individuals										
Territorial Mapping/ Demography	1 - 4	Regional	1 - 6	No measure of precision	High	All territories properly delineated	Much data provided beyond population	Invasive; high field effort	Must capture wolves	High
Case Study[7,11]		*24,000 km*[2 11]			*>1 wolf radio-collared in each of 7 packs, located 60 times annually*[11]					*4.21/km*[2,7]
Genetics	1 - 3	Regional	1 - 5	Very high	Low	Equal defecation rate among sex and age classes	Produces robust mark-recapture population estimate, provides additional genetic data	Technology issues for lab analysis remain to be resolved; high field effort	Roads or trails required	High
Case Study[12]		*15 km*[2]		*95% CI=± 5%*	*2 weeks*					*$24,000 for scat analysis*

*Levels of resolution include:
1 = Presence, absence, and distribution data
2 = Relative abundance estimates using direct and indirect indices
3 = Absolute abundance estimates
4 = Population demography estimates

**Objectives addressed include:
1 = Documenting a minimum of 20 wolf packs statewide to satisfy federal monitoring requirements for the first 5 years after delisting
2 = Estimate wolf population trend with a 90%CI ($\alpha = 0.10$) of 30% and 80% power to detect a 30% change in population status annually for long-term monitoring
3 = Estimate wolf population size and density once every 5 years
4 = Estimate occupied wolf range annually

***Estimates of abundance can be extrapolated when regressed against known wolf densities determined by other method

****When CI estimated using bootstrapping as by Fuller et al. (1992)

Case Studies:
[1] Crete and Messier 1987
[2] USFWS 2004
[3] Fuller et al. 1992
[4] J. Erb, MN Department of Nat. Res., unpublished data
[5] Smallwood and Fitzhugh 1995
[6] Fuller and Sampson 1988
[7] E. Jozwiak, Kenai National Wildlife Refuge, unpublished report
[8] D. Beyers, Michigan Department of Nat. Res., unpublished report
[9] Ballard et al. 1995
[10] Becker et al. 1998
[11] Burch 2001
[12] Kohn et al 1999