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Intensive Aerial Wolf Survey Operations Manual for Interior Alaska

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Introduction

Reliable methods for measuring population abundance and distribution are fundamental to informed management decisions and necessary to assess population response to management actions (National Research Council 1997, Pollock et al. 2002, Stetz et al. 2010). In Alaska, the need to develop and use the best population monitoring methods to obtain unbiased predator and ungulate population counts or estimates intensified after the passage of the 1994 intensive management law (IM; Alaska Fish and Game Laws and Regulations Annotated 2013:27–29). Under that law, for populations below population and harvest objectives, the Alaska Board of Game cannot significantly restrict harvest of certain ungulate populations without considering possible IM actions including wolf (*Canis lupus*) control to assist population recovery. Since the inception of the IM law, our ability to quantify wolf populations has never been under more scientific, legal, public, and political scrutiny (Titus 2007).

Since the 1970s, Alaska wildlife managers have used 5 aerial wolf survey methods to monitor wolf population size and trends (Table 1): 1) intensive aerial wolf survey (IAWS; Stephenson 1978, Gasaway et al. 1983, Hayes et al. 2003); 2) minimum wolf count (MWC; method also referred to as reconnaissance, McNay 1993); 3) sample unit probability estimator (SUPE; Becker et al. 1998, 2004; Patterson et al. 2004); 4) territory mapping using radiotelemetry (TMR; Ballard et al. 1987, 1997; Burch et al. 2005; Adams et al. 2008); and 5) transect intercept probability sampling (TIPS; Becker 1991, Becker and Gardner 1992). The TIPS technique is no longer used due to a less efficient sampling design and reduced precision compared to the SUPE (Becker et al. 2004).

Table 1. Comparison of current wolf population survey methods used in Interior Alaska.

Survey label	Type	Area	Sampling	Survey intensity[a]	Description
Intensive aerial wolf survey (IAWS)	Total count for time surveyed	≥1,500 mi^2	Total coverage	≥0.8 min/mi^2	Approximates a census of wolves in the study area, number of packs, and pack size and distribution
Sample unit probability estimator (SUPE)	Population estimate	>1,350 mi^2	Stratified Sampling; 30–47% area sampled	0.8–2.0 min/mi^2	Precise, unbiased estimate of population size and number of packs
Territory mapping using radiotelemetry (TMR)	Population census (not including transient wolves)	No minimum or maximum; cost limited	Radiocollar and monitor all packs	Enough flights to ensure counts and territory size (≥60 locations)	Used in intensive ecological studies
Minimum wolf count (MWC)	Verify presence	No size restriction	Partial to total coverage	≥0.6 min/mi^2	Verify legal requirements, sample of pack sizes and distribution

The IAWS, MWC, and SUPE methods are commonly used by managers and researchers in Interior Alaska. All require following wolf tracks in the snow without the need for radio collars. The IAWS method was designed to identify the total number of wolves, packs, pack sizes, and general distribution in a defined study area (Stephenson 1978), however in many cases the number of transient wolves are estimated and not censused. IAWS is a one to multiple-day survey suitable for areas ≥1,500 mi^2 (Gasaway et al. 1983, 1992; Hayes et al. 2003). The survey consists of aerially searching the entire study area at a standardized intensity 1–10 days after a fresh snow. All fresh (made since the snow event) wolf tracks are followed until the wolves are found and then backtracked to determine their complete travel route after the snow event. Since IAWS approximates a census, a precision estimate is not generated. Except for the TMR method, IAWS is most useful in evaluating predator-prey relationships because the number of packs and pack sizes are important factors in explaining predation rates. For example, in a hypothetical area supporting 20 wolves, the number of ungulates killed will differ, if it includes 1 pack of 20 compared to ≥2 packs of varying pack size (Hayes et al. 2000).The MWC survey uses the same tracking methods as IAWS but requires less survey intensity and not all wolves must be found. The MWC survey is used to confirm a given number of wolves following intensive management and periodically, to obtain a general evaluation of wolf numbers in an area. The SUPE method uses a stratified network sampling design to sample wolf tracks to derive the population estimate including single wolves (Becker et al. 1998). This technique was developed to estimate wolf and pack numbers and statistical confidence limits over large areas (1,900 mi^2–12,100 mi^2) with varied terrain for less costs compared to an IAWS (Becker et al. 1998, Patterson et al. 2004). The TMR method, used primarily in wolf research projects, requires that ≥1 wolf in all packs in an area are radiocollared and regularly tracked to obtain enough locations to assess pack size and composition and to map territory boundaries (Burch et al. 2005). This technique is usually too expensive to be practical for management purposes, but may be the only option in areas with continual poor snow tracking conditions (wind scouring, track obliteration by wintering caribou [*Rangifer tarandus*], etc.) or for early winter surveys when snow and light conditions are suboptimal. This method offers the most comprehensive measure of the number of wolves in packs, the number of packs, changes in pack size during the year, and pack distribution.

Purpose of the Manual

This manual provides guidance on how and when to conduct IAWS and MWC surveys. The situations and methodologies to conduct a SUPE (Becker et al. 1998, 2004; Patterson et al. 2004) or a TMR (Ballard et al. 1987, 1997; Burch et al. 2005; Adams et al. 2008) are well presented in the literature, but adequate protocols for IAWS and MWC methods are not. The exclusion of the SUPE and TMR methods from this manual should not be interpreted as a lack of endorsement. These survey techniques have proven to reliably assess wolf populations when designed and executed properly. Choice of an appropriate wolf survey method will depend upon the study objectives and on the financial and logistical resources available.

The necessity of a wolf survey manual becomes more apparent when we examine survey methods used to assess wolf management objectives for 2009–2013 in Interior Alaska (Table 2). These data illustrate that the most appropriate survey method was used in 9 of the 15 management situations. In most cases, less intensive survey methods were used due to budgetary constraints. However, in several cases, less appropriate methods were chosen due to a lack of information or understanding.

Table 2. Wolf survey methods used relative to management objectives and activities in the 9 wolf management areas in Region III (Interior and Northeast Alaska) during 2009–2013.

Objective type	No. of areas with this objective	Appropriate survey methods				No. surveyed correctly
		MWC	IAWS	SUPE	TMR	
Verify minimum numbers	5	Y	Y	N	N	5
Verify unit/subunit range of densities	3	N	Y	Y	Y	0
Trend areas to monitor pack number and sizes	2	N	Y	Y	Y	1
Determine areawide population size to monitor harvest	2	N	Y	Y	Y	1
Determine wolf numbers relative to potential wolf predation effects	2	N	Y	N	Y	1
Estimate population size with an estimate of precision	1	N	N	Y	Y	1

WOLF CHARACTERISTICS RELEVANT TO POPULATION SURVEY DESIGN

We can estimate wolf abundance during the winter using snow tracking because wolves 1) commonly move long distances leaving distinctive tracks (Stephenson 1978); 2) mostly travel in packs; 3) occupy all suitable habitats resulting in nearly a continuous distribution across Interior Alaska (although they are uncommon around Fairbanks and North Pole); and 4) mostly have discrete territories. Packs generally consist of a breeding pair of wolves and their offspring that range in age from pups to 4 years old (Mech et al. 1970, 1998) and usually number between 2 and 20 wolves (larger packs have been documented but rare). Territory sizes are between 230 mi^2 and 900 mi^2 depending on prey availability and movements and interaction between wolf packs (Ballard et al. 1987; Mech et al. 1998; Adams et al. 2008; Craig Gardner, ADF&G, unpublished data). Smaller territories are more common in areas of greater ungulate biomass (Ballard et al. 1987; Mech et al. 1998; Adams et al. 2008; Gardner, unpublished data). During the winter, wolf packs primarily travel as a unit throughout their territory traveling in search of prey and to maintain territory boundaries (Mech et al. 1998), however individual pack members can spend time away from the pack. Daily movements of ≤45 miles in the Interior have been documented (Mech et al. 1998).

Factors that complicate wolf surveys include 1) pack size changes (declines) between early and late winter even without harvest (Mech et al. 1998, Adams et al. 2008); 2) pack territories that overlap study area boundaries; 3) territory overlap between packs (Mech et al. 1998, Burch 2005, Adams et al. 2008); 4) extraterritorial forays (Burch et al. 2005); 5) pack separation (Messier 1985); 6) lone wolves can be either transients or residents temporarily away from their pack (Adams et al. 2008, Gardner et al. 2013); and 7) restricted movements related to prey distribution (Mech et al. 1998), prey handling (Hayes 1995) or deep snow (>12″; Dale 1997). Each of these factors needs to be considered in survey design and survey interpretations. For example, Adams et al. (2008) and Mech et al. (1998) documented population declines between early and late winter of 34% with a 12% harvest rate in the Brooks Range and 22% with a 3% harvest rate in Denali National Park and Preserve, respectively. This natural decline complicates comparisons between early winter and late winter survey results because levels of dispersal or nonhuman-caused mortality are not usually known for most survey areas. Also, this natural decline makes any early winter estimates based solely on the combination of spring survey results and harvest suspect. Wolf distribution and extraterritorial forays complicates defining boundary rules and in determining resident pack identities. Because there are very few areas in Interior Alaska closed to wolf movements, we must assume that any study area will contain various fractions of multiple wolf pack territories along its borders, meaning some packs will be in and some out on a given survey day. Further, it is possible that during a survey wolves will not be detected in large areas (>200 mi^2, minimum Interior Alaska home range size), even in saturated wolf populations. These situations mostly occur because the resident pack is on either a short-term (multiple day) foray away from their territory (>12 mi; Mech et al. 1998, Burch et al. 2005, Adams et al. 2008) or on a long-term foray (weeks), because their primary food source has moved from their territory (Burch et al. 2005). Nondetection can also occur when packs movements are restricted for longer periods (weeks) due to the presence of an abundant food source (Mech et al. 1998) or for shorter durations (2–3.5 days) when handling large ungulate carcasses (Hayes 1995). Pack mobility can also be hindered by heavy snowfall for >2 days (Dale 1997). There can also be uncertainty regarding pack alliance for some wolves. For a number of behavioral reasons, ≥1 wolf may not be associated with their pack on a given day. A study in Ontario, Canada found that individual members of packs are separate from their packs >1 km approximately 10% of the time during the winter (J. Benson and B. Patterson et al., Trent University, Ontario, Canada, unpublished data). During mid-February through mid-March it is common for breeding pairs to be temporarily separated from their packs (Messier 1985; Mark McNay, ADF&G, unpublished data) as well as ≥1 wolf may be away on a predispersal foray (Adams et al. 2008). In addition, adjacent territorial packs may be in close vicinity on a given survey day. The chance of missing wolves or mistaken pack associations is inversely proportionate to sampling intensity. Survey intensity must be adequate to sort out the tracks and correctly identify individual packs. However, if the survey is conducted over 1–3 days, some packs may be underestimated due to the absence of individual wolves if their track segments cannot be connected to their pack. These wolves may also be misclassified as lone wolves.

The list of complicating factors is long and varied and complicates all of the survey methods that rely on tracking wolves in the snow. Some affects are mitigated by the size of the study area; larger areas have less issue with boundary packs due to a larger study area to boundary ratio. Some issues are inherent with every survey (i.e., lone wolves) and have the potential to cause mistaken evaluations. Counting wolves is not laboratory science where each step can be fixed and controlled. Topography, snow conditions, ungulate abundance, and wolf distribution vary by survey and area making it more difficult to define the sampling methods. Even some seemingly simple decisions such as determining sampling duration to ensure survey efficiency can vary depending on snow depth and coverage, wolf and ungulate densities, and survey crew expertise. In this manual we provide detailed descriptions of IAWS and MWC survey methodologies and discuss the influence different factors may have on sampling intensity, survey timing, and duration.

Intensive Aerial Wolf Survey (IAWS)

General Description

The objective of the IAWS method is to count all wolves and packs in a defined study area. The survey takes ≥1 day to complete (Stephenson 1978) and is timed to maximize track detectibility (see Linnell et al. 2007) based on local conditions. The IAWS method can be conducted over an extended period of time using multiple snow events in a given winter. Gasaway et al. (1983) completed a survey in a 6,590 mi^2 area over a 3-month period and 324 hours of survey time with multiple surveys. If only one survey is conducted, results from IAWS (as are those from the MWC and SUPE methods) are a snapshot of a population and may not generate a complete overwinter picture of the resident wolf population in a study area due to absence-presence of packs during the survey.

Assumptions

The IAWS requires similar assumptions to those required by the SUPE method (Becker et al. 1998, 2004; Patterson et al. 2004). These are 1) all wolves move and leave tracks following the snow event; 2) pre- and post-snow event tracks can be distinguished; 3) no post-snow event wolf tracks are missed; 4) post-snow event wolf tracks are continuous and can be followed forward and backward; 5) packs and pack size are correctly enumerated; and 6) wolves are never counted more than once. The most difficult assumptions to meet are 1, 3, and 5. Not meeting assumptions 1 and 3 will cause negative bias for both the number of wolves and packs. Failing to meet assumption 5 can cause the estimate of wolf numbers or pack sizes to be biased high or low. There are no required steps upon survey completion to confirm if assumptions were met in either the IAWS or SUPE. There are, however, strict requirements for suitable weather and survey intensity to minimize the chance of violating assumptions. In situations where individual pack counts are questionable, these packs should be re-tracked to verify counts.

Effort and Cost

The IAWS method provides the most comprehensive account of wolf numbers and pack sizes and their distribution in the study area that can be accomplished without the use of radiotelemetry. However, costs are greater for IAWS compared to SUPE and MWC because the entire study area is intensively surveyed. The SUPE technique is less expensive per unit area because it is based on stratified sampling with a recommended sampling fraction of 30–47% of the survey area (Becker et al. 1998).The MWC method is less costly because its objective is not a population count allowing these surveys to be conducted at reduced survey intensities.

WHEN TO USE IAWS

The IAWS is most appropriate if management or research objectives require comprehensive data on wolf abundance, pack sizes, composition and juxtaposition, and funding is not available to conduct a TMR. It is well-suited to monitor wolf population abundance in an area prior to and during wolf control under an IM program. Outside of IM programs, IAWS is appropriate when managers require periodic and reliable assessment of wolf numbers and population structure as part of their management programs, particularly in areas where wolves are an economically important or highly sought after furbearer, are a significant predator on intensively hunted ungulates, or are part of contentious management programs. For research, IAWS can provide reliable wolf population counts for use in ecological studies and/or evaluations of management measures without the added expense of telemetry studies.

The IAWS, MWC, or SUPE techniques are not appropriate in areas of the Interior with high concentrations of caribou as their associated tracks and trails make it impossible to find all wolf tracks. In such situations, the more reliable method for assessing wolf abundance is a longer term study using the TMR method. However, if a population count is necessary for that year, an IAWS survey could possibly work but it would have to be conducted multiple times (increasing costs) throughout the winter and timed to caribou movements from area to area. Even if only a verification of a minimum number of wolves is required but the area is frequented by caribou, additional funding to support multiple surveys should be expected. We will discuss this scenario and reporting requirements later in this manual (see Minimum Wolf Counts, page 21).

Designing IAWS

Recommendations in this manual were developed with the primary objective of finding all packs ≥2 wolves present at the time of survey. The number of wolves and packs found during a particular survey may be more or less than the actual overwinter number of resident wolves and packs for that study area due to temporary movements. Any discrepancies can be evaluated by repeat surveys over the winter. We recommend counting only wolves associated with packs instead of counting all wolves (i.e., discounting lone wolves) because since the inception of the IM law, the primary objective for wolf surveys conducted in Interior Alaska has been to assess the role of wolf predation in limiting ungulate populations. Lone wolves can either be transients or resident pack members temporarily on a foray. Although exclusion of lone wolves in some cases may underestimate pack size, transients constitute the majority of the lone wolf segment and they are not considered to be a significant predator of ungulates (Adams et al. 2008). Further, the pool of transient wolves varies throughout the winter so the count or estimate found for a particular survey period may or may not be comparable to other times of the winter. Lastly, few transient wolves settle during January–March and become part of a breeding unit. In terms of assessing wolf population trends and recovery, the number of breeding units (packs) rather than total wolves is the important measure.

SURVEY AREA SIZE

Stephenson (1978) recommended a minimum IAWS survey area of 1,500 mi^2. We recommend that the minimum size should be ≥3,000 mi^2 because wolf territory sizes in Interior Alaska are large and a study area of ~1,500 mi^2 would generally only encompass 3–4 packs. We recommend that survey areas be large enough to include ≥6 packs (Burch et al. 2005). The maximum survey area size is dependent on study objectives, survey window, number of survey aircraft, and available funding. Intensive aerial wolf surveys have been completed in areas as large as 4,656 mi^2 (Unit 20C, Tony Hollis, ADF&G, unpublished data) and 6,587 mi^2 (Unit 20A, Gasaway et al. 1983). Survey intensities were 0.9 and about 3 min/mi^2, for the Unit 20C and Unit 20A surveys, respectively.

SURVEY BOUNDARIES

Survey boundaries usually follow game management unit or landownership boundaries. These boundaries generally follow prominent topographical features like rivers or ridge systems. Whereas these delineations are easy to follow, they often are not the most efficient survey boundaries because wolves often use major rivers or prominent ridge systems both as pack boundaries and as travel corridors during the winter (Mech et al. 1998). It is not uncommon for tracks of several wolf packs to be in close proximity along these travel corridors making it more difficult to ascertain the number of packs and number of wolves in each pack as well as determining which ones should be included in the survey. For example, McNay (1993) described a track segment that traversed 56 miles along a prominent ridge system. Two aircraft separately followed the track segment; both found 6 wolves and both concluded there was 1 pack of 10–14 wolves. The area was revisited following another fresh snowfall and 3 packs were found totaling 19 wolves. To help discern tracks of different packs and to ensure all packs that use the survey area are included, we recommend that survey areas be designed so that major rivers or prominent ridges are inset from the boundaries. In most cases, this should help the survey crew detect how the different packs come into or depart these common travel routes. Ungulate distribution can also affect survey results. Multiple packs can be in close proximity in areas that support high local prey densities (Burch et al. 2005). Including such areas in smaller study areas or along the survey boundary could cause complications in interpreting results. If available, we recommend utilizing historic wolf and ungulate distribution and movement data, wolf harvest data, and local knowledge to identify these areas and then decide how best to delineate the study area to meet survey objectives. It is imperative that survey crews are aware that it is possible for multiple packs to be in close proximity and the importance of distinguishing between packs.

SEARCH INTENSITY

We define search intensity as the cumulative time spent searching for and tracking wolves in a study area. Stephenson (1978) initially recommended a search intensity range of 0.16–0.28 min/mi^2 with flight transects separated by 6 miles. Gasaway et al. (1983) evaluated search intensities (including time spent tracking wolves) ranging from 0.16–0.5 min/mi^2 level and concluded that survey intensities ≤0.5 min/mi were inadequate and wolf abundance would be underestimated. The minimum necessary search intensity is dictated by the assumption of detecting all fresh wolf tracks. Tracking efficiency varies due to type of vegetative cover and terrain, light conditions, survey crew (especially pilot) experience, the number of packs tracked and their movement patterns, the number of days since the snow event, pack spacing (closely associated packs can be easier to miss), and track deposition by other species (e.g., concentrations of caribou) (Becker et al. 1998). We evaluated various search patterns and intensities used in surveys conducted in 3 different areas of Interior Alaska (McNay 1993; Gardner, ADF&G, unpublished data; Hollis, unpublished data). All 3 studies followed snowfalls of >6″ and in general had excellent light (full sun or high overcast) and calm wind conditions. Survey lines were flown at 80–85 mph ground speed at altitudes ranging from 300′ to 800′ above ground level (AGL). We measured the length of the magnetic north-south and east-west components (most common survey transect headings) of all the wolf track segments, mapped out search patterns if available, and compared search times (Table 3). The shortest segments measured 0.9–1.8 mile and all segments <3 miles were associated with ungulate kills. A search pattern with flight lines separated by 1.0–1.5 miles ensures that all track segments are intersected. A search grid of 2 miles could have potentially missed 17% of the packs (2/12 packs) during the Unit 20C survey (Appendix A; Hollis, unpublished data). Maintaining a 1.0–1.5 mile separation will require search intensities of 0.8–0.9 min/mi^2 when not tracking wolves. Search intensity will increase to ≤2 min/mi^2 when wolves are being tracked because flight speeds will be slower and more time will be spent circling compared to when flying a straight transect (Becker et al. 1998, 2004). Even in areas with open terrain, distance between transects should be ≤2 miles. For isolated forested areas with thick overstory or windswept areas, it is sufficient to fly the perimeter looking for tracks if these areas are <2.5 miles in diameter. For areas ≥2.5 miles in diameter, transects must be flown but select routes that maximize track sightability. Throughout the survey, crews should look for concentrations of ravens (*Corvus corax*) because this species commonly scavenges wolf kills.

Table 3. Shortest distance (mi) wolf track segments relative to days following snow event from 3 study areas in Interior Alaska.

Area	Days after a snow event	Shortest segments (mi)
Holitna River[a]	3	1.8
Minto Flats[b]	2	0.9
Kantishna[a]	2	1.8

[a] Intensive aerial wolf survey (IAWS) survey (Gardner, unpublished data; Hollis, unpublished data).
[b] Transect intercept probability sampling (TIPS) wolf survey (McNay 1993).

Search intensities of ≥0.8 min/mi^2 and 1.0–1.5 mi/flight line are comparable to survey intensities used by Becker et al. (1998) while conducting a successful wolf SUPE survey in a portion of the Yukon and Koyukuk River valleys (Unit 21D). Longer search times were required in sample units that were more forested, had higher ungulate numbers, or if wolf tracks were followed. Considering these factors, we recommend for initial study area delineation and budgetary planning to assume average search intensities of 1.0 min/mi^2. The time necessary to fly to and from the study area must also be considered. If funding is inadequate, then the size of the study area must be reduced if IAWS is the preferred method. The other option is to conduct a SUPE which would allow the larger area to be surveyed for the same amount of funding.

Inclusion Rules for Packs

Deciding which wolves and packs to include in survey results will depend on the population inclusion rules. These rules should be based on the study objectives. Inclusion rules do not have to be the same for all surveys. In terms of packs, Becker et al. (1998, 2004) described 2 inclusion rules used during SUPE surveys. One included only packs with more than half of their track segments within a study area and the other was to determine "pack size" by multiplying the actual pack size by the proportion of the track segment the pack travelled within the study area. The latter method is more costly because it requires more tracking outside of the study area to determine the proportion. Boundary rules used in past IAWS or MWC included 1) all wolves found within the study area and 50% of the total number of border wolves counted (Mark Keech, ADF&G, unpublished data); 2) all wolves found within and all wolves that were tracked from but found outside the study area (Glenn Stout, ADF&G, Unit 24B unpublished data); and 3) all wolves found within the study area but no wolves that were found outside (Roger Seavoy, ADF&G, Unit 19D unpublished data). All of these approaches are valid but will generate different results. To minimize confusion when using survey results to design or to compare to other surveys, a thorough description of the pack inclusion rule must be included with the survey results.

If the study objective is to identify all resident packs in the study area during winter, potential complications are extraterritorial pack movements out of the study area by resident packs or into the area by trespassing packs. These forays can last a few days to weeks and documented distances travelled have been up to 50 miles (Mech et al. 1998; Gardner, unpublished data). If during a survey, large vacant areas (>200 mi^2) are found containing only old wolf tracks or no wolf tracks at all, most likely the resident pack was on a foray during the survey. An example is the 2012 Unit 20C survey where we found no wolves in an area about 1,000 mi^2 (2–3 wolf territories) in the western portion of the study area (Appendix A:Fig. 3). We knew from discussions with National Park Service biologists who were conducting a wolf research study in the area that resident packs existed in that area but were not present during the survey. To verify use of temporarily vacant areas, an additional survey(s) will be required. A more difficult scenario occurs when a trespassing pack comes into the study area but a snow event has erased their back trail. Circumstantial evidence this has occurred would be finding more packs in an area than would be expected based on ungulate densities; however, resident packs can be in close vicinity. To verify, repeat surveys will be required to document if any of the multiple packs in an area move away from the study area or if all remain. The occurrence of long distance and long-term forays has been documented in the Interior. Packs that made these moves were from areas that supported low ungulate abundance during the winter (Mech et al. 1998; John Burch, National Park Service, unpublished data; Gardner, unpublished data). Mostly these packs would move into areas supporting high numbers of wintering moose (*Alces alces*) or caribou and stay for months overlapping territories of resident packs. In this case, even though these packs are not year-long residents of the study area, they are an important contribution to the winter predator pool. If a comprehensive view of resident wolves and packs during the winter is the objective, additional surveys will again be necessary. However, the entire study area does not have to be resurveyed; just the areas where more or less wolves than expected were found during the first survey.

MEMBERSHIP RULES FOR TRANSIENT WOLVES

The inclusion of lone wolves in Interior Alaska survey results is common but how the number is generated is not standard. Population estimates generated by the SUPE method include single wolves and percent single wolves based on actual track data. The other common approach was to add 10–15% to the population estimate to account for single wolves (Fuller et al. 2003). This estimate range has been questioned because it does not account for known differences in seasonal dispersal rates (Burch et al. 2005, Adams et al. 2008). Another potential problem with both these inclusion methods is that neither recognizes that lone wolves can either be a resident pack member temporarily separated from its pack or a transient wolf that may or may not settle in the study area. If wolf predation effects are the primary objective for the survey it is important to discern if the lone wolf is part of a resident pack but, unless it is in close vicinity of its pack, this may be impossible to verify without multiple surveys. More important concerns are that during the winter most lone wolves are transients (Adams et al. 2008, Meier et al. 2009), the greatest number of transients occur during January through April (Adams et al. 2008; Gardner, unpublished data) during the period when most surveys are conducted, and most of these wolves observed during this period will not settle in that area (Gardner, unpublished data). The take home message is that any count of lone wolves relative to the study area is most likely wrong. Except for study areas with the objective of verifying the number of wolves remaining after control activities, we recommend the inclusion rule for lone wolves is to not include them in the population total or in the density estimate. If a count of lone wolves is desired, their proportion must be determined using survey data and not by subjectively adding 10–15%.

SURVEY UNITS

To increase survey efficiency we suggest that the study area be subdivided into survey units equal to the area that can be surveyed during 1 day at an intensity of ≥0.8 min/mi^2 and a flight line grid of 1.0–1.5 miles. This subdivision will highlight the number of survey planes and time necessary to complete the survey. In our Unit 20C example (Appendix A:Fig. 1), we subdivided the study area into 14 320.0–352.0 mi^2 sample units. We recommend that survey units be further subdivided into 16.0 mi^2 sample blocks similar to a SUPE survey (Appendix A:Fig. 1; Becker et al. 1998) to assist survey crews in assessing their spatial coverage during the actual survey. Each sample block in the reference grid should have a unique ID to coordinate multiple survey aircraft. Another benefit to subdividing is that it is easier for the principal investigator to evaluate coverage following each survey day and decide if areas need to be revisited. Missing areas during any one day of survey does not compromise survey results as long as these areas are subsequently searched and fresh wolf tracks are backtracked to guard against double counts.

As with study area boundaries, if possible, try to keep survey unit boundaries away from rivers or other known important wolf travel routes. Even though wolf tracks can be found anywhere, as discussed above, wolves often select rivers and ridge tops for travel. Avoiding use of wolf travel routes as boundaries can reduce possible confusion if used by multiple packs and enhance safety by reducing the chance adjacent survey teams will be following the same wolves (Appendix A:Fig. 1).

SURVEY FLIGHT PATTERNS

The topography of the survey units will dictate the most efficient flying pattern. In large flat areas, transects will be the most efficient. In steeper terrain, the pilot should choose the survey pattern that best enhances observability. In most cases, flight lines will follow elevation contours along the hill in addition to looking at the ridge tops and valley bottoms which are important travel corridors for wolves. In any habitat, to most efficiently track wolves, the highest altitude the lighting conditions allow usually is best. Tracking from a higher altitude improves tracking efficiency by allowing the survey team to look out further to track which will reduce circling time. It is common for inexperienced crews to survey at too low of an altitude (~≤300′ AGL).

Surveys should start at one corner of the study area and work outward in a concentrated, expanding manner to complete a contiguous portion each day, similar to SUPE method (Becker et al. 1998, Patterson et al. 2004). If there is a portion of the study area that is more important in terms of management questions or is more prone to inclement survey conditions (increase track deposition, scouring winds, etc.), these areas should be completed first. This approach will guard against missing or double counting any wolves. An additional benefit is that if poor weather conditions cause the premature discontinuation of the survey, the results will reflect a census of the area completed (Becker et al. 1998). As previously recommended, an efficient method to ensure the study area is surveyed adequately is to subdivide the area into ~350 mi^2 survey units. For example, in Appendix A:Figure 1 the eastern end of the study area was most important to the management question. Thus, survey units E1–E7 were completed during the first day of survey.

SURVEY CONDITIONS

Similar to SUPE, the IAWS method requires certain sunlight, snow, and wind conditions in order to find and track all wolf tracks in the study area. The base snowpack (~ ≥10″) must be deep enough to effectively follow tracks. This is particularly important in more forested areas and during lower light conditions. New snowfall must be adequate to cover old tracks, sunlight needs to range from bright sun to high overcast conditions, and winds should be <20 mph with no to light turbulence. Surveys can be conducted following a 1″ snowfall as long as the light conditions are adequate, but snowfall depths of ≥2″ are preferred. Restricted sunlight due to cloud cover, falling snow, and nightfall creates poor survey conditions. Deteriorating conditions will first be noticed in forested habitats. High winds make it difficult to see and follow wolf tracks due to turbulence and blowing snow. Further, these conditions can become stressful and fatiguing for pilots and observers, which can lead to lower detection rates. Weather conditions must be evaluated prior to and during each survey day. If not suitable before beginning the day's survey the decision is easy to make. The more difficult decisions happen when weather conditions deteriorate during the day. During marginal conditions, survey quality can be maintained to a point by increasing its intensity. However, regardless of the financial investment, if tracking conditions become inadequate to meet survey assumptions, it must be postponed.

Surveys can be conducted throughout the winter, but the lower sun angle during November through mid-January reduces the number of hours with suitable light for tracking. We recognize that it is often desirable to conduct wolf surveys during autumn to better evaluate predation effects and because packs are more often intact compared to the spring. However, because of the combination of waning sunlight and minimal snow coverage and depth during autumn it is rare that conditions are adequate during this period. In Interior Alaska, the best wolf survey conditions are during February through mid-April due to increased sunlight and good snow conditions. We recommend conducting the IAWS during this period.

SURVEY TIMING AND INTERVAL

In the Interior, the common range of a snowfall event is 2–10″. Even though surveys can be conducted 1 day following the snow event (Stephenson 1978; Becker et al. 1998, 2004), we recommend initiating the survey 2–3 days after snowfall assuming favorable weather forecasts. The longer delay allows wolves to move and make more tracks, including those that are on kills. The greater distance animals travel in snow increases the probability of locating their tracks (Becker et al. 2004, Linnell et al. 2007). For multiple day surveys (≥3 days), we still recommend beginning 2 days after snowfall if an adequate weather window is forecasted. In areas prone to weather events or if the long range forecast does not indicate ≥5 day window, plan to initiate 1 day post-storm. For all areas, following snowstorms that deposit >10″, we recommend delaying the survey until 2–4 days after the storm because deep snow can impede wolf movements (Dale 1997).

The allowable time interval to conduct IAWS is predicated by meeting survey assumptions and will vary between study areas and years due to terrain, ungulate densities, and weather conditions. With each passing day following the weather event, the length of the wolf track segments will continue to increase making it easier to find tracks; however, longer track segments result in increased tracking time and expense. Eventually, the combination of both old and fresh wolf tracks and track deposition by moose, caribou, and sometimes lynx (*Lynx canadensis*) will reduce the efficiency of the survey and survey assumptions may be violated. Becker et al. (1998) recommended a survey interval of 1–4 days for the SUPE method, but we contend that this interval can be extended if conducting IAWS in certain areas. Based on discussions with experienced wolf survey pilots, the survey window should be limited to 1–5 days in areas with high densities of moose (>1 moose/mi^2) and up to 10 days in areas with low numbers of caribou and moose assuming suitable weather conditions.

In areas with abundant caribou, an IAWS survey following one snow event may not be possible. Each year there are areas in the Interior that cannot be surveyed due to large numbers of wintering Fortymile and Nelchina caribou obliterating wolf tracks no matter how quickly after the snow event the survey begins. If caribou are limited to a portion of the study area or herd size is small, it is possible to conduct IAWS, but this area needs to be surveyed promptly after the weather event before caribou track accumulation is too great. As previously described, because caribou move between areas during the winter, a wolf population count might be obtained using the IAWS method but multiple surveys will be necessary.

SURVEY APPROACHES

There are 2 approaches to conducting IAWS. The most common approach is to complete the survey following one snow event. This approach reduces logistical planning and potential conflicts with other projects, yields defensible results quickly, and requires a smaller portion of the operating budget for transportation to and from the study area. However, as previously discussed, results from surveys of short duration reflect the survey period only and may not be indicative of the resident overwinter pack structure due to movements in and out of the area. Another approach is to conduct the survey across multiple snow events. This latter approach can require fewer pilots for any single survey. Further, a better measure of the study area’s pack structure can be obtained through confirmation of questionable packs that were temporarily absent or present due to extraterritorial forays. The disadvantages are a more protracted survey, increased chance to miss wolves that moved from unsampled to previously sampled areas or to double count wolves that moved from previously sampled to unsampled areas, changing pack size due to dispersal and mortality, and increased costs to cover additional travel to the study area. It is crucial that survey results are mapped following each survey day with descriptions of pack sizes, color composition, wolves with distinguishing marks, and distribution to minimize the possibility of missing or double counting packs.

Survey Aircraft

Aircraft used to conduct IAWS must be limited to ski-equipped tandem models that can be flown safely at slow speeds (75–85 mph) and offer excellent visibility for the pilot and observer. The most common models used are the Piper Super Cub (PA-18), Bellanca Scout, Aeronca Champ, or Aviat Husky. Side-by-side seating aircraft (i.e., Taylorcraft various models) can be used but it is more difficult for the observer to assist in tracking because the pilot will most likely align the plane to keep the tracks on their side. Four-place aircraft such as Cessna models and Maules are generally not acceptable due to poor ground visibility and higher groundspeeds.

The necessary number of aircraft is based on the expected survey window, the size of the study area, search intensity (0.8–1.0 min/mi^2 plus shuttle time), and if the survey is to be completed following one or multiple snow events. For example, in our 4,656 mi^2 Unit 20C study area, we planned for 1.0 min/mi^2 survey intensity (77.6 survey hours) and 3-hour shuttle time for each plane to get to and from the study area each day. We wanted to complete the survey mostly in 2 days because portions of the area are prone to wind events requiring 39-survey hours/day. To minimize effects of survey crew fatigue, we wanted to limit flight hours to 8–9 hour/day, including 5–6 hours for survey and the remainder as shuttle time. To meet these time objectives, we needed 7 survey planes (39 total survey hours/6 hour of survey). With that number of crews we were able to complete most of the area in 2 days with a minor amount of resurveying on day 3.

Survey Crew Performance

Even though wolf tracks are distinctive, aerial snow-tracking is a specialized skill. The IAWS technique requires pilots with expertise in low and slow flight and the ability to recognize and follow wolf tracks through varied terrain and habitats. Some pilot-observers excel at it, most do not. The tracking abilities of the pilot are usually more important than those of the observer, so careful selection of survey pilots is vital to the success of the survey. The study leader must factor in skill levels when choosing crews, areas where each crew will survey, survey conditions (presence of caribou, more wind scoured), and even interpreting results (i.e., deciding if an area should be resurveyed). It is beneficial to employ observers who can track wolves, but a less experienced observer can be paired with an expert pilot-tracker to be trained. More survey time may be required in such cases. Preferably, observers should be trained by experienced tracker pilots in areas where there are radiocollared wolves prior to the survey. Note that rough flying conditions and rugged terrain can negatively impact pilot and observer performance due to stress and fatigue.

During the survey, pilot-observer teams must spend most of their time searching for wolf tracks. Prior to each survey flight, the survey team needs to program the assigned survey area into the onboard GPS units, understand the data recording requirements, have the data sheets ready, and if possible familiarize themselves to the type of terrain in the area to help plan how it should be flown.

SURVEY PILOTS

First and foremost, survey pilots must be able to track wolves through the variety of conditions and habitats we have in Interior Alaska. Pilots are responsible for aircraft safety and determining the most efficient manner to survey an assigned area. They must maintain radio contact with each other to relay aircraft positions and weather conditions. Timely communication is required between adjacent pilots whenever it is necessary to follow tracks outside of an assigned area. The "buddy system" will remain in play until all survey planes are safely on the ground at the end of each survey day. It is very important that each survey pilot accepts their personal limitations and discontinues when conditions exceed their abilities. The project leader needs to make this point clear to each pilot prior to the survey.

We always need to be on the lookout for new wolf survey pilots. Pilots who exhibit potential and interest should be encouraged to learn the necessary skills. Excellent wolf-tracking pilots develop their skills through many hours of tracking wolves through all types of snow conditions and habitats. Our policy should be to train pilots and observers at every opportunity. Project leaders should create training opportunities while benefitting their project by combining experienced with less experienced pilots-observers in areas that need to be resurveyed.

Almost all of our best survey pilots learned their skills while trapping or hunting wolves. However, surveying wolves and hunting wolves can be very different. Surveying wolves requires all packs be found even ones that had moved very little or were difficult to track due to forest cover. In contrast, aerial hunters and trappers will often high-grade their search effort to find the more accessible packs. It is important that the project leader stresses to each survey crew the importance of the required search intensity.

OBSERVERS

Since wolf surveys require pilots to circle at slow speeds and at low altitudes, any weight in the back of the airplane affects airplane performance and safety; only dependable observers should be used. All observers should be capable of taking thorough and detailed notes, not be susceptible to motion sickness, and have a keen interest in tracking or learning how to track wolves. Observers are responsible for ensuring data quality. This includes ensuring that data forms (Appendix B) are legible and complete and that survey protocols and methods were followed including terminating the survey if conditions are not suitable. It is important that observers review data with their pilots after each day's flight to ensure quality because key information may be lost as memories fade.

Conducting IAWS

SNOW TRACKING

The entire area must be surveyed for tracks at the required search and flight line intensity. It is not acceptable to primarily focus on natural wolf travel corridors, such as drainages and ridge tops (i.e., "high grading"). For example, 1 of 12 packs (8%) detected during the Unit 20C survey might not have been found if only the major river and creek drainages were surveyed. The pack travelled along a minor drainage for <400 yards and the rest of the track (~10 mi) meandered through black spruce (*Picea mariana*) forest and muskeg away from drainages and ridge tops.

All fresh wolf tracks are followed from the intercept point until wolves are observed. The entire track segment is determined by backtracking. Track segments and survey routes are mapped by onboard GPS. During multiple day surveys it is possible to encounter a track that originated in or travelled into previous surveyed areas. These tracks must be followed and checked against tracks found during previous surveys to determine if they are new wolves or not. Where possible, discernible wolf track segments made before the snow event should be followed, mapped, and pack size estimated, to help assess if all packs were found during a survey.

PACK COUNTS

Following a wolf trail through deep snow in open country with good light conditions is easy. However, in Interior Alaska most wolf tracking is going to involve considerable time following tracks through trees. It can be difficult to follow even fresh wolf tracks through forested areas or windblown terrain, or through older wolf tracks and those of other species such as caribou, moose, or even lynx. Wolf behavior can also complicate tracking because wolves commonly backtrack their own trails making the pack look larger than what it really is and can complicate decisions on the most recent direction of travel. Further, individual wolves often separate from the pack and rejoin further along the trail requiring more trails to be followed. Good snow and light conditions will help but the most important factor is the diligence of the survey crew to follow all wolf track segments to ensure correct assessment of pack alliances. If unsure of track vintage or what direction the wolves are travelling, land and verify.

Once a wolf pack is sighted, note the number of wolves present as well as their individual colors and behavior (i.e., possible breeding pair). If the survey is conducted during early winter, the number of pups can usually be verified by their size and behavior. Any discrepancies between the number of wolves counted and what was estimated by tracks prior to visual contact needs to be resolved. The most common cause is that wolves have split off from the pack. Adult wolves often leave the pack and can be >1 mile in front of most of the pack when being tracked by airplanes. The best method to determine if any wolves have split off from the main pack is to widen the circles around the observed pack to locate tracks that have left the main trail. During backtracking, crews need to be sensitive to any new trails that may have formed. Pups often fall behind the main pack and can be overflown. Another complicating factor is that breeding pairs often disassociate from packs during breeding season (mid-February through mid-March). Verifying if the pair is actually a resident pack or are associated with a larger pack is important to survey results and management implications. This will require all track segments of the pair and the nearby pack be followed to determine if the 2 groups can be tied together.

If vegetation prevents observing all or a portion of the wolves tracked, it will be necessary to estimate pack size based on the number of individual trails or the number of beds in a resting area. If need be, land and investigate the tracks or beds to try to get a better count. In situations where pack size is questionable, the pack should be tracked again later in the survey to obtain a more accurate pack count. If pack size cannot be resolved using count and track data, then report pack size as a range (i.e., 4–5 wolves). However, the rate of visually observing packs is often an indicator of survey quality. Based on past survey results, >60% of packs tracked should be observed in their entirety. Lesser observation rates indicate that the survey interval was extended too long and due to track deposition and poor snow conditions the wolves could not be effectively tracked. If the observation rate is low due to quality of the survey conditions, then the project leader needs to consider postponing the survey. Estimating most packs from track counts will reduce the evaluation of the range of pack sizes.

DATA INTERPRETATION

Density Estimates

IAWS results are normally expressed as density estimated by the number of wolves detected divided by the size of the study area. Density is the accepted abundance format to evaluate and compare populations. However, because the results of an IAWS represent a snapshot, are correct only for that survey period, and because there are a variety of acceptable inclusion rules, there can be some confusion in interpretation. Even though the density estimate is valid for a particular day or period of days, it can be substantially higher or lower than the overwinter density of resident wolves in an area. For example, a wolf survey conducted in a 2,764 mi^2 portion of Unit 24B during March 2006 produced a density estimate of 28.2 wolves/1,000 mi^2. This 2,764 mi^2 area was later included in larger study areas surveyed in March 2011 (4,638 mi^2) and March 2012 (4,752 mi^2). The density estimates during those years were 15.8 (2011) and 14.0 (2012) wolves/1,000 mi^2, about 100% less than the 2006 estimate (Stout, unpublished data) and more biologically believable based on ungulate abundance. These results suggest that a combination of survey area size, boundary placement, and wolf distribution during 2006 had a substantial effect on the estimate. Based on ungulate population and harvest trends during 2006–2012, there was little chance the wolf population declined by half. This situation emphasizes the importance of study design, but also that study results need to be carefully evaluated relative to past surveys and to published wolf densities in similar habitats-prey densities to assess if the results are biologically feasible.

The use of different inclusion rules between studies complicates density estimates because they affect the number of wolves used in the calculation. For example, comparing boundary rules used in the Interior during past surveys (Roger Seavoy and Mark Keech, personal communication), density estimates that include only wolves detected within the study area will be less than estimates that include 50% of the wolves found outside if the same area size is used. To standardize results and comparisons between years and areas, we recommend that we follow the method of Becker et al. (2004) to estimate the number of wolves by multiplying pack size by the proportion of the track segment within the study area. We concur this will be the best approach to include boundary packs. For long-term study areas, results from repeat surveys will better define pack distribution improving the density estimate by improving both the estimate of wolf numbers and the area surveyed.

IAWS results are valid for the area surveyed. However, decision-makers are often not aware of this limitation and management biologists are often expected to estimate wolf densities for larger or distinct areas. We need to carefully consider the management ramifications of expressing IAWS results as a density for much larger areas due to spatial differences in habitat quality or prey densities. We recommend utilizing published density estimates from areas with similar ungulate densities instead of extrapolating survey results beyond their boundaries. This approach would be analogous to the knowledge–based assessment of habitat potential used for bears (Miller et al. 1997). For example, in low-density Interior Alaska ungulate areas, a defensible estimate would be 10–18 wolves/1,000 mi^2 (Burch et al. 2005; Rodney Boertje and Craig Gardner, ADF&G, unpublished data) and in high prey areas (i.e., Unit 20A; Gardner, unpublished data), 23–34 wolves/1,000 mi^2.

Using the IAWS Method to Monitor Population Trends

Annual or biennial IAWS's can effectively be used to evaluate wolf abundance trends by monitoring the number of packs and range of pack sizes within a defined study area (Burch et al. 2005). Wolf densities reflect individual pack sizes and the number of wolf packs occupying a given area (Mech et al. 1998). Further, pack numbers and sizes are important parameters for understanding the effects of wolf predation on ungulates and the effects of harvest on wolves. Results increase in importance as surveys in an area are repeated. However, pack sizes cannot be compared between different wolf populations because similar pack sizes may correspond to very different wolf densities as average pack territory sizes may differ substantially between areas.

In Interior Alaska, study areas ranging between 3,000–4,000 mi^2 in size will encompass 6–13 packs (Burch et al. 2005; Jason Caikoski, ADF&G, unpublished data; Gardner, unpublished data). Accurately establishing the number and size of packs are likely to be iterative processes such that areas on the landscape where packs are missed or where wolves may concentrate on a temporary basis are identified following multiple surveys. This scale of monitoring strikes a balance between the need for a large, representative sample of a wolf population and logistical and budgetary constraints. Assuming the study area is close to the base of operations, an annual operating budget of $8.4–$11.2k (~$2.8k/1,000 mi^2, not including transport to study area or lodging) is appropriate given current logistical costs.

Retrospective Early Winter Population Estimates

For planned or ongoing wolf control programs, it would be desirable to enumerate early winter wolf populations. These counts would improve estimates of overwinter predation rates and the number of wolves that should be removed. However, it is rare that wolf surveys are conducted during this time due to inadequate snow conditions. Therefore, most early winter estimates are derived by adding wolf harvest data and an estimate of transient wolves (usually 10%) to the number of resident wolves counted during late-winter surveys. Due to the lack of data, these estimates rarely account for the number of wolves that died during winter by other mortality factors. The problems with this approach are that harvest numbers rarely reflect the actual take of resident wolves (Adams et al. 2008), the standard 10% estimate for lone wolves is suspect (Burch et al. 2005, Adams et al. 2008), and the omission of wolves dying from nonharvest causes can be substantial (e.g., estimated to be 20% of the early winter population [Adams et al. 2008]). Harvest data are not indicative of the number of resident wolves because of the influence of transient wolves. Peterson et al. (1984) and Adams et al. (2008) found that transients were more vulnerable to harvest and constituted a higher percentage of the harvest in an area relative to their presence. For example, in an intensively trapped area south of Fairbanks, in Unit 20A, harvest data indicated that 50–70% of the wolves in several radiocollared packs were removed by harvest whereas pack size only declined by 20–33% and that included all mortality and dispersals (Gardner, unpublished data). Because of the difficulty in estimating harvest effects, the number of transients, and level of nonharvest mortality, these retrospective estimates of early winter wolf numbers should not be used. Instead our assessments of local wolf populations and their possible effects on ungulate populations should be based on actual numbers of packs, average pack sizes, and density found during an actual IAWS.

REAL TIME DATA RECORDING

GPS/GIS Instructions

Following the methods outlined in this manual will require GIS support during the planning and data processing phases of a survey. This can be accomplished in coordination with regional support staff skilled in GIS or a member of the survey team with GIS experience. If planned properly there should be minimal technical expertise needed during the survey itself. The biologist conducting the survey should work with the GIS technician/analyst to prepare the survey files and review the daily tasks of downloading track logs and assessing survey coverage/intensity. Following these methods will increase the time needed to prepare for a survey and process the final data, but doing so will increase the quality of the survey by documenting survey coverage/intensity and providing a final product (map) that can be properly archived.

Reference Grid

Once the study area boundary is defined, it is helpful to create a reference grid that overlays the area. This can be accomplished using third-party tools which work within ArcGIS (Esri 2012) (e.g., Jenness Enterprises Repeating Shapes [Jenness 2012] or Spatial Ecology's *genvecgrid* command within Geospatial Modeling Environment [Beyer 2012]). The size and shape of the grid cells is flexible when using these tools, but squares or rectangles are the easiest to deal with. Each cell in the reference grid should be assigned a unique ID.

It is useful to convert the final reference grid into a Garmin compatible track file so that it can be uploaded into pilot and observer GPS units. Because almost all department and contracted survey pilots currently use the Garmin 296 or 496 GPS models, care needs to be taken so that the track contains less than 700 (GPSMAP 296) or 1,000 (GPSMAP 496) points per track (some older handheld Garmin units are limited to 500 points per track). The conversion of the survey grid from shapefile format to Garmin compatible track file can be done using ArcMap and the DNRGPS or DNRGarmin extensions from Minnesota Department of Natural Resources (2012). Due to the limitation in the number of points or vertices the track can contain and the number of tracks that can be saved to a GPS unit, it is usually necessary to create a single part polyline shapefile by tracing the final reference grid and ensuring that the number of vertices is not exceeded for the specific GPS unit. The shapefile can then be converted into a GPS eXchange (.gpx) formatted file. This .gpx file can be transferred to GPS units as a track via a number of programs (DNRGPS, DNRGarmin, Garmin MapSource, Garmin BaseCamp, [2012] etc.).

Track Data

At the end of each day, survey and wolf track logs should be downloaded and backed up. Track logs can be organized by pilot/date and converted to shapefile (.gpx to .shp) (using DNRGPS or

DNRGarmin) or geodatabase formats once the survey is completed. The resulting shapefiles/geodatabases will need to be sorted by date and time and parsed out using the times on the data sheet that correspond to wolf track segments. For this reason it is imperative that accurate time is kept on the data sheets. These selected segments should be saved into separate shapefiles or packaged into geodatabases.

Final Map

The final map should contain the area surveyed based on the total coverage of track logs and the wolf track segments. Information on color and number of wolves can either be labeled graphically on the map or included as attributes in the track segment files. A digital archive should be created that contains information on all aspects of the survey including conditions, personnel, cost, as well as copies of all data sheets, track logs (survey intensity), track segments, survey area, and interpreted results (number of packs, singles, etc.) (Appendices A and B).

Alternate Data Collection Methods

The above methods describe the most basic level of data collection needed to properly document the survey, especially if observers are not used and data collection is left up to the pilot. If funding is available, other data collection methods can be employed that may increase efficiency in assembling the final data. Instead of relying solely on the GPS track log it is possible for the observer in each plane to have a GPS-enabled tablet computer (running ArcPad or similar software, options also exist for iOS devices) on which additional data can be recorded. Using this setup, observers are able to digitize track segments more accurately since the plane does not necessarily fly directly over the wolf tracks along their entire length. An additional advantage to this method is that total track files do not have to be parsed out after the survey is complete because they are created individually by the observer. Disadvantages include increased cost for the equipment, additional skills to operate the software, the potential for technical problems with the equipment, and that the operator may be less attentive to the actual track requiring the pilot to solely recognize any deviations (wolves departing or joining). It is likely that these alternate methods will become easier to implement as technology advances and becomes more affordable.

Survey Maps and Data Sheets

The data sheet used in Unit 20C surveys is included (Appendix B) but can be modified to meet survey needs. Essential information includes descriptive information such as date, observer-pilot team, specific study plot location, aircraft type, description of survey conditions, survey start/stop times, on track start times and latitude-longitude position information describing start of track, where wolves were found, number and color of wolves, and backtrack information.

Survey maps (paper size: 8.5″×11″, 8.5″×14″, or 11″×17″) depicting individual sample areas and survey blocks will aid navigation. Larger maps will reveal more topographical detail that would aid the survey teams in choosing the most efficient flight pattern. Maps should be generated in GIS prior to the survey. To make maps legible, you will need to print at a scale of approximately 1:300,000 (Kellie and DeLong 2006). A poster size map depicting the survey area, survey units and blocks, fuel caches, and daily results should be created prior to the survey and kept at base camp to monitor daily progress. The base map should be updated daily with wolf track segments and pack size and color composition.

Output

The finished product of IAWS will contain maps illustrating wolf track segments and survey flight lines, a total count of wolves and packs, pack sizes, and the calculated search intensity in terms of distance between survey lines and time spent (min/mi^2). When reporting results, a thorough description of methods including the boundary rule and the inclusion of lone wolves is necessary so others can evaluate findings. Further, any distinct areas that supported multiple packs should be described to aid future survey design. Survey results published in management and research reports will include search intensities and figures illustrating survey search patterns.

IAWS Checklist

Is IAWS the appropriate survey to meet the study objective(s)?

Yes if the objective is to evaluate the number of packs, range of packs sizes, and their distribution at a particular time (one time survey) or throughout mid to late winter (multiple surveys).

No if the objective is to evaluate the number of wolves and packs in an area without requiring additional data on range of pack sizes, if funding is not adequate to conduct IAWS, or if the area in question is >5,000 mi^2. If any of these conditions apply, then the SUPE method is more appropriate.

Pilot-observer-aircraft requirements (see pp. 13–14):

- Pilots: Highly qualified at low and slow flight and tracking wolves.
- Observers: Excellent note takers, not prone to air sickness, not required but helpful if they can track wolves.
- Aircraft: Piper Super Cub (PA-18), Bellanca Scout, Aeronca Champ, or Aviat Husky.

Survey condition requirements (see p. 11):

- Snow: A starting snow base of ≥10″; surveys should occur after a ≥2″ snowfall or wind event that are adequate to mostly cover tracks made before the storm.
- Light: Direct sunlight or high overcast conditions (light must be bright enough that tracks are distinctive).
- Wind: ≤20 mph dependent on if the tracks are being filled in and presence of turbulence.

Minimal-optimal study area size (see pp. 6–7):

- Encompass 3,000–4,000 mi^2.

Required search intensity (see pp. 7–8):

- ≥0.8 minutes/mi^2.

Survey timing (see pp. 11–12):

- In most situations, begin survey ≥2 days after the snow event. In areas with abundant ungulates or prone to wind events, the survey can begin 1 day following the snow event.

Recording survey coverage and wolf track segments (see pp. 18–20).

<u>GPS</u>

At a minimum the pilot needs to have a mapping GPS unit (Garmin 296, 496 or comparable unit) capable of accepting the survey area as a track file. If an observer is present, it is also useful to have this person operate a handheld mapping GPS unit (Garmin 60 or comparable unit) to serve as a backup in case the primary GPS fails. Both GPS units should be set up so that a detailed track log is recorded for each day of the survey.

<u>Data Sheet</u>

In order for GPS track data to be fully utilized a detailed data sheet must be kept to record wolf tracking start and stop times. This allows the track file to be parsed out into wolf track segments after the survey is complete.

Minimum Wolf Counts (MWC)

In terms of data quality and defensible results, the best wolf track survey methods available are the IAWS and SUPE. However, there are management scenarios that require less intensive wolf surveys. In IM areas where wolf control is being conducted, there can be legal requirements to ensure that a minimum number of wolves exist in the control areas following management actions. Thus, MWC could be conducted with the objective to confirm a given number of wolves. The survey would end once the target number is reached. The intensity of the survey necessary to verify minimum numbers will depend on the success of the control program. The deficiency of this type of survey is that the ensuing number will not be a complete count of the population and little use for evaluating program effects.

To conduct MWC, the first step is to analyze available harvest and control data to identify areas where wolves are likely to occur and in what numbers. Survey efforts should first concentrate in areas where wolf removal was lowest during the control action. In cases where wolf removal was generally high throughout the control area, or if the management objective is determining the number of and size of packs following control activities, then survey coverage and intensity may equal that of IAWS. A thorough description of survey intensities used and geographic area covered is necessary to reduce any chance of confusion as to what the survey results represent. Since a minimum observed number rather than an estimate is required, a SUPE survey would be inappropriate under such circumstances.

Managers have expressed the need to periodically obtain a general evaluation of wolf numbers in an area by using the MWC method. They argue that management objectives often do not require exact numbers of wolves and packs, but instead call for more coarse-scale surveys. However these results, which undoubtedly would benefit the area biologist, offer little to the long-term knowledge of wolves in the area and worse could cause false impressions of the wolf population. We strongly recommend against using MWC in this manner but instead, conduct IAWS in a defined area to determine population trends based on numbers of packs, pack sizes, and density. Results from this type of survey will be valid in the short and long term. In wolf saturated populations where the number of packs in an area does not change appreciably, mean pack size provides a useful index of population trends (Burch et al. 2005).

Table 4. Recommended survey standards to conduct an intensive aerial wolf survey (IAWS) or minimum wolf count (MWC) in Interior Alaska.

Protocols	IAWS	MWC
Interval	2–10 days	1+ days
Intensity-spacing	1–1.5 mi	No limits
Intensity-time	≥0.8 min/mi^2	No limits
Snow event	≥2″	No limits
Lone wolves	No	Yes

REPORTING REQUIREMENTS

When reporting results of an IAWS or MWC survey, the following information will be required to ensure correct interpretation and usage of the data:

1) survey type
2) pack and lone wolf membership rules
3) description of snow event
4) description of areas supporting multiple packs, i.e., ungulate concentrations
5) survey timing relative to snow event and number of days to conduct
6) survey intensity expressed both as minutes/mi^2 and average/range of distance between survey flight lines
7) quality assessment of survey crews
8) number and type of survey aircraft
9) number of packs, range and average pack size, total number of wolves, and percent of packs and pack members observed
10) maps displaying survey flight lines and wolf track segments
11) survey cost
12) for ADF&G internal reports, location of archived digital files on WinfoNet including data sheets, track logs, shapefiles, study area, and final map.

Further, if the survey was not successful because survey assumptions were not met, a brief description of how survey assumptions were violated (i.e., weather, caribou tracks, etc.) is necessary.

PROTOCOL REVISION

Over time, revisions to the manual are to be expected. Careful documentation of changes to the protocol, and a library of previous protocol versions are essential for maintaining consistency in data collection and for appropriate treatment of the data during data summary and analysis. While reporting, the protocol version used to design the survey will be included.

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Appendix A. Intensive aerial wolf survey example: Unit 20C, March 2012.

During 11–13 March 2012, we completed an intensive aerial wolf survey in a 4,656 mi^2 (12,059 km^2) portion of Unit 20C (Fig. 1). Survey timing coincided to the time of year when packs approach their lowest numbers (Burch et al. 2005). Our objective was to determine the number of wolves and packs to aid future management decisions.

We subdivided the census area into 14 sample units ranging from 320 to 352 mi^2 (Fig. 1). We further subdivided the survey units into 20–22 16 mi^2 sample blocks to assist survey crews in assessing their area coverage. Prior to the survey, we explained to each survey crew the required sampling intensity and that transects were probably necessary in most areas to ensure adequate coverage. Following the first 2 days of surveying, we identified any sample blocks or portions of blocks that were missed due to localized inclement weather or because the crew tracked wolves through a portion of the area but did not return to complete the unit. We returned on day 3 to complete these areas.

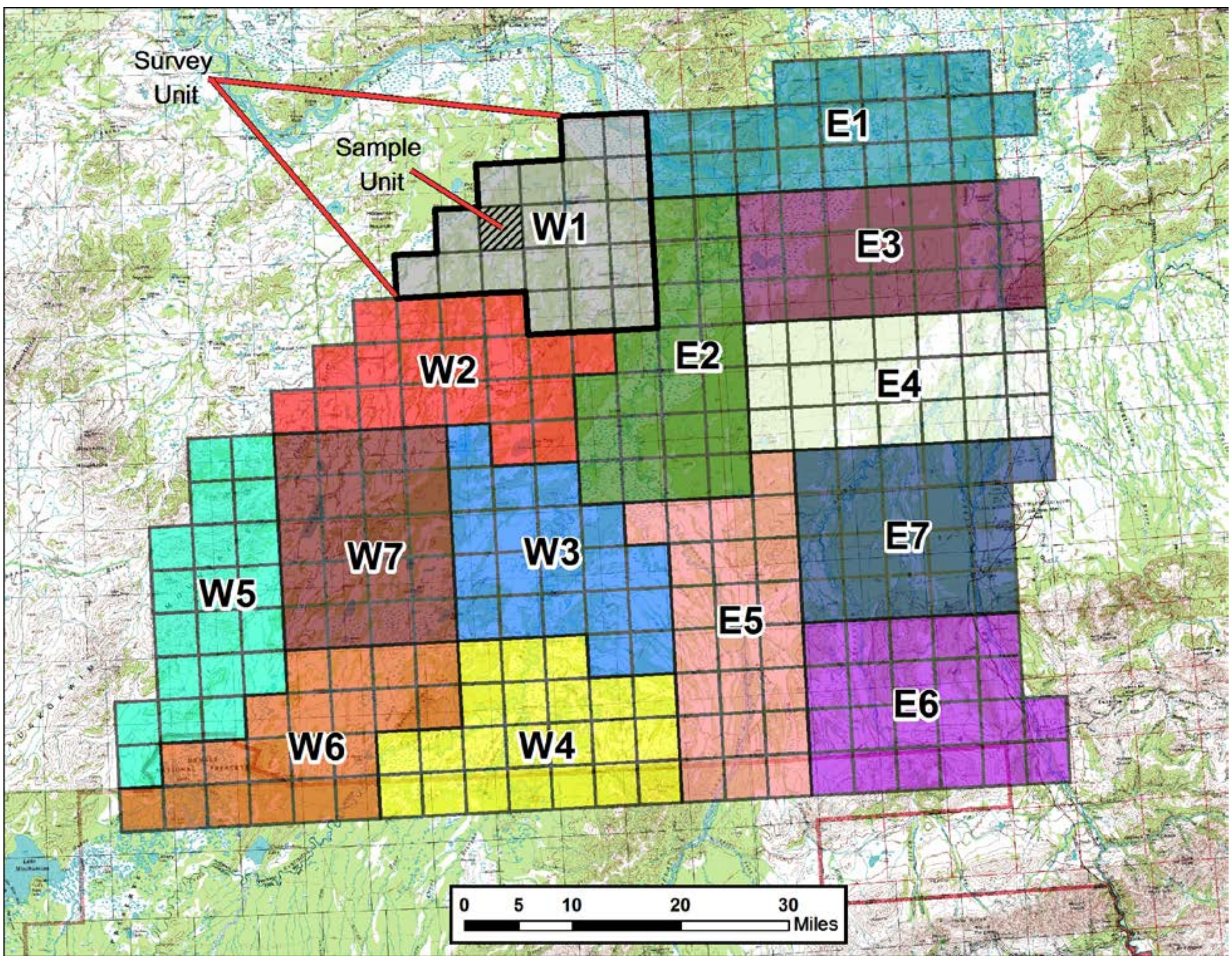

Figure 1. The 4,656 mi^2 Kantishna intensive aerial wolf survey study area subdivided into 14 survey units and 21–23 sample units, Unit 20C, Interior Alaska.

We initiated the census 5 days after a 6–12″ snowfall and 2 days after a ≥25 mph (40 km) windstorm. Snow conditions were excellent. We used 7 survey crews to complete the survey. Survey intensity averaged 0.91 min/mi^2 (0.4 min/km^2, Table 1). Sampling intensities varied due to habitat type and the presence of wolves. Some sampling units consisted primarily of burned timber/shrubs due to the 2010 wildfires and could be surveyed from a higher altitude requiring fewer transects. Two to four transects were completed in each sample block except for 1 block located within the Clear Air Force restricted airspace. Also, more survey lines were completed in the southwest portion of the study area than mapped due to a malfunctioning GPS. Figure 2 illustrates survey line spacing.

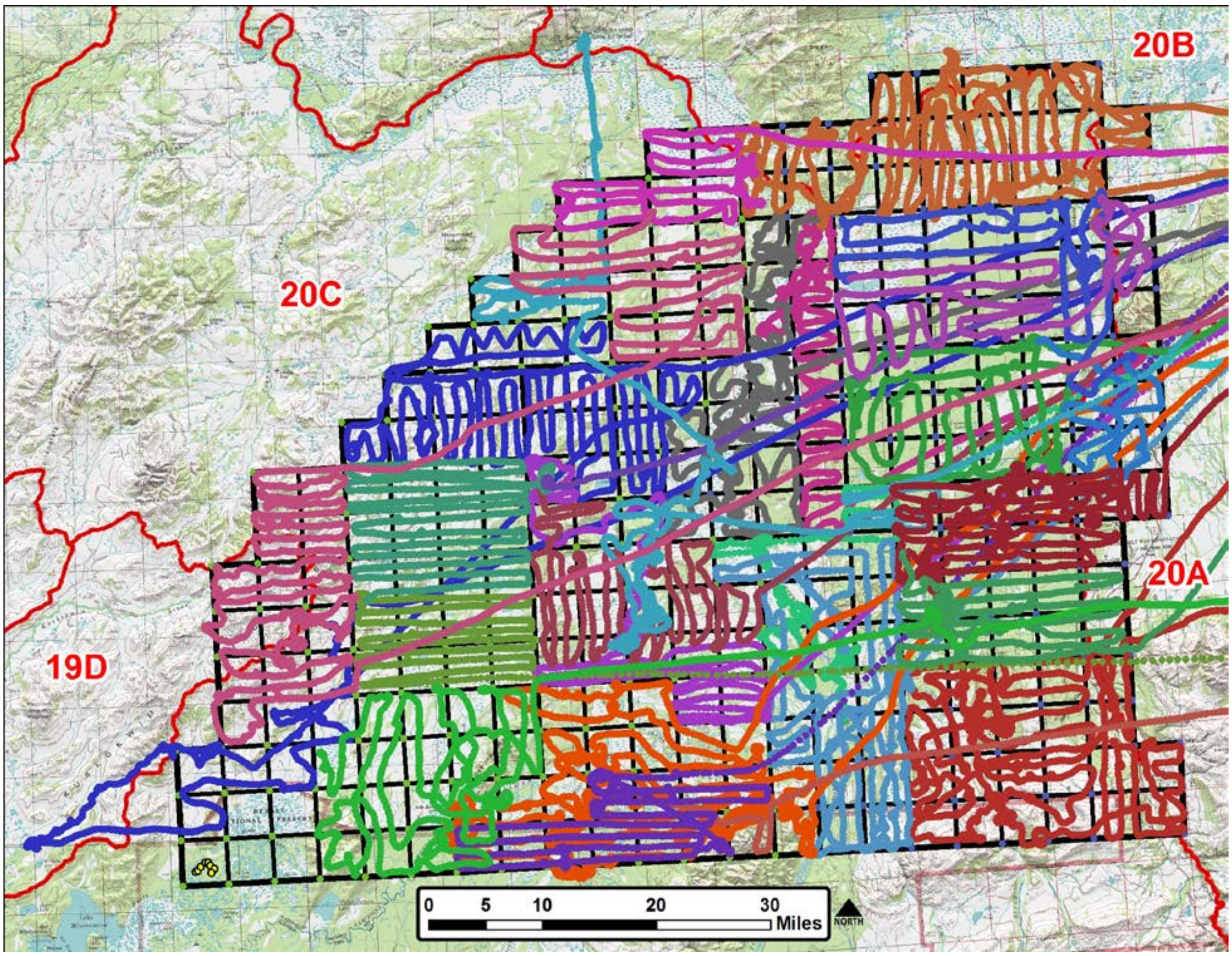

Figure 2. Survey line spacing used during the Kantishna River intensive aerial wolf survey, February 2012.

Table 1. Survey intensity used to count wolves in a 4,656 mi^2 (12,059 km^2) portion of Unit 20C in Interior Alaska during 11–13 March 2012.

Area	Size (mi^2)	Time (min)	Intensity	Tracks (Y/N)	No. of packs	Pack size	Singles
E1	352	360	1.02	y	1	2	1
E2	336	350	1.04	y	1	2	1
E3	336	215	0.64	y	1	2	
E4	336	215	0.64	y	0	0	
E5	336	384	1.14	y	1	7	
E6	352	328	0.93	y	1	4	2
E7	336	392	1.17	y	2	2,7	
W1	320	267	0.83	y	1	5	
W2	320	236	0.74	n	0	0	
W3	320	345	1.08	y	1	5	
W4	352	436	1.24	y	1	2	
W5	320	239	0.75	y	1	10	
W6	320	201	0.63	y	1	2	
W7	320	295	0.92	n	0	0	
Totals	4656	4263	0.91		12	50	4

Local survey conditions varied during the 3-day survey. During day 1, survey conditions were excellent throughout the area, during day 2 the southern portion had varying but adequate light conditions and some wind in the higher terrain, and during day 3, light conditions were good but high winds were a factor. The survey was primarily completed during the first 2 days and on day 3, most or our effort was directed to check small areas that had received inadequate sampling. Overall, we rank the survey conditions as good. Cost to complete the census was about $20k.

Our total count was 54 wolves, 4 of which were singles. We included all wolves and tracks found during the survey. We found 2 other singles but additional track information collected on subsequent days verified these were members of known packs. Of the wolves tracked, our observation rate was 59.3%. We found 12 individual packs with an average pack size of 4.2 wolves (range = 2–10; SD = 2.94 wolves); 6 of the packs were pairs. Figure 3 includes all wolf track segments found during the survey. Following the pack inclusion rule outlined in Becker et al. (1998), the estimated density was 4.1 wolves/1,000 km^2 (10.7/1,000 mi^2). Our density estimate does not include single wolves.

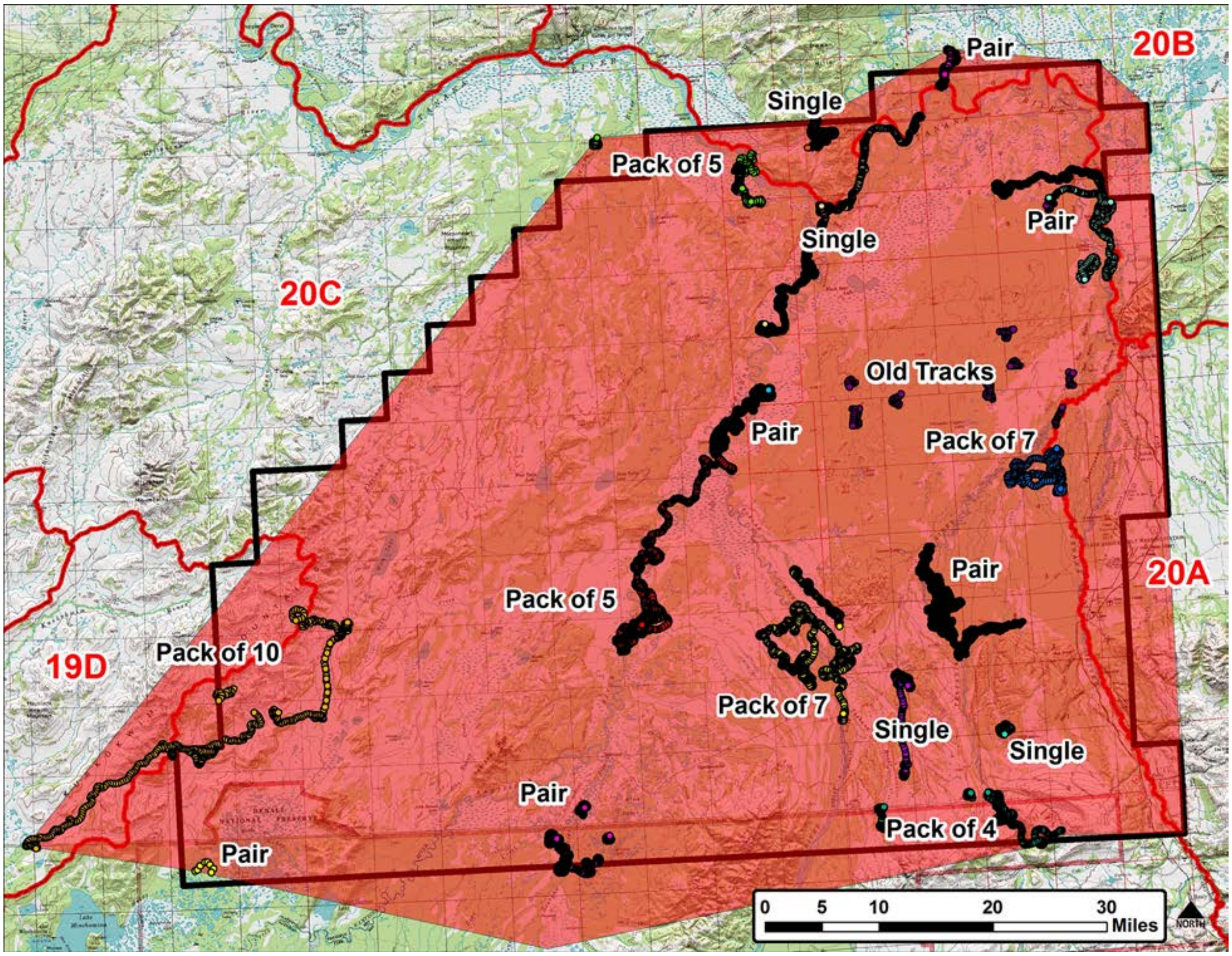

Figure 3. Wolf track segments found during the Kantishna River intensive aerial wolf survey, February 2012.

Appendix B. Data form used during the Kantishna River intensive aerial wolf survey, February 2012.

WOLF SURVEY FORM

Date _____________________ GMU ______________ Aircraft Hours _______________

Pilot _____________________ Observer ____

Study Area:____ Survey unit:__________________

Snow age	Snow cover	Light type	Light intensity	Predominant habitat in SU	Survey rating
1. 1–2 days	1. Complete	1. Bright	1. High	1. OPEN lower elev. shrubs/wetland	A. Excellent
2. 3–4 days	2. Some low	2. Flat	2. Medium	2. DECIDUOUS FOREST birch/aspen	B. Good
3. 5–6 days	veg showing		3. Low	3. MIXED FOREST	C. Fair
4. 7+ days	3. Bare ground	Wind speed		4. OPEN CONIFEROUS FOREST	D. Poor
	showing	<5 mph		5. DENSE CONIFEROUS FOREST	
		6–10 mph		6. SUB-ALPINE FOREST	
		>10 mph		7. BURN	

SURVEY INFORMATION	**1**	**2**	**3**	**4**	**5**
START TIME					
END TIME					

TRACK AND PACK INFORMATION

Ref. #	Lat/Long track first spotted	Sample unit	Time track spotted	Time wolves found	Lat/Long pack sighted	Pack size	Wolf colors	I/O	Lat/Long backtrack ends	Time track ends
1										
2										
3										
4										
5										
6										

Single Wolves	**1**	**2**	**3**	**4**	**5**	**6**
START Lat/Long						
END Lat/Long						

Comments:____

____