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Designing studies to monitor grizzly bear linkage zone effectiveness| Exploring options for the Swan Valley Grizzly Bear Conservation Agreement case study

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DESIGNING STUDIES TO MONITOR GRIZZLY BEAR LINKAGE ZONE EFFECTIVENESS: EXPLORING OPTIONS FOR THE SWAN VALLEY GRIZZLY BEAR CONSERVATION AGREEMENT CASE STUDY

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Designing Studies to Monitor Grizzly Bear Linkage Zone Effectiveness: Exploring Options for the Swan Valley Grizzly Bear Conservation Agreement Case Study (131pp.)

Director: Len Broberg

The US Fish and Wildlife Service (USFWS), with Endangered Species Act jurisdiction over all lower 48 US grizzly bear populations, has attempted to develop innovative strategies to protect grizzly habitat. One of the first collaborative habitat conservation plans in this vein was the Swan Valley Grizzly Bear Conservation Agreement. This agreement was developed with a geographic information system based Linkage Zone Prediction model (cumulative effects) and is currently protecting habitat including linkage zones in the Swan Valley of western Montana. Now, the USFWS needs to assess whether its experimental conservation efforts are working in the Swan Valley. Many recent grizzly bear monitoring studies contribute valuable information to this endeavor. Some of these studies are reviewed, with discussion of their relevant techniques, successes and failures. This thesis supports an informed selection of a study methodology most capable of evaluating the linkage zones in the most statistically sound manner.

Three ideal questions that might collectively evaluate linkage zone effectiveness are framed by their strengths and limitations to demonstrate the multitude of challenges any study design will face in a real landscape. The combined results of five additional study objective questions should further improve the selection of the most suitable future study design for evaluating linkage zones. A two-part study is suggested to derive the value of both the Swan Valley Grizzly Bear Conservation Agreement in general, and the linkage zones that constitute the protective elements of that agreement. Twenty-year annual background sign surveys are encouraged, as well as three periods of combined intense global positioning telemetry and DNA based grids. I conclude with suggestions for the implementation of these methods in the near future.

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INTRODUCTION

Lower 48 grizzly bears (*Ursus arctos horribilis*) and their habitat are currently protected by their ' 'threatened' status under the Endangered Species Act (ESA). Grizzly bears suffer high mortality from many human related causes. Relying on research, managers have assumed that open roads, residences, timber extraction and recreation areas have had significant impacts on grizzly bear mortality (Mace & Manley 1993; McLellan & Shackleton 1989a, 1989b, 1988a, 1988b; Mattson et al. 1987; Dood et al. 1986). The US Code Annotated clearly states that, "Each Federal agency shall in consultation with and with the assistance of the Secretary, insure that any action authorized, funded, or carried out by such agency is not likely to jeopardize the continued existence of any endangered species or result in the destruction or adverse modification of habitat of such species which is determined…to be critical…"(16 U.S.C.A §1536(a)(2)). Furthermore, the 1993 Grizzly Bear Recovery Plan required evaluation of the potential for linkage zones (LZs) within and among the current recovery areas. This includes the Northern Continental Divide Ecosystem (NCDE), where recovery cannot be achieved without occupancy in the Mission Mountains portion of this ecosystem (USFWS 1993). Pursuant to this statutory directive and recovery plan, the US Fish and Wildlife Service (USFWS), with jurisdiction over all US grizzly populations, has attempted to develop innovative strategies to protect grizzly bears from incidental takings. One of the first collaborative habitat conservation plans in this effort was implemented in the low-elevation areas of the upper Swan Valley in western Montana through the implementation of the Swan Valley Conservation Agreement and its LZs. Now, the USFWS needs to assess the value of its grizzly bear conservation efforts in the Swan Valley.

This document supports an informed selection of a study protocol to promote statistically sound assessment of grizzly bear use of the Swan Valley Grizzly Bear Conservation Agreement (SVGBCA) LZs as part of the USFWS Grizzly Bear Recovery Program. It begins with a description of the Swan Valley. Next, some background describing the LZ concept is furnished. This is followed by a thorough review of all techniques currently available to monitor grizzly bears. Then I supply a general description of statistical considerations and model capabilities. After which, I discuss three ideal questions, which when asked together could assess whether the LZs are working to promote healthy connectivity for two grizzly bear sub-populations. Eventually, I will apply this entire review to the Swan Valley case study area to derive the selection of the most appropriate study methodology. Considerations described throughout this thesis will be boiled down to a series of questions leading to the ultimate selection of a study design. The project concludes with management recommendations to promote the successful implementation of a preferred methodology.

CHAPTER I

The Case Study, Swan Valley, Montana

It is my hope that this case study will accomplish two goals. First, I hope to supply an adequate description of the upper Swan Valley and information that has been gathered describing its grizzly bears to guide the selection of a monitoring plan. Secondly, I would like this chapter to serve as a case study that could be readily used as a template for description of other linkage zones in other Rocky Mountain valleys in the future. Hopefully, additional LZs will be implemented, connecting remnants of once quite extant grizzly bear habitat in the lower 48 states.

The Swan Valley

The Swan Valley lies between ridges of the Mission Mountains to the west and the Swan Mountains to the east, at latitude 47 North and longitude 114 West (Fig.1). Each of these mountain ranges houses a large percentage of wilderness area. The Missions Mountain Wilderness (MMW) runs approximately 48 km. north to south and 12 km. east to west at its narrowest point. Directly to the west and south of the MMW, lie the Salish-Kootenai Tribal Wilderness and Tribal Primitive Areas, respectively. The western boundary of the Bob Marshall Wilderness complex (BMW) extends north to south along the entire length of the western most ridge in the Swan Mountain Range. Elevation varies substantially in the Swan Valley.

The highest peaks are at elevations greater than 3000 m above sea level. The valley floor was carved by the Pleistocene glaciers (Alden1953) and is in the range of 940-1450 m above sea level. The Swan Valley is characterized by a flat bottom which transitions abruptly into steep mountains. The valley is extremely moist for the northern Rocky Mountains due to its maritime climate. Average rainfall varies substantially in the valley. The center of the valley receives an average 70 cm. of rainfall. The surrounding mountains receive approximately 150 cm. of moisture, mostly precipitating in the form of snow (Servheen 1983).

Human occupation of the 158,362 ha upper Swan and Clearwater Valley floor has remained fairly sparse with approximately 550 developed sites (Sandstrom 1996). The largest towns are Seeley Lake, Condon, and Swan Lake. The Swan Valley remains a rural valley, under increasing development pressure. Abundant recreation opportunities and its proximity to Glacier National Park draw tourists during the active bear season. However, timber production remains the largest industry in the valley.

The Mission Mountains of western Montana house a small population of grizzly bears, estimated at 16-25 adults in 1981 (Servheen 1981). These bears are somewhat isolated by the Swan Valley from the bulk of the NCDE, which holds one of the two largest populations of grizzly bears in the conterminous 48 states. Unfortunately, no recent data describing abundance or demographic rates of the grizzly bears using the upper Swan Valley (called upper Swan Valley due to its closer proximity to the headwaters of the Swan River watershed than the South Fork Project study area, located further north) has been systematically collected. However, the USFWS has generated a voluntary-compliance management agreement to help protect a conservation area and LZs, which by design include much of the remaining high-quality grizzly habitat fragments in the upper Swan Valley.

The Linkage Zone Prediction Model

Reserve design is an emerging field of conservation biology. The application of geographic information systems (GIS), and satellite imagery has vastly extended our abilities to analyze wildlife habitat. This technology has also sparked much discussion surrounding our abilities to properly locate, and then conserve this vital wildlife habitat.

Developing LZs in a rural setting is more complicated than simply identifying critical habitat. The process is as much about people as it is about bears. Typically high-elevation areas remained protected because of their difficulty of human access and harsh climate. That explains why LZs are now needed in the more fertile and temperate low-elevation areas. These are the same areas where people concentrate on the landscape to fulfill our own life history needs. This conflict of interest explains why Servheen and Sandstrom (1993) decided to model Clearwater / Swan Valley LZs by using the following four criteria: riparian habitat (spring food/ideal travel ways), hiding cover availability, proximity to human developments, and proximity to open road density. This was a departure from traditional efforts, which were based mainly on food availability (Craighead et al. 1982; Mealey 1977).

The SVGBCA Linkage Zone Prediction (LZP) model was an attempt to include the main things bears need in low-elevation habitat (early spring food and good cover for travel) and the main threats to their survival there (human developments and motorized access) (Sandstrom & Servheen 1993). The goal, as the term LZP implies, was to predict where grizzly bears had the best chance of survival in low elevation areas. The entire 1620 sq. km. valley was broken into 648,960 (50 x 50 meter) pixels. Then each pixel was assigned a ranking for each of the four components. The riparian and cover components were ranked according to satellite and GIS layer scores. The proximity to human developments and open roads was ranked on an inverted scale. All four values were summed to create a map ranking each pixel in the valley with a value between 7 and 20. The areas with the highest scores have the most riparian habitat, most cover, furthest distance from human dwellings and furthest distance from open roads. Once the scoring map was generated, the best looking areas were prioritized. Then the USFWS Grizzly Bear Recovery Project attempted to encompass as much high-ranking habitat as possible into LZs stretching from the Mission Mountain Wilderness east across the valley to the Bob Marshall Wilderness.

An iterative process of designing regulations for these LZs was then conducted by the Grizzly Bear Recovery Project (Servheen pers.com.) The thrust of the SVGBCA lies with restrictions in open road density and the timing and location of timber management activities. Several other restrictions worth noting are the prohibition of logging professionals carrying firearms on the job, and some restrictions on firewood cutting. The point of this voluntary agreement was to avoid the incidental take of grizzly bears. It was certainly not to permanently halt timber harvest and associated road construction, but rather to manage it in a manner that would reduce mortality and maintain grizzly bear movement across the valley, especially during the two critical times of the active grizzly bear season (April 1-June 15 and September 1- Nov 15) (Swan Valley Grizzly Bear Conservation Agreement 1995, 1997). Note that Sandstom (1996) later refined the LZP model for the Clearwater / Swan, using smaller pixels (30m) and a slightly different GIS cumulative effects model.

The SVGBCA Linkage Zones

Four linkage zones extend east west across the Swan and Clearwater Valley. They are protected by the SVGBCA, lettered alphabetically from south to north (A, B, C, and D) (Fig.2). A portion of the southernmost LZ, straddling the Swan /Clearwater divide, has been delineated but is not subject to the SVGBCA, as it is outside the Swan Valley. The LZs were designed by the USFWS in a checkerboarded valley-floor landscape with three major land owners in the valley: Plum Creek Timber Company L.P., the Forest Service (Flathead National Forest), and the State of Montana (MT. DSL). The SVGBCA LZs collectively include approximately 976 sq. km., which is approximately 60% of the Swan Valley land area. Each of the SVGBCA LZs also contains wilderness in the western potion (except LZ 'D') and borders the BMW on its eastern boundary. Collectively, wilderness constitutes approximately 30% of the total LZ area. The largest zone (A) borders the Clearwater/Swan divide and encompasses approximately 365 sq. km of land. This unit also contains the largest percentage of wilderness. The LZ directly to the north (B) comprises the second largest protected portion of the valley with approximately 225 sq. km. The northernmost unit (D) is the next largest (200 sq. km.) and C is the smallest (186 sq. km).

Monitoring the SVGBCA Linkage Zone Compliance

Cooperative self-monitoring of compliance is mandated under Section 4 of the SVGBCA. The Flathead National Forest has reported that 27% of all bear management subunit area, including all partner ownerships, is above 1.0 mile per square mile road density, and 40% of all subunit areas are above a total road density of 2.0 miles per square mile. As a result of these road densities, at least one subunit (Porcupine-Woodward subunit) was out of SVGBCA open-road-density compliance in 1996, 1997 and 1999 (USDA, FS 1999).

During 1997, I mapped the motorized access in the three southernmost SVGBCA LZs for Predator Conservation Alliance (formerly called Predator Project) on behalf of Swan View Coalition and Friends of the Wild Swan. While this information is not complete without including the northernmost unit, it does describe the general on-the-ground condition of motorized access during the summer of 1997 We found that approximately 61% of all road miles were behind a closure device of one sort or another. However, 38% of the road miles were scored as open, 13% as closed, and 49% were rated restricted. We obtained an average total road density of 1.4 miles per square mile in the three LZs. When MMW areas are removed from the calculations, (not standard IGBC core security calculation protocol) average total road density in LZs becomes 2.17 miles per square mile. Perhaps the most important finding from the survey conducted that summer is that 60% of all road miles were receiving vehicular use (40% High, 20% low), regardless of by whom. When we buffered these roads receiving use in 1997 by the Interagency Grizzly Bear Committee recommended 0.5 km. buffer (IGBC 1994), we found that 31.4% of total LZ's area was above the IGBC secure core area road density (Stockmann 1998 Unpub. Report). This monitoring information points to the need to accurately monitor habitat as well as animals to make a correlation between protective measures and grizzly bear use or abundance.

The final draft of the SVGBCA was dated February 23, 1995 and was later amended on April 17, 1997. The voluntary SVGBCA restrictions are part of an incidental takings mitigation plan and are also expensive for extractive corporations and state land managers under pressure to produce profits for shareholders and the Montana School Trust. Stakeholders in habitat conservation plans need to know whether their expensive voluntary cooperation appears to be helping improve this grizzly bear population's viability. Findings that LZs are reducing Mission Mountain grizzly bear mortality and isolation, would suggest improved viability of this population. The question arises, how does a wildlife management agency, such as the USFWS, select the best questions and methods to determine whether grizzly bears are benefiting from the Swan Valley Grizzly Bear Conservation Agreement and its linkage zones?

Historical Status of the Swan Valley Grizzly Bears

In order to make any statements or even pose any questions regarding the Swan Valley grizzly bears and the effect that habitat conservation measures have made, we first need a description of the historical status of this sub-population of the larger NCDE population. Swan mountain grizzly bears, farther northeast, were found to have average home range sizes only one-fifth of the average of those bears in the Greater Yellowstone Ecosystem (Mace & Waller 1997). Even still, local bears tend to have a large home range compared to the size of the Swan Valley. Some move around the entire Northern Continental Divide Ecosystem (NCDE) which stretches from the Rattlesnake BMU (north of Missoula) north to the Canadian

Border, and from Kalispell east to Choteau on the Montana Rocky Mountain East Front (RMEF). Existing information and current research efforts are briefly described here, and in each of the sections found in Chapter III, which review relevant techniques.

Grizzly bear telemetry studies began in the NCDE during the 1970's following threatened species listing of grizzly bears. Bears have been monitored in smaller study areas to make studies affordable and logistically feasible. The Mission Mountain sub-population has been recognized as a somewhat isolated population since the early 1980's, when Servheen (1983) first described that population in his Ph.D dissertation. These findings of a small and semi-isolated population formed the basis for his later efforts with Sandstrom in 1993 and 1996 to model and implement the LZs that form the heart of this case study. Aune and Kasworm (1989, 1986) reported on grizzly bears of the RMEF portion of the NCDE. Recent NCDE work has included study of the Glacier National Park and North Fork of the Flathead populations by Kendall, and Kehoe. It is noteworthy that Kehoe (1995) attempted to test the Linkage Zone Protection model used in the primarily Forest Service lands of the North Fork of the Flathead River, Montana / British Columbia, Canada. Although her study was telemetry-based, it has been generally criticized because of its small sample size. Mace, Waller, and many others working for the South Fork Project have extensively studied grizzly bears in the northern Swan Mountains recently (Mace & Waller 1997). During the fall of 1997, they released an extremely valuable reference, useful for designing Swan Valley LZ evaluation, called the "Final Report: Grizzly Bear Ecology in the Swan Mountains, Montana." This volume contains extensive findings of this impressive research team. Included is both a description of Swan Mountain grizzly bear ecology, habitat analyses, and population demographics (Mace & Waller 1997).

Perhaps most relevant to the grizzly bears of the upper Swan Valley, where the bulk of LZs exist on the landscape, is the on-going (informal) Swan Valley grizzly bear mapping project of NorthWest Connections (NWC), a non-profit founded in 1996. They have conducted unpublished track, sighting, rub-tree and baited remote camera studies during the past three years. The information they are collecting is currently helping provide a feedback mechanism useful for adaptive management, which is specifically included in the SVGBCA. The efficiency of these and other various techniques currently being used to monitor grizzly bears will be reviewed below.

CHAPTER II

The Linkage Zone Concept

Corridors have become an extremely hot topic in conservation biology in the last few years (Beier & Noss 1998; Rosenberg et al. 1997; Simberloff et al. 1992; Saunders & Hobbs 1991; Saunders & Margules 1991; Simberloff & Cox 1987). The value that protected habitat corridors provide for various animals is continuously debated. Ultimately, there can be no overarching statement made regarding the value of corridors for all species or even a single species, like the grizzly bear. The best we can do is to ask questions regarding the conservation benefits that appear to accrue to grizzly bears from specific corridor protections. If we begin to develop a body of evidence describing the effects that various conservation corridors have on grizzly bears we may eventually be able to make more informed statements regarding the overall value of these emerging management tools. As wildlife managers, we should avoid relying too heavily on corridors and other efforts at providing connectivity as a form of mitigation for excessive land development, especially prior to any conclusive studies that evaluate the effectiveness of these corridors.

Linkage zones are designed to protect habitat needed to support wildlife for periods longer than that needed for dispersal alone (Servheen & Sandstrom 1993). Therefore, they serve bears as improved habitat, not only as corridors. They can improve exchange between local populations but also "facilitate movement of an individual within its home range," (Rosenberg et al. 1997). The objective of a LZP is to identify land that will facilitate inhabitation as well as movement. Maintaining this secure habitat should then promote both natural foraging and dispersal behavior. These linkage zones are high quality habitat areas between a potentially insular population (Mission Mountain) and another healthier population (remainder of NCDE), allowing the possibility of movement and enhanced genetic interchange.

Positive Impacts for Bears

Probability of Extinction

Several techniques have arisen lately to estimate the viability of a population. These techniques obviously rely on the accepted definition of a population. Whether using a population viability analysis, a minimum viable population model, or a habitat viability analysis, incorporating conservation measures intended to maintain or restore connectivity between two or more populations (called a metapopulation) into your model, will likely decrease the probability of extinction. At least in theory, increased connectivity should provide several benefits to any population (Merriam 1991; Simberloff & Cox 1987). The so-called 'rescue effects' (Brown & Kodric-Brown 1977) will accrue to the population as new individuals disperse into areas where residents have extremely low density and genetic bottlenecks (Mills & Allendorf 1996). Enhanced connectivity should allow dispersing grizzly bears to recolonize suitable habitat if the resident population is depleted, maintaining the natural density of the area and injecting new genetic material into the local gene pool.

Genetic Variation - Inbreeding Depression

Although it has not been a major concern in conserving small grizzly bear populations to date (Servheen, pers.com.), rapidly declining grizzly bear populations may be vulnerable to inbreeding depression (Allendorf et al. 1991). Inbreeding depression can cause animals to have fewer distinct alleles at each locus (decreased heterozygosity), increasing the expression of deleterious recessive genes (Lacy 1997). The breeding of close relatives causes a reduction in fitness detected through, "higher mortality, lower fecundity, reduced mating ability, slower growth, developmental instability, more frequent developmental defects, greater susceptibility to disease, lowered ability to withstand stress, and reduced intra and inter-specific competitive ability (Allendorf & Leary 1986; Darwin 1868, 1876; Falconer 1989; Ledig 1986; Lerner 1954; Ralls et al. 1988, and Wright 1977)" (Lacy 1997). Genetic variation is a measurement of two features in a population, the amount of heterozygosity and polymorphism. With the implementation of successful linkage, heterozygosity in an isolated population should be increased for two intertwined reasons. First, due to added habitat security and lower mortality rates, the size of the overall population and therefore effective population should increase (Simberloff & Cox 1987).

Secondly, for the same reasons, the genetic drift, or non-random mating that occurs in small populations with few potential mating partners (Mills & Tallmon 1999) should be alleviated to some extent. Future matings should involve new alleles that will improve both the isolated population's and each individual's heterozygosity. Polymorphism will be affected only if the bears in the now more connected remainder of NCDE have different alleles at certain loci.

Crowding of the Habitat Remnants and the Fence Effect

Any investigation into the value of changes in habitat should contemplate crowding of habitat remnants and the Fence effect. Crowding of habitat remnants refers to home range adjustments that animals make by moving to the only areas of suitable habitat following habitat modification. When these changes are made animals will all try to occupy the remaining refuge areas for reasons of food availability and security (Lovejoy: In: Soulé 1986). When LZs are implemented on a landscape they can change the apparent food availability and security of an entire area. If LZs mitigate neighboring sacrifice zones, the crowding could be particularly pronounced. When evaluating grizzly bear LZs it is important to remember grizzly bear life history, where mothers teach their cubs feeding locations and strategies for their first two years. This matriarchal teaching may generate a confusing lag. If subadults learn to use certain habitat types, which are only available in a limited secure area, when dispersal ensues we may find higher than average mortality rates for these dispersers. This " Fence effect" is noted when offspring from the animals crowding habitat remnants can not disperse normally due to a hostile surrounding matrix (Krebs 1996). These effects can distort any evaluation of LZs and deciphering this effect may be further complicated by normally elevated levels of mortality for dispersers versus non-dispersers (Swingland & Greenwood 1983). The rotational design of harvesting subunits in the SVGBCA may also confuse any analysis of this effect. In general we would expect the crowding of habitat remnants and the Fence effect to temporarily inflate the abundance of grizzly bears in LZs. Eventually we should expect to see the typical effects of density dependence operating in the LZs. We might observe an increase in mortality, a decrease in reproductive rates, etc. (Akçakaya et al. 1997).

Negative Impacts for Bears

Several biologists have argued that implementing corridors may actually reduce a population's ability to survive, or at least have negative impacts. These impacts can be separated into genetic and environmental consequences. Increased genetic connectivity may suppress natural levels of genetic drift and this suppression is known as outbreeding (Leberg 1990; Templeton 1986).

Another potential negative side effect of implementing LZs, increasing connectivity, is their ability to facilitate any negative impacts of environmental stochasticity. Whether considering introduced species, weed invasions (Panetta &

Hopkins 1991), contagious diseases (Wilson et al 1994; Hess 1994), the spread of fire, or increased inter-specific predation, LZ implementation has the potential to increase negative consequences from added connectivity to other areas (Simberloff & Cox 1987). It is noteworthy that "no study has yet demonstrated negative impacts from conservation corridors," (Beier & Noss 1998).

Ecological Traps

LZs may become attractive sanctuaries for grizzly bears if extractive or development disturbance proceeds quickly in neighboring areas. It is possible that because of this concentration, people or other predators will now have an easier time locating and disturbing or even killing grizzly bears in this area which is now more appealing to bears. The greatest threat might be from increasing road use on the few open roads in a LZ. Also, if bears come to rely on the habitat protections in place under a conservation plan, and these protections are reduced or removed (as with the rotational design), then the bears may face an greater mortality risk than originally existed.

Negative Behavioral Responses

Ecological experiments always involve a risk of unforseen consequences. Bear behavior is highly unpredictable. For example, the increased connectivity LZs provide may help extend the home range of a dominant male, actually reducing the effective population size in a newly connected population. Likewise, increasing bear mobility may lead to more bears encountering one another. The amount of aggressive behavior may increase following linkage zone implementation, leading to additional intra-specific predation in limited cases. It is important to remind ourselves that we can do as much harm as good without exercising caution and holistic planning.

CHAPTER III

A Review of Available Grizzly Bear Monitoring Data Collection Techniques

What follows are descriptions of available data collection techniques used by bear-biologists around the world to obtain population abundance estimates, presence / absence information, demographic rates and trends of wild grizzly bear populations. The methods are organized in this section by their level of intrusiveness to bears flowing from most to least disruptive. They are also characterized by their dependence on assumptions, costs of execution, and some of the statistical considerations. Table 1 provides pros and cons of each of the methods found here for a quick comparison of each of these characteristics. Some computer software packages used in conjunction with these methods are also presented. Many of these methodologies persist in bear biology today and recent studies continue to generate advances in considerations and limitations. It is important to note that these descriptions are developing quickly with the most current findings surrounding these techniques arriving monthly in journals and technical reports in the Northern Rocky Mountains and other grizzly bear habitat areas around the world.

Intrusive Study Designs

Intrusive study designs include all methods that involve the capture and handling of bears. Some major benefits of these techniques are continuous monitoring opportunities, providing information that allows home range estimation and can test assumptions of population closure. Radio telemetry also supports estimation of age-specific survival and reproduction rates. When used in a matrix model these rates can yield an estimate of the finite rate of population increase. Furthermore, several quantitative analysis techniques, including 'sensitivity analysis,' can be used to quantify the relative proportional importance of the survival and reproductive rate estimates as factors influencing population finite rate of growth. Although telemetry techniques are not exclusively used for this analysis they have been used in the past (Hovey & McLellan 1996). This information may be useful in providing focus for future studies.

Each technique introduces some sampling bias. Therefore, any design that uses more than one recapture technique reduces bias inherent in any given method of capture alone (Harris 1986). But the question remains whether this simply alters, compounds, or reduces overall bias.

Intrusive methods can be further divided into methods that involve removal and those that do not. Miller and Ballard (1982) used a removal technique in interior Alaska to estimate brown bear density. By removing all captured bears from the study area they obtained a quick minimum abundance estimate. Then by estimating the size of the study area relative to bear home range estimates, they were able to calculate a density estimate. Given the Endangered Species Act protections afforded grizzlies in the lower 48 states, this removal technique would only be feasible for problem bears and not a systematic study design. However, this method does provide quick and relatively inexpensive density estimates in areas with predicted high densities, no threats of local extirpation and a need to assess habitat value to bears for conservation purposes (Miller & Ballard 1982). Non-removal methods rely on a marking device and introduce potential problems of changing monitored-bear behavior from that of the average member of its population.

Scents Used to Attract Bears

Scent stations are now frequently used to attract bears. They are used to lure bears for trapping, or to obtain photographs, DNA samples, and tracks. It is commonly reported that scent lures show diminishing visitation, as described by Mace et al. (1994), "We believe that both marked and unmarked grizzly bears were confronted with a novel technique during early photo sessions, but interest diminished as more sessions were conducted. We believe that a long-term program to estimate population size would benefit by presenting bears with a variety of attractants." This variety may include real baits (such as road-killed elk carcass, dead horses, livestock blood, etc.) or simply scent packages. The scents often used are fish and chicken, synthetic fermented eggs, putrid fish, pheromone, and estrus grizzly bear urine (Ball 1980). Some biologists have even gone so far as to try and patent scent lure recipes. In one novel approach to prolong exposure to cameras, some researchers nailed cans of sardines to the trees or spread dry dog food below the baits to help keep the bears within the field of view longer (Ball 1980).

One consideration, especially important in the early and late portions of grizzly bear active season at high elevation, is that cool temperatures may reduce the potency of any scent lure (Ball 1980). Natural or background food availability is another major source of variability in bait attractiveness. Attractiveness likely varies both spatially and temporally. These factors all affect assumptions of trap exposure. Ball (1980) found it difficult to prevent bears from removing certain baits. This also leads to problems in study execution based on a certain grid of attractants with a given level of trap exposure to bears. Ball (1980) found that by placing concentrated scents in sealed containers, bears where no longer able to disturb and consume the attractants. And finally he and others have suggested that pre-baiting also helps improve the rate of detection during a study (Ball 1980; Mace et al. 1994). Problems of trap exposure heterogeneity can be invoked by several of these factors, with some beyond the control of the researcher. It is therefore critical to acknowledge these sources for variation across a grid when reporting 'capture' results.

Marking Options

Several techniques have been used to mark bears for relocation in intrusive mark-recapture studies. The most obvious device is a radio transmitter most often for a bear this is a collar. Collars have become much less cumbersome in recent years. And while they are a burden to bears, they are now designed to breakaway after set time periods of time. The USFWS Grizzly Bear Recovery Project is currently trying collars equipped with a global positioning system (described below). Ear tags are commonly used to assist in photographic detection and are found to work very well, except when used in combination with flagging (Woods et al. 1997). The ear tags appear to uphold the assumption that no marks are lost during a study (Mace et al. 1994). Tattoos are often used for permanent identification. More recently, less visible techniques such as biomarkers have been used. In these cases, bears are injected with known chemicals (e.g., tetracycline hydrochloride) to allow future cementum, skeletal and fecal identification (Garshelis & Visser 1997). To my knowledge no investigation has been conducted into the feasibility of using topical markings (identifiable with ultra-violet or infrared technology) to assist in photographic detection, although this might become a useful marking technique.

The largest concern involving capture is capture mortality. Mark-based capture mark recapture methodologies also have the potential to reduce bear survival and reproductive rates, directly reducing the population finite rate of growth. Marking grizzly bears should be done carefully as these animals embody ideals of wilderness and healthy ecosystems to forest residents and visitors. Marking these animals runs the risk of dissolving public support for conservation.

Radio Telemetry Techniques

Radio telemetry techniques are the most commonly used intrusive method for sampling grizzly bears. While they are capable of providing a wealth of information describing grizzly bear movements, they introduce some risk of injury. Pease and Mattson (1999) state that they "... know of no evidence supporting the idea that trapping bears causes them to become human conditioned. Rather, the available evidence suggests that soon after a bear becomes human-conditioned it does something to precipitate a management response." The combination of human conditioning and capture stress likely explains any reluctance that several Mission Mountain land management entities might have to using radio-telemetry collars on bears.

Theoretically, radio-tracking information can now be combined with high-spatial-resolution remote sensing data to evaluate habitat use. This combination has been used to examine habitat selection by brown bears in Alaska by Craighead (1998), who suggested this as the best method to prioritize bear habitat conservation efforts.

Slow data accumulation is one major drawback of collecting survival and reproductive data on grizzly bear populations by radio-telemetry (Eberhardt et al. 1994). It may be that by the time data has been collected and analyzed it no longer applies. The short-term use of telemetry should probably be restricted to home range estimation, testing population closure assumptions, and compositional analysis using few habitat classes (e.g., time spent inside versus outside linkage zones). Changes in habitat security from humans may change, especially given the marked increase in human recreational access to key grizzly habitat. For example, rapid expansion in off highway vehicle (OHV) use on spring habitat trails, not covered by SVGBCA open road density standards, could possible alter survival and reproductive rates quickly. Discerning process variation and an actual trend in vital rate response to this hypothetical intensification of OHV use would require extensive and long-term telemetry data during the period of intensification. A long time lag in obtaining results may not portray short-term changes in food availability, under the effects of global climate change. For example, changes in protein availability, such as the reduction in the whitebark pine (*Pinus albicalus*) seed crop traditionally which provided much of the fall protein requirements for several Rocky Mountain grizzly bear populations, can happen quickly with changes in response to climatic changes. Although Whitebark pine has not been a major grizzly food source in the Swan Valley for more than 30 years (Servheen pers.com.), NorthWest Connections is currently involved in collecting information on the Whitebark pine distribution and seed production declines in higher elevations of the Swan Valley.

Agent Specific Mortality Rates Using Telemetry

Given that humans and our associated activities are likely the most common source of bear mortality (Pease & Mattson 1999), Heisey's and Fuller's (1985) suggestion that radio-telemetry techniques provide an additional opportunity to discern the importance of individual cause specific mortality factors seems especially valuable. If we have continuous monitoring of tagged bears, once a signal either stops or ceases movement for a determined period of time, researchers can locate the device and assess the mortality cause. For instance, this may allow us to discover whether most bears die because they are being pursued into roadways or shot. This option will be extremely exciting to members of the "declining population paradigm," (Caughley 1994). This paradigm describes a body of wildlife biologists who focus on isolating and quickly eliminating the most severe threats to bear survival to arrest the principal cause of a population decline. When agent-specific mortality findings can be identified, human-caused mortality can then likely be reduced. For example, in the Swan Mountains, Mace and Waller (1997) found that human hunting related deaths were the leading mortality cause for both adult males and subadult females, while natural and unknown causes were the leading causes of mortality for adult females and cubs. It is noteworthy that this elevated human caused hunting mortality of subadult females is believed to have had the greatest impact on the overall finite rate of growth of this study population (Mace & Waller 1997).

Estimating Survival Rates Using Telemetry

Perhaps the most difficult bear parameter to estimate is survival. The long 20-year average life span of a grizzly bear and their high survival rates together present a challenge to all traditional (short-term) studies (Harris 1986). Pollock et al. (1989) found that survival estimation from telemetry typically involves error due to its reliance on the assumption that each survival event is independent and has a constant probability over all animals and all periods (Bart & Robson 1982; Trent & Rognstad 1974). They assert that both of these assumptions are often unrealistic and restrictive due to spatial and temporal variability in exposure to mortality risks. For example, cub mortality associated with the death of their mother could lead to a lack of independence in individual mortalities (Pollock et al. 1989). Violation of this assumption prevents accurate estimates of survival and may underestimate variability of these estimates for entire populations (Pollock et al. 1989). They also recognize the problem that carrying a collar or other relocator can pose, and admit that it is diminishing as technological advances are reducing the burden these devices create for animals. They make another significant suggestion pertaining to the management of data involving censored animals (animals lost to direct predation, dead batteries, expired collar, or emigration) which are often assumed to be dead. Assuming either of the two extremes for all censored animals, either they are all dying or all surviving, can create upper and lower bounds of survival estimates.

Yet another problem plagues typical survival estimates from telemetry studies. The statistical power is always diminishing as the sample size is reduced from each death. As Pollock et al. (1989) explain, "Typically we assume r_j (the number of animals at risk at time j) is decreasing due to deaths and censoring but there is no reason it has to be. New animals will only be considered in those product terms where they are at risk. The formula for the variance of survival(t) also allows for new animals to enter during the study. Any newly tagged animals are assumed to have the same survival function as the previously tagged animals." This new design builds upon advice given earlier by Heisey and Fuller (1985) who suggested that the variance and sample size are related in a nearly linear fashion; as the population is halved the variances doubles. This new design opportunity should improve estimates by reducing their variance through the use of additional samples.

A final consideration for telemetry-survival study design is the span of interest for evaluating survival, which must be divided into intervals with daily survival and agent-specific mortality rates remaining constant for all individuals within each class being used (e.g., age). Sample bias will increase with the length of the interval and with decreasing daily survival rates. The independence violation arises whenever apportioning agent-specific mortality rates, and is illustrated by several authors (Heisey & Fuller 1985; Bart & Robson 1982; and Trent & Rongstad 1974). This is because daily survival is actually a function of survival on a given day as well as survival up to that day, with varying amounts of exposure to each agent. This function therefore lacks daily independence. This will introduce a bias in the agent mortality data.

This realization led Pollock et al. (1989) to extend the staggered entry design to a commonly used survival estimator (the Kaplan-Meier procedure). If one is trying to estimate survival rates or cause specific mortality then adding additional bears can maintain our statistical power. However, a sample from a small population size such as that obtainable by sampling the Mission Mountains/Swan Valley (15-40) will be too small for this estimator (Kaplan-Meier / staggered design). In their analysis, Pollock et al. (1989) found that ideally at least 40-50 bears should be collared at all times with precision suffering substantially unless the number is greater than 20 (Pollock et al. 1989). It is important to remember that if this estimator is chosen, then we must assume that newly tagged bears would have the same survival function as previously tagged bears. This is yet another assumption that may be difficult to support given that we would likely be adding younger or warier bears later to a study.

Mace and Waller (1997) estimated survival rates for each class of grizzly bear in the Swan Mountains. These rates were developed by using telemetry data (and attendant young with adult females) obtained from class samples ranging from 11 to 28 individuals each, for a period of ten years. Mean Swan Mountain grizzly bear survival rate estimates (95% CI) ranged from a low of 0.77 for cubs to 0.90 for yearlings. These estimates included total ranges of variation from 0.362 (0.638

1.00) for subadult males to 0.153 (0.826 – 0.979) for adult females. These levels of variation correlate well with the total number of bear years observed for each class (Mace & Waller 1997).

Estimating Reproductive Rates Using Telemetry

Several parameters must be estimated to yield reproductive rate estimates. Age of first parturition, interbirth interval, age of sexual senescence, mean litter size and the offspring gender ratio all influence reproductive rates. Typically telemetry and observations can be combined to develop estimates for these parameters. It is critical to måke an assumption regarding the ratio of female cubs if estimates of population finite rate of growths use reproductive rates. This ratio is often assumed to be 50% female (e.g. Hovey & McLellan 1996; and Eberhardt et al. 1994). However, demographic stochasticity tends to prevent this from happening in small populations, especially in the short-term. In fact, Mace & Waller (1997) report a Swan Mountain grizzly bear population sex ratio distribution of four females to each male, with female cubs constituting 64% of those born in that study area. Typically, only females bears are used to estimate overall bear reproductive rates (Pease & Mattson 1998; Caswell, 1989), and in general they have smaller home ranges and lower rates of detection than males. This can increase the number of bears that you need to capture to secure a large enough sample of females from a grizzly population. However, this skewed sex distribution in the Swan may facilitate obtaining sufficient a sample size to estimate these reproductive rates with some confidence.

Nearby Swan Mountain bear reproduction estimates were calculated by Mace and Waller (1997), during their intensive studies of that population. Mean litter size was found to be 1.64 cubs/litter with a standard error for that eight-year estimate of plus or minus 0.12 cubs/litter. A cub sex ratio of 64% female was reported from a more limited sample (n=9 radio-collared females reproducing litters). No significant difference in litter size was found among the various age classes of reproducing females. Age of first parturition ranged from four to eight with a mean of six years (n = 6). A mean inter-birth interval of three years, with a range of two to four years was also documented for Swan Mountain bears. This information comes from six complete intervals for five individual females (Mace & Waller 1997).

Compositional Analysis of Habitat Using Radio Tracking

Another concept, which has suffered from frequent study design flaws, is the use of radio tracking data to conduct compositional analysis of habitat use (Aebischer et al. 1993). Unfortunately, as Aebischer et al. (1993) point out, all available techniques contain at least one of four shortcomings affecting the validity of the analysis, often at the statistical level. The first problem is an inappropriate level of sampling and or sample size to conduct the analysis. The sampling may be serially correlated because bear locations are dependent on previous locations. They never have completely equal access to all habitat types, confusing analyses of their use. This may be especially pronounced given the elevation movements described by Servheen (1983) for Mission Mountain grizzly bears. Often assumptions are made that bears have equal catchability, and do not exhibit individual preferences or trap responses. If bears, in fact, do differ and the data is pooled across the population this "inflates the apparent number of degrees of freedom, rendering statistical tests over sensitive (increase in type I error)" (Aebischer et al. 1993). This creates a bias towards rendering a habitat type preferred, when it is actually not preferred. Hypotheses must be tested at the grizzly bear level, "(grizzly) habitat use is estimated either by the proportion of radio locations within each habitat or by the proportion of home range area (evaluated from the radio-locations occupied by each habitat)" (Aebischer et al. 1993).

The second problem arises from the confusion of avoidance and preference of habitat. It is impossible to identify whether a bear is positioning itself for either of the two reasons just mentioned. Therefore, habitat preference studies can hardly avoid the non-independence of proportions (Byers et al. 1984; Neu et al. 1974). In the Swan Valley, where human development density is low but very spread out and road density is high in the low-elevation habitat, discerning avoidance from preference during spring and fall seasons of intense use will be extremely difficult. Departure from random use is the ideal test for violation of this non-independence.

The third problem usually incurred is the variable habitat use of animals in different sex and age classes. Testing for this by using radio transmitter data again runs into problems of non-independence. " What is needed is a method analogous to ANOVA, in which the sample size is the number of animals in each group and in which between-group differences are tested by references to within-group between animal variation," (Aebischer et al. 1993). The small number of grizzlies in each class using the Swan Valley will reduce a researcher's ability to acquire helpful sample sizes of individual class bears in each of the habitat types found in the valley. A recent black bear (*Ursus americanus*) telemetry study by Gold (1997) encountered this exact problem when attempting a seasonal compositional analysis. Therefore, either bear classes or habitat classes will likely need to be combined to derive estimates of preference.

The final problem that most studies appear to encounter is the definition of a study area (Aebischer et al. 1993). Very few areas in the Northern Rocky Mountains have harsh natural boundaries where habitat value drops precipitously. Specific Swan Valley grizzly bear home ranges are not currently known. Any exercise defining study area boundaries must contain considerations for multiple levels of selection by grizzly bears. Does habitat selection involve cover, foraging, mating, etc.? Or does it include only those factors modeled to develop the LZs by the USFWS (cover, road density, human developments and riparian vegetation). Are other factors at play? Or is only one of these factors dictating behavior and habitat selection. These questions about the grizzlies using the upper Swan Valley make delineating a study area extremely difficult. Also, "If sampling is representative and sufficiently frequent to record little used habitat types, then the proportion of radio locations in habitat types estimates the proportion of the trajectory in each habitat. More frequent sampling, more closely approximates the underlying trajectory, thus providing more precise estimates of proportional habitat use, even though it also increases serial correlation" (Aebischer et al. 1993). The increased frequency and spatial precision of global positioning system (GPS) relocation may improve our ability to perform compositional analysis.

Several compositional studies were executed by Mace and Waller (1997) by using their radio-telemetry data set. They investigated elevational selection, home range selection, and the apparent impacts of roads, cutting units and cover classes on bear habitat selection. In general all Swan Mountain grizzly bears used avalanche cutes and slabrock more than other cover types during each season. Swan grizzlies had their highest density in areas with no roads (0 mi/sq. mi. open road density). They display diminishing selection for areas with increasing open road density. Grizzly bears were found to have no preference or avoidance for specific cutting unit types. All studies were restricted by small sample sizes (maximum n = 18 bears). This Swan Mountain Study, even with a larger sample size than the total number of bears potentially collarable in the upper swan, had sample sizes for various road density, cover and cutting unit classes which were often too small to draw powerful statistical inference (Mace and Waller 1997).

Estimating Spatial and Temporal Interaction of Male and Female Grizzly Bears Using Radio Telemetry

In a recent study, Mace and Waller (1997) attempted to articulate the spatial and temporal interactions of male and female grizzly bears in the Swan Mountains. They modeled intra-specific interactions based on time, space, and habitat use, using telemetry locations to calculate annual home ranges for all collared individuals. The degree of home range overlap was estimated for the various age and sex classes to ascertain levels of interaction (Mace & Waller 1997). Similar studies have been conducted by Wielgus and Bunnell in Canada, attempting to quantify seasonal and gender related grizzly bear interactions (Wielgus and Bunnell 1995, 1994). Spatial interaction studies may be an acceptable proxy for typical abundance and compositional analysis studies when evaluating the success of linkage zones at promoting connectivity of the somewhat isolated subpopulations, such as those spending time in the Swan Valley.

Translocation Opportunities for Monitoring Bears

Problem NCDE grizzly bears are typically translocated to the South Fork, Middle Fork and North Fork areas of the Flathead River. On a few occasions in the past they have been translocated to the Mission Mountains (Servheen, pers.com.). It should be noted that while translocated bears present an obvious opportunity to monitor (collar) bears, these bears rarely represent the remainder of the population. Woods et al. (1997) found adult female grizzly bears had average aggregate home ranges 730% larger than non-translocated female grizzly bears. With that said, problem bears being translocated should be monitored to assess both their future proximity to humans and their survival in new habitat. The survival rates data will guide evaluation of receptacle habitat areas.

Operational Considerations

"The time needed after marking for adjustment to a transmitter package, physical recovery from capture, stress, or injury, or resumption of normal social bonds (especially for young) often is, but should not be, included in survival calculations," (Heisey & Fuller 1985). The ability to identify causes of death must also be considered when determining how frequently relocations should be performed (Heisey & Fuller 1985). For bears, they likely need 2 days to recover and their deaths should be investigated as soon as their average daily movement (ADM) falls to 0 for 2 consecutive days.

Ground- Automobiles and Detection Tower

A distinction must be made between using fixed locations and mobile locators as the receivers of radio telemetry. Using mobile sources such as aircraft or automobiles increases the error potential for locations but also increases the researcher's mobility in a large study area. Using fixed, surveyed points can lead to less error and better readings. However, Lee et al. (1985) describe how even though radio telemetry bearings from free-ranging animals are discrete they are still only estimates (Springer 1979). A lack of this acknowledgement often leads researchers to preclude appropriate accuracy testing of their techniques from their study designs. (Hupp and Ratti 1983; Springer 1979). Lee et al. succinctly defined accuracy, error, precision and bias for telemetry studies below:

"Accuracy of bearings estimated using radio telemetry is a measure of discrepancy between true bearings and estimated bearings and has two components: error and precision. Error (ϵ) is the difference between the true bearing (θ) and the estimated bearing θ hat defined as $\epsilon_{ij} = \theta_i \quad \theta(\text{hat})_{ij}$ for each bearing i and replicate j. An error of a consistent nature is termed bias and is the average difference between estimated bearing and true bearing. Precision is the repeatability or amount of variation of estimated bearings. The placement of confidence limits on bearings to form error arcs (Springer 1979) flows from a researcher's estimate of precision. Intersection of two error arcs delineates a confidence area termed an "error polygon" by (Heezen & Tester (1967). Size and shape of an error polygon is a function of system precision and location of a radio transmitter in relation to receiving points. Equipment, observers, and techniques (Cochran 1980; Cederlund et al. 1979; Springer 1979) may affect precision." (Lee et al. 1985).

The Swan Valley like the rest of the Inter-Mountain-West presents challenges to accurate signal quality. The mountainous topography, assorted vegetative communities, and frequent stormy weather may cause signal refraction and distorted signal direction. Also movement of a radio-collared grizzly bear may cause signal polarization changes or modulation. This may further distort bearing readings affecting the interpreted locations (Lee et al. 1985). Signal distortions have the ability to reduce confidence in telemetry location precision. This would hamper a researcher's ability to assert confidently whether a location and its associated error radius are in a linkage zone or a non-linkage zone area. These problems further defeat traditional telemetry sampling potential in the Swan Valley, an area that due to its low density of grizzly bears already faces a low probability of providing adequate sample sizes for traditional statistical inference.

Testing Telemetry Error

Stated powerfully here, it must be understood that, "Use of radio telemetry to estimate locations of radio-collared animals must be accompanied by quantification of accuracy. The question of error must be addressed before conclusions from animal location estimates can be drawn," (Lee et al. 1985). Testing for telemetry error should be done using a situation as representative as possible of the true study design. Lee et al. describe several important steps to ensure that sampling bias is reduced, including: (1) placing points across all topographic and vegetative gradients; (2) avoiding pairing of test points and specific frequencies; (3) using a second observer when replicating tests to avoid the natural tendency to minimize the difference in multiple bearing recordings (Lee et al. 1985). Kehoe (1995) during her recent attempt to test the North Fork of the Flathead LZP estimated ground telemetry error by frequently blindfolding researchers with headsets and obtaining bearings.

Aerial Surveys- Fixed Wing Aircraft

Fixed wing aircraft are frequently used to relocate grizzly bears wearing radio transmitters. Weather can become a serious hindrance to systematic aerial collection of relocation information. Generally, studies employing fixed wing aircraft present a wide-ranging schedule used to assess bear locations. This may weaken a study by preventing consistent data collection frequency, affecting considerations of within versus among variation in home range estimates for unique age classes for example. Aerial relocation error should also be evaluated. Gold (1997) tested aerial telemetry error by weekly placing a radio collar in the field and having the uninformed relocation team (pilot and spotter) expend equal effort locating that collar and actual bears. Another consideration is the disturbance that the noise from a plane or helicopter can create on the landscape. I know of no studies that mention this as a source of disturbance. However, we must balance our good intentions to manage bears effectively (and the data required for this management) with the noise pollution that aircraft can cause.

Global Positioning System Collars

Exciting work is underway to use the global positioning system (GPS) satellites to track bears (Waller & Servheen 1999; Craighead 1998). One advantage of this new technology over other telemetry techniques is the ability to track bears in a systematic manner with more frequent (and precise) timing (every 1-2 hours) and more precise location information (accuracy error <15 meters, differentially corrected). This new technology reduces several sources of traditional telemetry error (triangulation, variation in flight times, etc.) The improved spatial accuracy and consistent timing of relocations obtained from using this form of telemetry may prove extremely valuable for evaluating LZs versus the rest of a landscape. Most importantly, GPS technology should allow us to conduct more powerful compositional analysis. GPS vastly improves our ability to detect the amount of time spent in linkage zones, seasonally, daily. Previously unavailable 24-hour movement information can now be collected, allowing us to understand bear movements under the cover of night. The increase in relocation samples should reduce the number of bears needed to make valid statistical inference concerning how individuals use habitat types. However, deploying GPS collars versus traditional collars to retrieve data for a given sample size (number of bears) will not improve our ability to make statements about the entire subpopulation. Waller and Servheen (1999) collected GPS tracking data for several bears (3) crossing the Highway 2 transportation corridor, which bisects the NCDE population habitat. The study will continue during the year 2000 active-bear season. Location information will be compared to traffic information obtained from train and automobile counters. They plan to use this data to test the Linkage Zone Prediction model that was devised by Servheen and Sandstrom (1993) and a cumulative effects model created by Waller in 1998 (Waller & Servheen 1999). This constant source of geographic information will hopefully allow researchers to understand daily, and seasonal use of habitat that connects two large tracts of secure habitat, a situation which is very similar to the Swan Valley (Servheen pers.com.)

Waller and Servheen (1999) decided that the 2100 gram units currently being used are too heavy to use on bears weighing less than 90kg. (cubs and yearlings). Units store the hourly GPS locations, which are preprogrammed to release on a predetermined date. The data is then downloaded upon retrieval of the collars. Waller and Servheen (1999) conservatively estimate the GPS unit battery life at 90 days. Dr. Seiger, who has been involved in the development of this technology with the US Army since 1982, described his belief that GPS unit battery life can be extended to 3-4 years if units are well programmed (Seiger 1999). However, his estimate may be unrealistic for grizzly bears because it does not include consideration of the additional battery power required to operate a simultaneous VHF unit for occasional fixed-wing relocations, used in this study. Since bears spend approximately five months a year in dens, battery power could be conserved during these sessile periods. Obviously, the ability to gain detailed and accurate location information from bears without having to capture them annually would be very important for grizzly bear research. Similarly, reducing the size and weight of GPS units will extend the applicability of this technology to all age classes of grizzly bears. Japanese producers currently have the smallest units for satellite tracking of fauna. They can get as small as 15 grams, although most are between 20 and 30 grams now (Seiger 1999). The units currently being used on grizzlies now cost approximately $4000 each. (Servheen pers. com.). Sieger also stated his belief that within ten years, the costs will be reduced markedly to approximately $100 per unit and $180 per tracking-year (Seiger 1999).

Mark-Resight Software Packages for Telemetry and other Techniques

Program NOREMARK has been used for brown bear mark-resight telemetry and photographic studies (Mace and Waller 1997; Miller et al. 1987). This software includes valuable design options helpful for determining the number of several variables (resighting occasions necessary, proportion of population marked, and the proportion of the population to resight) required for various levels of precision (White 1996). Four estimators are available with NOREMARK that allow the researcher to overcome typical assumption violations. NOREMARK's joint hypergeometric maximum likelihood estimator (JHE) assumes no individual animal heterogeneity but does allow for capture heterogeneity over time. The Immigration–Emigration JHE extends the practicality of this software to accommodate closure violations, which may be very important in the Swan Valley. This software can be run on most PC computers and is currently available on the Internet at: http://www.Cnr.colostate.edu/~gwhite/software.html.

Photographic Detection

Photographic detection has been attempted recently as means of obtaining information describing distribution, abundance and demographic rates for grizzly bears (USGS 1998; Mace & Waller 1997; Mace et al. 1994a, 1994b; Ball 1980). Technological advances make it possible to detect bears with either intervalometer circuitry acting as an electric switch (Ball 1980), or passive infrared detectors, used more recently. However, it should be noted that the detection of bears must either be transformed into an index or used with animals that are readily identifiable for mark recapture studies. Efforts to identify grizzly bears using remote cameras have progressed quickly. However, most recently Mace et al. (1994a) found no evidence to suggest that the photographic technique would have worked to estimate abundance without having a marked sample. They suggest that at least a quarter to a half of the population should be marked, and marking should persist for at least three years to get all the original two-year-olds. (Mace et al. 1994a) The use of ear markers or some photographic identification mark may lack public support, as described above.

Reported detection rates were originally low compared to other "capture" techniques (Harris 1986). These capture rates have increased recently and are as high as 50 to 92% (Mace et al. 1994b). However, the number of NCDE grizzly bears using the Swan Valley is too small to estimate size and sex of age classes separately. And the sighting rate seems to decline as bears become accustomed to an attractant that does not provide a reward (Mace & Waller 1997; Ball 1980). Annual visitation to scent-stations used for photographic detection may vary substantial with forage availability. This leads to an increase in the coefficient of variation and will reduce short-term studies' power to detect trends.

Using average daily movement (ADM) as a guide for selecting an efficient remote photo grid size has been suggested (Mace et al. 1994a). Some studies suggest that sex classes may also display visitation or photogenic differences. Females generally are exposed to fewer scent stations because of smaller average home range sizes. Wary females who do visit stations also appear to be more difficult to successfully photograph (Mace et al. 1994a; Barnes & Bray 1967). Common sense and several researchers have also suggested that bait rewards may influence "trap response" in subsequent photo sessions. Others note that non-game baits may provide dangerous food rewards leading to increased livestock predation and lack of public support for grizzly bear recovery (Jonkel 1993).

Lincoln-Peterson Estimates- Photographic Techniques

When conducting a Lincoln-Petersen photographic study (Seber 1982), grizzly bears are initially captured and marked (usually with ear tags). Then resightings are conducted with remote cameras during subsequent sampling sessions. Each camera session counts the number of marked and unmarked bears that are photographed. When individual bears are the sampling units, it is necessary to use a separation interval at each station to maintain independence of sightings. For example, Mace et al. (1994a) used a 24-hour separation period so that any grizzly bear seen at the same station more than once in a day was only counted once. In their study, bears that visited more than one station in a given day were considered two independent sightings. Without this separation interval, a population abundance estimate can be heavily influenced by one individual bear's behavior.

Other Photographic Mark Recapture Attempts

Karanth and Nichols (1998) used a completely photographic technique to successfully study tiger density in India. They developed capture histories for each individual with remote cameras at trail junctions and territorial boundaries. However, they were able to avoid actual trapping because each tiger was identifiable by its unique stripe pattern. By using two cameras activated simultaneously they were able to obtain solid mark recapture estimates with program CAPTURE (Karanth & Nichols 1998). Unfortunately, grizzly bears are not individually recognizable, precluding such a non-intrusive study design. I believe that creativity in marking and photography may hold potential for this study design. However, the low density of grizzlies also creates additional problems. The first is the need for many cameras and much labor to provide a grid capable of maintaining the assumption of equal catchability. This elevates the cost of any study and increases the risk of camera security. The second problem is the need to develop a boundary strip width, an area in which some bears are exposed to traps but not sufficiently to be considered part of the monitored population (Karanth & Nichols 1998; White et al. 1982; Otis et al. 1978; Dice 1938).

Camera Security

Remote cameras can easily be disturbed, by humans and wildlife alike, reducing the effectiveness of any "capture grid" and affecting assumptions of capture probability. This can bias estimates if disturbance goes undetected. Estimates of visitation will be biased low if absent or broken cameras are assumed to be functioning. And overall variance will increase if individual camera information must be negated because the disturbance date is unknown. For example, bears disturbed two of Ball's (1980) cameras without being successfully photographed. NWC has also been recently been deploying remote cameras in an attempt to identify individual bears in the upper Swan Valley. This project has yielded limited photographic information (Servheen pers. com). This is due to the absence of a complementary marking project. The largely unproductive photographic points in the Swan Valley (April 1998- August 1999) have not been disturbed by humans yet, however they have been knocked around by bears.

Technical Details

Ball (1980) missed nocturnal bear activity because cameras did not operate at night. This has been addressed by newer technology that now uses infrared sensors and flashes. This may be more disruptive to bears leading to additional camera damage. "To prevent loss of data, the study area should be small enough to allow the film to be replaced as soon as exhausted by study workers (Ball 1980). Using the cameras in conjunction with a marked population sample would reduce the need to rely upon natural markings or characteristics to identify individual animals and would provide more information on population numbers, since a capture-recapture technique could be used for analysis." (Ball 1980).

Costs of Photographic Techniques

Recent work in the Swan Mountains yielded costs of snaring and photographic capture sessions of approximately $20,000 and $14,000, respectively (Mace et al. 1994a) However to increase the capture probability, a smaller grid with additional cameras (and associated labor) would be needed. A three-year grid study can therefore be expected to cost more than $102,000. On the other hand, individual cameras can be used sparingly to determine absence/presence in all areas where bait or scent lures can be effective attractants. The costs of this type of camera application will only include the units needed to adequately assess the desired area, the labor needed to install and maintain the cameras and developing expenses.

Purely Non - Intrusive Study Designs

Non intrusive study designs may be more appropriate when small isolated populations are being studied. However, these methods, which generally impart less disturbance to grizzly bears, can currently provide only limited information as has been demonstrated by their use in the Northern Rocky Mountains and elsewhere. However, they are being experimented with and the results of these studies have provided some interesting lessons. They are especially advisable when establishing grizzly bear presence is the most important question to address. Often they compliment radio telemetry to provide additional information. DNA techniques are emerging as the favored non-intrusive methodology, although observations, sign survey, sighting indices and den surveys also are used. Sign surveys and observation information constitute the majority of grizzly bear monitoring to date in the Swan Valley. NWC has been mapping grizzly bear track and observation information since 1997 in the upper Swan Valley to identify patterns of low elevation spring habitat use.

(DNA) Techniques - Hair Snagging

Several advances have recently contributed to more effective DNA studies of large carnivores. DNA material that can describe species, gender, individual genotypes, and even parentage can be collected from nearly any animal tissue, or scat, making samples easier to obtain from low-density carnivores in thick cover. Hair with attached follicles has proven most productive for DNA analysis. Scat can be used, because of its DNA from the intestinal walls, but it contains a smaller amount of DNA and frequently also contains plant polysaccharides that prevent the necessary amplification of genetic material (Kendall et al. 1992). Wasser et al. (1997) have the most recent information describing techniques for using scat for mtDNA analysis. Scent stations are often used to attract bears that leave fur caught on barbed wire that surrounds the bait. Woods et al. (1997) reported their best results were obtained using a perimeter of barbed wire with a five meter radius around a central scent tree at a height of 30-55 cm. The USGS Biological Resource Department (BRD) (1998) has also been successfully extracting hairs from rub trees. Remote cameras are also now being used to evaluate bear behavior at DNA hair snagging stations (USGS 1998)

Some recent attempts are reporting lower than ideal capture probabilities of approximately 0.2 (Communication between Boulanger and Mills, 4/29/1999). On the other hand, Kendall with the USGS (1998) has found that hair snag stations are yielding samples with 80% frequency, and 90 – 100% of these hairs are sufficient to extract DNA. This means that although approximately one in five bears are likely to be detected, stations will need to be cleaned four out of five times. Cleaning barbed wire for entire grids therefore seems like a major time investment for this technique. Problems of cleaning the collecting device completely have also been discussed in the recent literature. Excitement that this technique has created in the wildlife biology community has been tempered by high costs and problems described as the probability of identification (PI). This PI problem affects both types of DNA hair snagging studies, minimum counts of unique individuals and capture-recapture studies. One must remember that DNA capture-recapture must still comply with rigorous sampling demands, and they face typical problems of population closure assumptions, small sample size, and capture probability variation as well as high costs (Boulanger 1997a). In fact, analysis costs alone range from $40 – 60 per sample, making this non-intrusive technique quite expensive.

The Probability of Identity

The promise behind DNA testing is that we can learn more from our sampling than with traditional techniques or photographic detection. In several recent papers authors have cautioned that DNA may provide an unwarranted sense of confidence in the abundance and density estimates that it provides. Mills et al. (1999) describe the problems that a "shadow effect," two or more animals with DNA fingerprints indistinguishable with typical non-invasive genetic analysis, can present when trying to perform mark-recapture data analysis. The inability to discern genotypes by the typical allele testing done at few loci can appear as additional capture heterogeneity in these studies. This heterogeneity can alter population estimates, their variance and introduce major bias for such estimates.

The biggest problem is that the probability of identity (PI) distribution is never fully understood for a wild population being studied. Furthermore, several authors have debated how inbreeding can enhance this problem (Mills et al. 1999; Donnelly 1995; Nichols & Balding 1991; Lewontin & Hartl 1991; Cohen 1990).

This problem of confidently determining identity in the presence of some inbreeding and several family groups may prevent accurate estimation of small isolated grizzly populations like the one inhabiting the Mission Mountains. Others suggest that the process of microsatellite measurements may be extremely variable due to the amplification process required to evaluate them (Mills et al. 1999; Parker et al. 1998; Jarne & Lagoda 1996; Bruford et al. 1996). The shadow effect can interact with different estimators and data analysis software in several ways. Mills et al. discuss the problems PI can introduce into mark-recapture studies. The shadow effect can be expected to negatively bias traditional Lincoln-Petersen (L-P) estimates. Mills et al. (1999) also report the surprising finding from their simulations, that increases in capture probability and true population size both lead to greater relative bias using the L-P estimator. They describe how PI problems can lead to a deceptive situation regarding the apparent precision of L-P population estimates, where a larger sample with a higher capture probability and which has a larger bias appears to have a lower relative bias. Program CAPTURE estimators also appear to negatively bias population abundance estimates in the presence of PI. The good news is that the PI problem can be largely resolved by using at least seven independent loci for DNA analysis (Mills et al. 1999), a promising proposition. The Glacier National Park and Canadian bear biologists appear to be leading the field in the advancement of DNA study designs for grizzly bears and the latest reports should be available at both www.mesc.usgs.gov/glacier/dna, and www.for.gov.bc.ca/ric.

Sighting Indices

Sighting indices include aggregation indices, observation card systems, and aerial censuses. Aggregation sighting indices have recently been criticized for limited use due to low levels of natural aggregation occurrence in the lower 48, and their inability to provide consistent information and accurate density estimates. They are commonly attempted at feeding concentration sites such as productive fisheries and in the past at Yellowstone N.P. garbage dumps. Critics cite problems that the availability of substitute food can impart to these techniques. This problem might be reduced by developing a long-term study of a stable population, but may be inadequate when a trend needs to be detected in a short time frame, a tough task for any technique given environmental stochasticity. The second problem offered is that density estimates require a measure of the area that provides the home range or all of the life history requirements for all the grizzlies seen at a given aggregation site.

Chestin, in his recent paper describing Russian bear monitoring techniques, suggests that bears should be monitored while they are most spread out, which should allow the most accurate extrapolation to a larger area. Both he and Lobachev et al. (1988) found spring the ideal time to census, during the breeding season. Although sighting information is not without weaknesses, it is promoted by the

Gosokhotuchert, the Russian wildlife department responsible for censusing grizzly bears (Chestin 1994). Several shortcoming of this study design for monitoring bears in U.S. LZs seem obvious. Low density populations dwelling in dense cover will make sighting very difficult. Confusion with American black bears (*U. americanus*) would certainly present a problem, especially in the dense cover of the Northern Rocky Mountains. Finally, a major problem likely exists for using sighting indices (as well as other non-invasive techniques) to evaluate future LZs. This is the result of poor expectations for agency access to mainly private lands in the low elevation habitat, where future LZs are proposed. Wilson (1997) administered a survey of landowners in a proposed Northern Rockies Ecosystem Protection Act (NREPA) corridor, and he found that they were generally opposed to granting federal agency access to their lands.

Observations

Observations can be used as either an index or for a Lincoln-Petersen estimate if animals have unique markings. Swan Valley observations are currently made by some citizens, and they are confirmed by NWC professionals whenever possible. Bears are also observed every August via spotting scope at McDonald Peak in the Mission Mountains to obtain a minimum grizzly bear count. Although this information is helpful, it has several shortcomings as a study technique for the Swan Valley. First, it lacks a rigorous approach that would allow for estimation of abundance that included error estimate. Secondly this sighting aggregation site can not be census all the bears using the Swan Valley, preventing it use from leading to a real understanding the value of the Swan Valley Grizzly Bear Conservation Agreement LZs. Observations in the Swan valley could become a Lincoln-Petersen estimate if two conditions were met. First, if Swan Valley grizzlies were marked by a readily identifiable means (ear notch, radio collar). And secondly, if the inclusion of a grizzly in subsequent samples was ensured as completely independent of its inclusion in the first sample (marked animals). The first condition could possibly be met, however, meeting the second condition may be more difficult. For example, using the same areas for multiple observation efforts would violate this assumption. However, if this can be done then bear abundance can be estimated (Arnason et al. 1991).

Females with Cubs-Of-The-Year

The most heavily relied upon measure of minimum grizzly bear populations in the recovery areas of the Northern Rocky mountains is unduplicated counts of females with cubs-of-the-year (COY) (Mattson, 1997; USFWS 1993). This estimate is the sum of all sightings of this class of bears by all grizzly bear study team members and limited uncontrolled observations, in a given year. Knight et al. (1995) suggest that this class is readily identifiable because of several "diagnostic features," namely a family group with one large bear (mother) and one or more small bears (cubs). Summation of the previous three years counts (based on the 3-year average inter-birth interval for adult female grizzly bears) is used to determine a minimum population size. This females with COY-based estimate is then used to calculate a mortality limit for grizzlies in each of the five occupied recovery areas of the lower 48 states (USFWS 1993). This technique may be helpful if a study designed to evaluate LZs relies solely on changes in overall population size as a proxy to LZ value.

Sign Surveys

Grizzly bears leave several indications of their presence on the landscape, including tracks, scat, fur, den excavations, foraging excavations, and tree markings. This bear sign presents an opportunity to determine grizzly presence, and often activities, (e.g. movement, feeding, etc) in many habitat types. NorthWest Connections has conducted limited rub tree sign surveys in 1999 on all trails accessing the Mission Mountain Wilderness (MMW). The identification of grizzly bear rub trees has been used to index grizzly bear use of the MMW. This index was then correlated with human use levels on these trails. NorthWest Connections found that rub tree abundance was negatively correlated with human use levels on these trails. This is indication that even low-impact sign surveys using trails could disturb grizzly bears. Also, this and other surveys are all indices of bear presence and therefore must be calibrated with another technique to obtain sign detection probabilities needed for abundance estimates. Although indices derived from constant effort levels do provide trend information they do not provide any measure of error, (e.g. confidence intervals) as described below in the chapter on statistics (IV). The implications of this shortcoming are that spatial and temporal variability in estimates cannot be compared to the variance within individual estimates, therefore trends cannot be adequately evaluated.

Track Surveys

Tracking bears can be done best in wet soils or snow. This restricts this method's use in the semi-arid Northern Rocky Mountains. Some researchers have attempted to use track information to monitor bear movements in spring and summer, including NWC, the Swan Valley-based non-profit group currently assisting the USFWS Grizzly Recovery Project.

Debate exists as to whether individual bears can repetitively be identified by the size of their footprint. Klein (1959) attempted to use tracking to identify brown bears in the dense rain forest in 1958. He decided that the most reliable measurement of the track was its width across the toes, cross validated by measuring the length from heel pad to middle toe, exclusive of the nail. However, he found that the width across the toes varied more with the substrate conditions than the measurement width of the forepad. Another significant lesson was the need for rain to obliterate old tracks. He admitted that determining the amount of track duplications was difficult in areas with high grizzly concentrations. It was especially tough between cubs of the same litter, preventing assessment of the number of cubs present. Timing lessons indicated that 1-2 days after a hard rain was the best time for tracking, although extended periods of rain or seasonal conditions that elevate river levels may prevent tracking in some of the best areas to obtain measurements, gravel bars and mud banks. Considering all these weakness, Klein found the tracking method unreliable as a bear population index "under Alaskan conditions." He also noted that the reliability of the method decreases as the size of the unit increases. (Klein 1959).

Likewise, Edwards and Green (1959) found that "tracks from the same bear where so variable that they invalidate this technique." Lindzey et al. (1977) attempted to use scent stations to attract back bears for purposes of indexing the population in an area of New York. They raked areas around attractant-baited trees, but they found they had problem calibrating their index and their attractants showed diminishing allure to bears as time progressed.

On the other hand, several Russian bear biologists (Chestin 1991; Kudaktin & Chestin 1987; Pazhetnov 1979) have used tracks more recently to monitor grizzly bears. They also note that small areas are monitored more accurately, because they rarely hold bears with the same size track. They developed a methodology that monitored grizzly bear trails because of their high level of track registration (Chestin 1994). They used tracks (and observations) to create "coefficients used in density calculations, based on a study period that averaged ten days. In their study, two people were able to examine an area 50 square km. every 1-2 days. Chestin also reminds his readers that this technique requires individuals "experienced in track searching and distinguishing, and moreover knowing the whole territory very well." (Chestin 1994). It is worth noting that this size area described by Chestin (50 sq. km.) is almost exactly the figure described by Servheen as the density (1/49 sq. km.) of grizzlies in the Mission Mountains; forming the western extent of the Swan Valley, Montana.

NorthWest Connections has mapped grizzly bear observations and confirmed tracks in the upper Swan Valley since 1997. Although this informal effort has relied on muddy road and trail transects, it has by no means been a comprehensive investigation into the presence of grizzly bears in the Swan Valley. Data describing opportunistic sightings and track identification throughout the valley have also been placed in the database to show all confirmed bear location between 1997 and 1999. By analyzing track measurements using software developed by James Halfpenny, NWC has been able to derive an estimate of how many individual bears have been detected in the low elevation spring habitat of the Swan Valley. They estimate a minimum of 10, a maximum of 23, and most likely 13 different individuals have been tracked to date. While this tracking index is valuable for several reasons, it must be coupled with a capture probability to generate a population estimate. They have also mapped these grizzly bear locations atop a topographic backdrop, a riparian layer, etc., to see if any obvious patterns emerge.

Russian tracking mentioned above appears to have been more intense than current NorthWest Connections work. However, by extrapolating the size of the Swan/Clearwater Valleys 1620 sq. km. (we would therefore need approximately 65 well-trained tracking professionals working for ten days. Costs would therefore be approximately $52,000 (@ 80/day), unless a reliable volunteer effort could be organized. Even if a team was somehow organized to comb the Swan Valley for tracks, the thickness/impassability of the vegetation, climatic conditions and the problems identified above will still preclude effectively using this technique to detect trends.

Scat Surveys

Variability in grizzly bear scat production can lead to problems calibrating scat volume to bear presence. Roth found that a grizzly bears' sign can vary from as much as 0.3 to 8.8 scats per day (Roth 1980: In Harris 1986). Harris attempted to draw a Pearson correlation between both scat indices and tree marking and Jolly-Seber estimates. He was unable to obtain a correlation significant at the 10% level (Harris 1986).

Using scat also presents another major challenge to researchers, discerning black and brown bear scats can be difficult for any researcher in the field when both species present; that is nearly everywhere in the US where grizzly bears are found. Harris suggested that fecal bile acid analysis is a useful lab technique to help make this distinction, but likely at significant financial cost. The density of bears in the lower 48 is low compared to Alaska (1/0.59 miles2), where Schoen asserted that the number of scats was not large enough to determine bear abundance (Schoen 1984).

Most recently, Kendall et al. (1992) have been attempting to determine the power of sign surveys to detect trends in nearby Glacier National Park. They found that in an area were trails are generally necessary conduits to bear movement, in a topographically and vegetatively-restrictive environment, scats are more abundant than tracks. Kendall et al. found several problems preventing effective short-term trend monitoring using sign surveys such as their own, "...at best, such data will reliably detect only substantial, potentially threatening declines, and then only with large sample sizes, relatively abundant sign, and the annoyance of false alarms." However, they believe that sign monitoring may provide an inexpensive method with measurable power to detect marked declines (e.g., 20%) in sign; based on an assumption correlating sign decrease with population decrease.

Other findings of theirs are worth noting. Sampling within-year replicates will improve power because it reduces variability more than annual sampling alone. Trail selection should represent the entire area housing the grizzly population you wish to study. Increasing the number of trails appears to improve power more than increasing the length of segments. Pooling data from several years improves power and reduces the impact an unusual year has on the power (Kendall et al. 1992). For those interested in this study method, the USGS-BRD continues to experiment in Glacier NP area, and they offer many useful lessons for timing, etc., which can be viewed at www.mesc.usgs.gov/glacier.

Den Surveys

Surveys have been conducted to count bear dens and to count bears as they move to and from dens. Servheen and Klaver (1983) found that while grizzly bears rarely use the same den twice, they did not document use of a den again that had been visited by a human during the summer. This finding should prevent researchers from interfering with bear dens, especially in an area that supports a small and somewhat isolated population of grizzly bears. However, bear dens are visible from a helicopter by locating excavated materials on the slope [(Mean = 30° for Mission Mtn. bears (Servheen 1981), Mean = 63° for Swan Mountain bears, (Mace & Waller 1997)] below the den, often occurring in high-density grouping (Servheen & Klaver 1983). Unfortunately, distinguishing freshly excavated and older dens may be difficult. Moreover, individual bears may excavate multiple sites in a given season, ultimately selecting only one as a den. These problems prevent robust minimum counts by using annual aerial den surveys.

Servheen also documented abrupt elevation movements for Mission Mountain bears, with denning induced by the first severe snowstorm. Although this data is from the population mainly using the Missions west of the ridgeline, it does hold promise for monitoring bears as they move to their dens. This method was also suggested by Abnamov et al. (1979) and Kostoglod (1979). Chestin (1994) noted several problems with this technique. First, bears that migrate to their dens early will be missed, and the period that this migration happens is quite brief (Chestin 1994). Common sense also tells us that the same snowy weather that drives the bears to their dens would likely cause some problems for researchers. Finally, using den surveys creates the problem of delineating the area that these bears are using during their active season to obtain abundance and density estimates. Ascertaining grizzly bear presence may be the only rigorous use of the den survey (Aerial and observational) technique, reducing its value for directly evaluating linkage zone effectiveness.

CHAPTER IV

Inherent Challenges for Questions to Assessing Grizzly Bear Linkage Zone Effectiveness

Evaluating corridors and their effectiveness at promoting animal movement still provides a major challenge to the world of wildlife management. Nicholls and Margules (1991), in an article about designing studies to demonstrate the biological significance of corridors, make the following statement," The question still remains, is it possible to design and implement a statistically and biologically sound study to test if corridors enhance the movement of individuals between connected remnants compared to unconnected remnants?" (Nicholls & Margules 1991 In: Saunders & Hobbs 1991). I will begin with a brief discussion of challenges that all grizzly bear monitoring studies face. Then I will attempt to provide some insight into the many difficulties inherent in designing LZ evaluation studies. A review of statistical realities and suggestions for using prospective simulation-based modeling is then presented. Once I have developed a solid background of the challenges, I will suggest some ways we can proceed. Barriers to conducting a Swan Valley LZ study are discussed here but also expanded in the case study protocol selection chapter (V).

Defining Objectives

Defining objectives can be difficult but this should be done before any wildlife management study is undertaken to avoid wasting limited conservation funding. As Harris (1986) wrote so succinctly, "One simply cannot answer the question what method is best to use until one answers the question 'Precisely what do we need to know?'" Many questions can be composed to evaluate grizzly bear LZs. Exercises could be conducted exploring the LZP model, compliance, enforcement, public attitudes, or the conservation value of LZs for other species. They are all valid investigations, but they are also beyond the scope of this project. The focus here is describing the effectiveness of LZs at protecting bears in low-elevation habitat and conserving grizzly bear population occupancy in an area (the Swan Valley) where bears face threatening, human-caused, mortality risks. The best way to ascertain this LZ effectiveness is to describe seasonal use of linkage zones, with documentation of how use levels react to management inside the LZs.

General Grizzly Bear Monitoring Challenges

Nearly every published article describing a grizzly bear study recites the difficulties associated with monitoring grizzly bears in its introduction. Authors often describe that long-lived grizzly bears are a very low-density animals with large home range size. They are also a dangerous predator living in densely forested, mountainous habitat. They are often extremely difficult to observe, and the distinction between them and the American black bear (*U. americanus*) can be difficult. Grizzly bears also lack unique natural markings needed to readily identify individuals. In addition, recent DNA techniques have found that grizzly bears have low genetic variation, compared to black bears and many other mammals, plaguing DNA–based genotypic detection as well. These realities usually lead to small sample sizes and low capture probabilities for all grizzly bear studies. As described below, these two problems can drastically reduce the power of monitoring studies. Variability in habitat quality, and its carrying capacity, can also make habitat studies troublesome. Several other challenges are consistently found in grizzly bear monitoring studies, and they are summarized here.

Sampling Factors

Grizzly bear sampling should be well thought out and analyzed with simulation software prior to expensive research experiments. The ability of any study to yield statistically significant findings is based on several factors that determine the sampling regime. The length of a study and frequency of sampling will be crucial in determining the studies' ability to test a hypothesis. The longer the study and the more frequent the sampling, the better the ability the sampling has to reflect changes in demographic parameters. While long data-intensive studies may be accurate, they suffer from greater exposure to non-demonic intrusions (Hurlbert 1984). Long studies also run the risk of not supplying information in a timely enough fashion to direct management. This may be especially important when studies are intended to provide feedback for adaptive management efforts supporting endangered species recovery. On the other hand, sampling from long studies tends to capture the temporary impacts of environmental stochasticity (Thompson et al. 1997). A multiple-time-period study may therefore provide the benefits of both short-term and long-term studies.

The next sampling consideration is defining the study area and any grids used to "capture" grizzly bears. Costs and logistic considerations must be balanced with the realities of animal density and home range size. Smallwood and Schonewald (1998) report that carnivore density estimates are most frequently dependent upon study area delineation. A study area for linkage zones should therefore avoid investigating only areas were grizzly bears are known to dwell to avoid biasing density estimates. This issue is addressed specifically within the descriptions of various techniques found in chapter III of this volume.

Age / sex class structure and corresponding variance in use patterns must also be considered when designing a sampling protocol. Not only should a researcher consider differences in bear behavior but also in capture probabilities and mortality associated with different age / sex classes. An understanding of these differences can allow the researcher to design a sampling regime that will either realistically portray the entire population or obtain accurate parametric data for a given class. For example, Mace and Waller (1997) found that the female to male ratio of the Swan Mountain population is 4:1. This ratio needs to be considered in the design of a capture program if adequate samples of each sex are to be used. This point is also discussed in the following section describing the value of sensitivity analysis in providing future grizzly bear research focus.

Indexes versus Estimates of Abundance

Indices have often been used to study animal abundance. Several factors that frequently evade the control of a researcher often contribute to differences in grizzly bear sign amounts used to develop grizzly bear indices. While they are informative and frequently non-intrusive, grizzly bear indices are point estimates. Therefore, they are incapable of making solid trend analysis by themselves. Indices must be calibrated with additional studies to make statements about relative abundance. Another major weakness of these point estimate-indices is their lack of error estimation and confidence intervals. The lack of error estimation is discussed above in the section on track surveys in Chapter III. Estimates of abundance are generally superior to indices. However, they come at a much larger financial cost and level of disturbance to grizzly bears. Estimates also rely on more complicated formulas and assumptions.

Mark-Recapture Techniques

Many mark-recapture grizzly bear studies have been conducted recently. They either rely on a one-time re-sight event (e.g., Lincoln Petersen) or they develop capture histories for each animal of the population to estimate vital rate parameters (e.g., Jolly-Seber)(Nichols 1992). In either study type, several assumptions are made regarding the capture probability of each animal and the heterogeneity of capture among individuals of the target population. Fortunately, most of these general assumptions can be relaxed in response to on-the-ground capture probability heterogeneity. There are now software packages capable of suggesting which capture heterogeneity model displays the best fit to your given data set.

Open versus Closed Models

A closed population's composition does not change during the course of a given study (Nichols 1992). Determining whether a population under study is a closed population is essential for obtaining accurate parameter estimates. The delineation of a study area is another key factor when thinking about population closure. Using natural geographic barriers to movement is very helpful for assumption compliance. Creating a periphery zone allows for testing of grid exposure calculations that can be helpful in correcting for violations of the closure assumption. Most grizzly bear monitoring projects are based on the assumption of a closed population. However, in their discussions, most authors note that this assumption was likely violated in some way. For example, Mace and Waller (1997) found that one male grizzly moved 59.3 km. during a six-day period, enough to leave almost any study area. The chances that a grid could be set up to accommodate this scale of movement are very slight. Designing the duration of a study is paramount to compliance with the population closure assumption. It is very unlikely that a grizzly bear population is closed over the course of an active season, although it may be closed for a short period of time (e.g, two weeks in mid summer when bears are at high elevations).

Parameter estimators also exist for open populations. These estimators generally require at least 3 capture sessions to estimate vital rates for the target population. This capture intensity presents a logistical and financial challenge for grizzly bear studies. Several authors have described studies that combine more than one time period to obtain parameter estimates. These studies are designed to be inclusive of closed population estimators in the short term and open population models in the long-term. These may be most appropriate for grizzly bears given their enormous home range size and their low capture probabilities.

Habitat / Resource Selection Models - Compositional Analysis

The concept of determining which habitat is preferred or most commonly selected is not new in wildlife biology. Several studies have even ranked bear habitat by use (Craighead et al. 1998). Like all compositional analysis studies, they have often run into statistical problems. Alldredge and Ratti (1986) conducted a review of several papers that attempted to evaluate wildlife resource selection. They found that although type I error was adequately controlled, type II error was always a major problem in testing hypotheses regarding resource selection. The variables that determined the probability of making a type II error were the number of habitats used, the number of animals used, the number of observations per animals and the magnitude of the differences to be detected. The statistical power (discussed below) of studies was elevated in general as the number of animals increased. Their descriptions of the strengths and weakness of several common techniques for estimating preference are very helpful. However, they conclude that regardless of the method used, if few observations (<15) of few animals are used, the probability of type II error is unacceptably high (Alldredge & Ratti 1986). Another challenge is incorporating the variation in availability and preference for various sex and age classes. Each grizzly bear is dealing with variable levels of territoriality, and inter-specific competition (Thomas & Taylor 1990; Peek 1986; Owen 1972; Hilden 1965) with black bears and other carnivores, (e.g. wolverine). This can become especially troublesome when studying a small grizzly bear population, providing few samples.

Seasonal / Daily Considerations

Bear activity is largely dependent on the seasonal forage availability. Interior US grizzly bears spend approximately five months in their dens, sleeping. On the other hand, they travel extensively during their active season. They depart from their dens and move directly to the lowest elevation areas to obtain the earliest spring vegetation. Then they ascend, following the fresh food supply, reaching the ridge-tops by mid summer. As autumn approaches, they advance down to low-elevation areas again before returning to mid-elevation dens in November. This continuous movement during the active season demonstrates the grizzly bear's reliance on available forage. While these movements present challenges to any study grid, they also indicate that a bear's degree of attraction to any scent station or carcass will vary with the seasonal abundance of traditional food sources. This variability in attractiveness could affect capture probabilities. Because the quantification of background food availability and its effect on bait attractiveness is nearly impossible, correcting bias for this source of capture heterogeneity will be impossible.

Grizzly bear activity levels are also affected significantly by daylight. Darkness may provide a source of cover for bears moving across a hostile matrix, such as the private land on the floor of the Swan Valley. There is obviously much more daylight during the mid-summer than during either early or late active-season. Female Swan Mountain grizzly bears were fitted with motion-activated collar from 1992-1994 to investigate their activity patterns (Wenum 1997). They were most active during daylight hours, with some activity noted at all times of the day. They showed correspondingly higher activity levels during the summer than during the spring and fall seasons (Wenum 1997). This dependence on daylight may therefore affect seasonal grizzly bear survival rates in areas where human threats are present. Pease and Mattson (1999) performed a maximum likelihood estimation of demographic parameters to determine the contribution of several independent variables to grizzly bear mortality. Of all the factors they included, they found that grizzly bear mortality rates varied most with season. They found that the effect of season on mortality was, in fact, an order of magnitude higher than the next most influential factor (Pease & Mattson 1999).

The mating season certainly affects bear movements during the spring. It can be expected that male bears are both in search of a mate and more likely to displace less dominant subadult males and wary females with cubs. Mattson et al. (1987) found that females and subadults both avoided dominant males, who tended to dwell in the most productive habitat. Any study design should recognize these daily and seasonal determinants of bear behavior, and plan accordingly. I recommend that future studies at least attempt to model the ratio of males to females, with a full description of age distribution also being strongly encouraged. Because LZs will variably affect proportions of different-gender-sized home ranges, a preliminary understanding of population demographics will help develop expectations for the seasonal magnitude of LZ impacts on the entire population. Demographic information can only be gathered through capture techniques (e.g. DNA hair testing) with complete classification requiring more intense capture and assessment (e.g. snaring). Studies focusing on spatial/temporal gender interactions like those conducted recently by Mace and Waller (1997), Wielgus and Bunnell (1995, 1994) and Mattson (1987) are also advised to complement all other future grizzly bear findings.

"The definition of a time origin is crucial...In radio telemetry there is no natural time origin. Survival from the origin could be seriously influenced by seasonal effects, with survival for 1 week from a summer time origin quite different than survival for 1 week from a winter time origin"(Pollock et al. 1989). Researchers are cautioned against extrapolating survival rates for a short time period to the entire year or into matrix models that project finite rate of growths using season specific survival rates. This can be corrected by designing and using survival studies that extend for several years. For all these reasons, seasons need to be considered when attempting to evaluate grizzly bear demographic rates.

Linkage Zone-Specific Challenges

Separating Mortality Factors

It may be difficult to sort out the impact of controllable and uncontrollable factors on the mortality of bears. Uncontrollable risks include those intrinsic to the population, like intra-specific predation, plus other natural mortality factors extrinsic to the population, such as catastrophic natural fire and avalanches. Controllable mortality causes are those caused both directly and indirectly by people and their activities. Demographic problems such as inbreeding, reduced fitness by loss of genetic variation, and demographic stochasticity can be elevated by unnaturally low population size (and genetic pool) which may be the result of high levels of human-caused mortality. Without radio tracking every grizzly bear and then conducting an inspection of every death, it is very difficult to separate natural and unnatural causes of death. For example it may be that the best spring habitat is protected, but lies at the base of an avalanche chute. This confusion suggests another difficulty in correlating survival rates with LZ protections.

Linkage zones are designed to protect bears from excessive human access and human caused mortality. Evaluating the effectiveness of LZ regulations thus requires some understanding of background levels of mortality in nearby remote areas (without human-caused deaths) and in nearby unprotected areas (areas with no open road density, timber harvesting, and firearm regulations for humans). The effectiveness of Swan Valley LZs should consequently be considered with an understanding of natural levels of spring and fall mortality and abundance for grizzly bears in other areas of the Northern Continental Divide Ecosystem (NCDE). Grizzly bears in the NCDE generally have a long life expectancy, (approximately 20 years) and high survival rates, especially for adult bears ranging from 0.67 to 0.89 (Woods et al. 1997). Their abundance varies with habitat quality, but abundance has been estimated in the tremendous range of 1/200 sq. km. (Rattlesnake Mountains) to 1/0.01 sq. km.(Mission Mountain, riparian seep concentration)(Servheen 1983).

Confounding - Covariance of Landscape Variables

Two more problems arise when attempting an evaluation of LZs. Confounding is the confusion of factors which are not resolvable with sampling techniques. Consider that LZs were to protect the best remaining grizzly bear habitat fragments in a landscape. They accomplish this protection by restricting human access to grizzly bears and their best habitat as identified through a Linkage Zone Prediction (LZP) model. This design factor confounds any investigation into the present or future value of these LZ protections, especially when a 'before and after study' is not an option. The reason 'before and after' studies are often not possible for LZ evaluation is because the urgency of conservation measures outweighs the value of a strong monitoring project. Even under these ideal 'before and after' circumstances, the effects of environmental stochasticity in an entire valley presents another problem, preventing perfect determination of LZ value.

Covariance of landscape variables is the source of much of this confounding and prevents a statistically sound study of LZ effectiveness. Landscape covariates includes differences in vegetation, climatic conditions, and all environmental gradients across the landscape affecting the habitat quality for bears in conjunction LZ. These covariates will make adequately sampling (controlling via replicability) any experiment to evaluate only the effects of LZ protections nearly impossible. Although some calculations and analyses can be conducted to incorporate the many covariates operating on a landscape level, this quickly makes an experiment unmanageable. The principle of parsimony, keeping models as simple as possible to explain phenomena, would be violated if a study attempted to incorporate too many factors that might be covariates. Decreased degrees of freedom and weaker statistical inference will generally result from trying to include any covariates. A pilot study is recommended to determine which factors are the most powerful covariates. Considering these problems, the best solution involves attempting to identify covariate gradients across the valley to see if they flow predominantly north to south or east to west. If they flow mainly north to south then the layout of LZs versus non-LZ areas in the Swan Valley may largely negate the impacts of the gradients. No matter what the situation, adequate interspersion, replicability, and control are required in the valley to make any statistical inference from grizzly bear data.

Unfortunately, the inevitable confounding of the LZP model, environmental conditions and human activities makes determining the effects of human activities alone on mortality and abundance impossible. Given this problem, the challenge is then deciding the best way to evaluate whether these restrictions are helping bears dwell and survive in these areas and reporting it in light of this uncertainty to the public.

Sampling Replicability

Replicability is the degree of similarity that can be achieved among experimental units. It reduces the "noise" or random variation within experimental unit measurements, and improves the precision of any estimate of treatment effects. Together replication and interspersion of treatments ensure that an experiment is not incorporating freak events as treatment effects. Unfortunately, replication is impossible when large-scale systems or entire valleys are being studied (Hurlbert 1984). This impossibility should be appreciated and embraced, and should not become a source of pressure for the researcher to deceive readers with confusing statistical analysis in a report in order to be published. However the validity of analyzing unreplicated samples from treatments depends on the treated and untreated experimental units starting and remaining identical, except insofar as a difference is generated by the treatment effect (Hurlbert 1984). This enduring, comparable-condition-requirement creates yet another tough obstacle to evaluating the effectiveness of LZs. As mentioned above, confounding of the LZ prediction model and landscape covariates will likely violate this requirement.

Randomization versus Interspersion

Randomization is used in experimental design to achieve interspersion without experimenter bias. Interspersion refers to the temporal and spatial spacing of replicates in sampling units. It is suggested when one is trying to reduce the effects of unidentifiable gradients and non-demonic intrusion (unintended impacts that chance events can have on an on-going experiments)(Hurlbert 1984). Randomization is often used to achieve adequate interspersion. However, randomization does not always provide adequate interspersion especially when few replicates are used. The distinction between a randomized and properly interspersed sampling design can best be described by referring to the type I error expectation that is a consequence of each. When a researcher attempts to predict the type I error probability rate and they use randomization, they are actually deriving an estimate of pre-layout type I error expectation. This differs from the actual layout-specific type I error probability, which can not be individually assessed, but is of more interest to both the researcher and his/her audience (Hurlbert 1984). Ideally enough sample sites would be used in a LZ evaluation that randomization would provide adequate interspersion. However, due to the low elevation nature and the desirability to protect all low-elevation habitat, adequate sampling interspersion may be very difficult to achieve. If interspersion is not obtained for any LZ study it should be prominently reported by the author(s).

Controls

Controls are used by biologists to decipher the effects that some treatment has on an animal population versus the effects that time has on that animal population. They often attempt to isolate the treatment area and compare the abundance or density of a species. In a LZ evaluation, the goal is to understand how the LZs affect grizzly bears. It is therefore desirable to evaluate how grizzly bears are doing nearby without the impact of grizzly bears to "control" for the 'LZ treatment effect'. However, this may be impossible. One reason, addressed below, is that bear home range will almost always be larger than a LZ, or at least it will contain some area inside and outside of a LZ. The other reason is that no identical population, at least devoid of systematic differences (sex ratio, diet, etc.), with a similar degree of isolation and no LZs is available as a control.

Biological Dispersal and Linkage Zone Size

Another obstacle facing any evaluation of grizzly bear LZs is the size of the LZ compared to a bears home range and mean dispersal distance. It becomes imperative to consider whether a LZ is providing a conduit to typical dispersal and foraging movements, or whether the LZ is just a small, protected area lying inside the home range of a grizzly bear. The latter scenario, where LZs only constitute a portion of each bears home range is the most likely for grizzly bears. The relative size of LZs certainly varies for the various age and sex classes for grizzly bears, as well as seasonally within each class. For example, Servheen (1983) reported adult male Mission Mountain grizzly bears had a mean home range size of 1,402 sq. km. Mace and Waller (1997) reported that Swan Mountain adult males displayed a mean home range size of 768 sq. km. These figures are approximately 3-9 times the area of each

SVGBCA LZ. On the other hand, one Swan Mountain subadult female bear displayed a very small (35 sq. km.) home range, while the mean adult female home range was only 121 sq. km. (Mace & Waller 1997). These sizes indicate that LZ protections could have tremendously variable impacts on these different age and gender bears. This creates a question of whether LZs help female more than male grizzly bears. Sexual and seasonal (spring, summer, fall) differences in home range sizes may lead to different value of LZ protections for each sex. For example, Mace and Waller (1997) report that early-season (mean = 404 sq. km.) Swan Mountain male core areas (core isopleths were ≥ 70% of 95% adaptive kernel home range) were larger than in the late season (mean = 235 sq. km.), while late season female core areas (mean = 74 sq. km.) were larger in than early season (mean = 58 sq. km.) areas. Although estimated total home range size changes more seasonally for males, seasonal variability in core isopleth as a percent 95% adaptive kernel home ranges was not found to be significant for either sex (Waller & Mace 1997). This implies that male grizzly bears may benefit more from multiple LZs than females in the spring. Males have higher mortality risk due to their higher probability of encountering threats, associated with more extensive travel (larger home ranges). This difference is especially important considering that females apparently greatly outnumber (4:1) the adult males in the Swan Mountains (Mace & Waller 1997).

Inferential Statistics for Grizzly Bear Monitoring

Although inferential statistics can be used to elegantly report scientific information, they are poorly understood by the general public and frequently misused by the scientific community. Statistics can confuse readers and prevent them from understanding the take-home message of any study. This project attempts to describe the limitations that statistics apply to monitoring LZs. These limitations should be read carefully, because they could prevent the undertaking of a well intentioned, and well executed study, which might yield information no more informative than the flip of a coin.

I begin by introducing type I and type II errors. Next, I develop the relationship between these two error types and other sampling variables worthy of consideration for a solid monitoring plan. Eventually I will inject some advanced or non-traditional statistical concepts receiving increased attention lately in monitoring studies.

A null hypothesis states that there is no treatment effect. A type I error is made when the null hypothesis is rejected even though it should be accepted. The likelihood of this happening is termed α (alpha). This type of error traditionally drives sampling design and the uppermost risk of making this type of error is conventionally set at 5 percent (typically seen as $p < 0.05$). A type II error is made when the null hypothesis is accepted even though it should be rejected. This type of error has been an emerging concern of biologists lately. The probability of committing a type II error is termed β (beta).

Statistical Power

The power of a study (1-β) describes the probability of an analysis detecting the treatment effect for which it is testing. Power analysis can be used to explore various sampling designs and also to interpret results (Taylor & Gerrodette 1993) which are conducted to compare resource use, ascertain the likelihood of detecting population trends, and for making vital rate (e.g., survival rate) comparisons between multiple areas. High power is the aim of any trend monitoring study. A trend is detected if the slope of the regression varies significantly from zero (Gerrodette 1987). Trend detection power has five basic parameters that are related with an equation: the number of samples, the rate of change in the quantity being measured (effect size), the coefficient of variation (measurement precision and environmental variation), and type I and type II errors (Gerrodette 1987). Power increases when the number of samples increases, the rate of change being measured increases (effect size), or the precision of the measurements increases.

Improving sampling to maximize trend detection power should be done in three ways. First, additional replicate samples should be taken evenly along all existing spatial gradients. As Green (1979) pointed out, the differences among areas and time can only be compared to the existing differences within an area (spatial variation) or time period (temporal variation). If a trend exists, increasing within year sampling and reducing among year sampling will accomplish two desirable goals. First, this will improve quantification of sampling error, and second it will increase the detectable effect size among sampling periods. However, if no trend exists then reducing among sampling frequency will not increase detection power. Within year samples must remain sufficiently spaced in time to insure that the independence of samples is maintained, otherwise autocorrelation will happen, negating statistical inference.

Samples should also be taken in similar ways (e.g. similar baits used as attractants) for each sampling session. If this is done, then overall sampling bias is reduced and a single measure of precision (CV) can be applied to all samples. This satisfies a major assumption in power analysis. However, this may be difficult given the aforementioned problems of diminishing bait attractiveness experienced when using the same non-consumptive bait repetitively.

Detecting Upward versus Downward Trends

Endangered species monitoring is often focused on detecting downward trends. It is therefore important to note that power to detect increasing trends is lower than the power to detect decreasing trends (Gerrodette 1987). Another noteworthy property of the statistical power relationship is that proportional upward trends are easier to detect than upward trends involving absolute changes. The situation is reversed for downward trends. This fact, combined with the realities of one-tailed versus two tailed tests described below, suggests that studies attempting to detect only downward trends changing by absolute amounts will have the highest power. (Gerrodette 1987). This should be considered in regards to expected changes in abundance, survival rates and reproductive rates for individual bears as a result of LZ habitat enhancement. Will adjustments in reproductive rates affect abundance proportionally? Will mortality numbers be reduced in a linear relationship proportional to reduced open road density, etc.?

One – tailed versus two-tailed tests

When designing a study to detect trends a decision must be made about the importance of these trends, if they exist, in either direction. That is to say, downward trends may be more important to perceive than upward trends in endangered species management. The use of a one-tailed statistical test can increase power over a two-tailed statistical test needed to detect trends in both directions, holding all other variables constant. However, it is important to remember that a one-tailed test has no power at all to detect trends in the opposite direction (Gerrodette 1987). Grizzly bear researchers are often more interested in detecting downward trends, which serve as an alarm. However, when we are studying the expected benefits of LZs we anticipate upward trends will be more likely. This creates the need for a major decision. If a one-tailed test is selected *a priori*, then the study may provide results that have zero power and is therefore a waste of money and effort. On the other hand, if a two-tailed test is selected *a priori*, we may either require unrealistic sampling or sacrifice the power of a study to detect trends in either direction. In their prospective power analysis, Zielinski and Stauffer (1996) estimated that if maintaining power and type I error probability was desirable, using a two-tailed versus a one-tailed test of hypotheses would require sample sizes 20-50% greater. Unfortunately, given the uncertainty of success flowing from LZ implementation we would likely need to test for trends in both directions. However, it may be advisable to design a larger study encompassing short term studies that detect only downward trends every couple of years, with high power, and a simultaneous long term study to detect trends in both directions.

Advanced Statistical Thoughts

New Decision Rules for Balancing Type I and Type II Errors

Several authors have suggested resetting the critical probabilities of type I error and type II error relative to the costs they would involve for management. Committing a type II error could lead to an erroneous opinion of habitat conservation benefits. I remind the reader that since LZs are expected to improve grizzly bear habitat, the hypotheses used to test LZs may be inverted compared to traditional imperiled-species monitoring studies. If this is a serious source of confusion while reading, then I recommend referencing Zielinski and Stauffer

(1996), Mapstone (1995), Taylor and Gerrodette (1993), and Thomas and Taylor (1990).

As mentioned above, scientific reporting convention has been to set alpha at a maximum of 0.05 and let type II probability error float. This conventional decision rule does not reflect the actual costs that committing these errors can create. Committing a type I error in grizzly bear monitoring could mean that our analysis forces us to decide that there is an effect when in actuality none exists. Whereas, committing a type II error could mean that we proceed with the belief that there has been no positive habitat effect even though one really exists. Type II error might therefore lead to canceling conservation measures (e.g., LZ protections) misperceived as unwarranted. If we did proceed down a path based on the decision made by conventional statistical analysis we may need to make very expensive corrections in the future based on legislative directives (ESA, etc.).

Given that committing type II error may be more costly than committing a type I error in grizzly bear monitoring, it is advisable to depart from convention and create new decision rules for statistical significance. Mapstone (1995) suggested that a preliminary investigation should be conducted to assess the costs of committing both type I and type II errors. The economic analysis of these costs is still largely undeveloped. Depending on how the study is designed, committing each type error can lead to major changes in an area, resultant from say local extirpation or triggered legislative directives. Techniques to assign value to biodiversity, species persistence, sustainable economies, etc., must attempt to sum all stake holder's projections of these values. Although contingent valuation surveys and other instruments are helpful to develop these economic comparisons, 'apples and oranges' are often being compared. Techniques for assessing the various costs of each type error in the Swan Valley would require creativity and should be reviewed by the public before proceeding

Given that some satisfactory comparison can be made, Mapstone's next step is to set the ratio of critical type I and type II errors to reflect this cost ratio. This new set of decision rules would be more balanced in its attention to both error type probabilities (Mapstone 1995). Designing a 'Mapstone approach' for the Swan Valley is a large project in itself and beyond the scope of this document. However, one can imagine that if the costs of type II error for a future study involved the non-detectability of a Swan Valley grizzly bear extirpation (and an expensive subsequent reintroduction), this could easily alter the preferable balance of type I and type II error probabilities. For example, extirpation of the grizzly bear in the Mission Mountains would likely invoke a lengthy and costly government (USFWS) EIS process, reviewing the options for a reintroduction.

Bayesian Approaches

The inferential statistics almost always used in scientific reporting are labeled classical statistics. They have become so standard that journal editors will often require their application to studies in order to approve articles for publication, even when they might not be appropriate (Hurlbert 1984). Another realm of statistics also exists, called Bayesian statistics. Although in-depth discussion of these techniques is beyond the scope of this project, the manner in which they differ from traditional statistics is worth mention. Bayesian statistics derive smaller confidence limits bounding vital rate estimates by combining the results of a given study (likelihood function) with prior knowledge from previous studies. While the classical statistician would rely on the likelihood function alone, the Bayesian statistician multiplies the likelihood function with the prior function to obtain a posterior function. The posterior function is inversely weighted by the variance of the multiple components, helping to represent the precision of each study (Johnson 1977).

Probably the greatest advantage of Bayesian analysis is that *a priori* knowledge of non-negative values can help constrain the confidence intervals. For example, if we obtained a low figure for grizzly bear density, then the normal distribution around that mean would likely extend into negative values. We can be certain that these negative values are not true in the study area. Therefore, we can reduce the confidence interval of our parameter estimates. Efron and Morris (1973) have discussed different mechanisms for combining the results of a given study with *a priori* information to allow additional control over the weighting of factors contributing to the posterior function. The use of Bayesian statistics may be most appropriate for a long-term study of LZs, however, it may be important to reject a contribution from studies which either did not report error rates or that were conducted prior to a major change on the landscape, such as the introduction of new conservation measures.

Additional Question Considerations

Sensitivity analysis

Sensitivity analysis of vital rates can be used to determine which age and sex class individuals should be the focus of grizzly bear research. Several biologists have attempted to develop techniques that rank the multiple vital rate parameters, which contribute to estimation of the finite rate of growth. The techniques vary in their technical details, but they all attempt to highlight which parameter value makes the largest proportional impact on the finite rate of growth. If the most elastic parameter value (e.g., subadult mortality) can be ascertained then efforts can be made to alter and monitor this rate and increase the population finite rate of growth. Some grizzly bear studies indicate that adult survival has more influence than sub-adult survival on population finite rate of growth. They also suggest that reproductive parameters lie in between these two survival parameters in terms of proportional contribution to the finite rate of growth (Eberhardt et al. 1994). This is additional justification for attempting a study that can accurately measure how LZs affect all vital rates, especially adult grizzly bear survival and reproductive rates.

Strong inference

Strong inference involves the simultaneous testing of multiple hypotheses. This may allow a researcher to cull more information from a capture or monitoring effort than would normally be gleaned from a single hypothetical-deductive exercise. Strong inference can promote a clearer understanding of all the variables that may be acting within and upon grizzly bear populations, using little additional effort. Given that LZ studies are likely to be examining a small number of bears, strong inference seems to make the most productive use of any intrusive monitoring effort.

The Questions

Many sub-questions could be envisioned to test the hypothesis that LZs protect bears in low elevation habitat and conserve an isolated grizzly bear population facing severe human caused mortality risks. Following the guidance of my committee I have selected the following three ideal sub-questions, to show their limitations in a real landscape:

1. Does reducing road density and logging activity appear to increase bear numbers/usage in the linkage zones?
2. Do grizzlies have higher numbers/usage in linkage zones than would be randomly expected?
3. Do grizzly bears have a higher survival in linkage zones?

Together the answers to these three different questions should test a hypothesis concerning the effectiveness of LZs to grizzly bears. Taken in turn, the benefits and challenges of each are described.

Question 1 investigates the relative abundance of grizzly bears within LZs. It relies upon two assumptions. The first assumption is founded in the majority of grizzly bear research, that roads and timber harvesting activities reduce the quality of bear habitat and increase bear mortality (Mattson 1998, 1996; Mace et al. 1996; Mattson 1992, 1990; McLellan & Shackleton 1989, 1988; Meagher & Fowler 1989; Craighead et al. 1982; Knight et al. 1988). Mace et al. (1999) reported that resource selection probability function values increased as road density decreased in the Swan Mountain Range. Waller (1992) investigated the effects of cutting units on Swan Mountain grizzly bear utilization, within 95% convex polygon home ranges, and found mixed results. Mace et al. (1999) also reported that female Swan Mountain grizzly bears were "significantly and negatively associated with increasing densities of all roads and presence of high-impact human activity points." In another recent study, Waller and Mace (1997) reported that Swan Mountain grizzly bears used cutting units, within 95% convex polygon home ranges, less than expected during spring and fall seasons, and more than expected in the summer.

The second assumption is that the SVGBCA actually reduces logging and road density in the linkage zones. The previous lack of annual monitoring reports, which were mandated by the SVGBCA, is a major problem because it prevents comfortably relying on this assumption. Furthermore, the lack of clarity in the SVGBCA regarding standards for assessing the amount of logging related activities is an additional problem. Clarifying measures to quantify these reductions in human disturbance on the landscape is the first step in drawing any correlation between linkage zone protections and bear population abundance / usage. Testing question 1 would require advanced knowledge of timber harvesting plans and would therefore require the full cooperation of any private and public timber-harvesting managers. Plum Creek Timber Company is very active in collecting data to improve their forest management activities. They maintain a comprehensive database of roads in the Swan Valley. They probably also have the best available aerial photographs. The Swan Ecosystem Center, a non-profit cooperative organization that bridges management action with public input in the Swan Valley, is another good source of information for conducting this study. This group is currently conducting a Swan Valley Landscape Analysis project. This project should provide a comprehensive assemblage of all existing and desirable spatial information for the Swan Valley within four years (GIS, satellite, wildlife monitoring, etc.) If this monitoring is completed and we can quantitatively measure these reductions, then we must reach consensus of the best way to measure bear numbers must be attained.

It is important to consider how bear numbers should be counted. I believe that bear numbers should be defined as size of the population between the two ridges that contain the Swan Valley, during breeding season. In either case, it must be decided whether we are asking if bear numbers respond to either specific or overall reductions in linkage zone road density and logging. The SVGBCA incorporates a rotation plan to manage roads and timber harvest in grizzly bear management subunits that might facilitate or hinder answering this question, based on its timeframe relative to a study timeframe. If one attempts the more ambitious model of how specific reductions in logging and road density affect bear numbers, we need to use a more extensive form of compositional analysis (telemetry-based). It would be needed because few if any bears will spend all of their time completely inside or outside of a linkage zone. Therefore, we would need to determine how grizzly bears are using the various habitat components inside LZs relative to their proximity to roads and timber activities. Typical weaknesses of compositional analysis, such as discerning between use and preference and defining a study area are described above and in the 'techniques' chapter. The largest obstacle would be obtaining a sufficiently large sample size of grizzly bears to answer this question. Sample sizes of 15 and 20 are suggested as minimum thresholds to make any statistically valid statements (Pollock et al. 1989). This sampling requirement would mean that nearly all of the bears using the Swan Valley would need to be collared. Additional problems include sampling replicabilty, a lack of a reference or control population, and environmental stochasticity acting as non-demonic intrusions via variability in landscape covariates. However, GPS telemetry would likely be the best available technique for resolving the usage portion of this question. It would give us the most frequent and precise sampling option for the limited number of bears observable in the Swan Valley. However, GPS collar data can only provide information for a limited number of bears, preventing determination of relative abundance inside and outside LZs. Therefore another technique would also be needed, for example DNA mark, to derive this relative abundance.

If a decision is made instead to test only whether the aggregate LZ road density and logging reductions are increasing bear numbers, then several monitoring options exist. Relative abundance can be assessed with bait or scent lure techniques such as: DNA hair snagging, remote cameras, sign surveys, or observation techniques. Costs and statistical inference capabilities are highest for telemetry techniques and less for less intrusive methods. As the researcher moves from population estimators to indices she loses the ability to complement her estimates with confidence intervals which makes error reporting impossible.

Any answer to this question would also benefit from a long-term monitoring effort to determine within versus among year variation in proximity to roads and logging operations in LZs. Given that most Swan Valley home ranges envelop LZs, anyone attempting to answer question 1 with statistical integrity, accepting its limitations, would probably want to acquire expensive satellite imagery, and GPS collars, making a large budget a necessity. The need to recapture bears to re-collar them with current GPS collars would also markedly increase the level of disturbance to grizzly bears, possibly risking injury or elevated levels of mortality. Additionally, if this annual capture program is required for a long-term study, then novel attractants will be needed to trap bears.

Question 2 is very similar to question 1 and it explores the amount of time grizzly bears spend in LZs compared to LZ relative abundance on the landscape. It is another relative abundance question, similar to question 1, this time addressing the entire valley or study area housing the LZs. Using random expectations would be extremely helpful in assessing LZ value for a homogenous landscape. However, the confounding with the LZ design model, environmental stochasticity and variability in human-caused mortality threats (threats not managed by the SVGBCA) described above are especially troublesome for this question. It may be possible to overcome this problem if we trust that we can rank habitat value from a bear's eye view (i.e., a more complex model similar to an LZP model). This requires a leap of faith in the scientific community, one that will make many scientists uncomfortable. Using a capture grid, either DNA or photographic grids or some combination of the two may allow one to answer this question. However, the size of any grid would still be smaller than mean adult grizzly home ranges in the area. Also, a large grid could only be logistically maintained by a very large study-team for a short period of time. If the grid is set for limited time period then the information it yields regarding use of the LZs will be limited to that time period. Likewise, a track survey of the area would be limited to the times of the year when climatic conditions allow for tracking with consistent identification probabilities. So here again we find that GPS collars on all bears may be the preferred technique to answer question 2, although obtaining a large sample size would again be difficult and if possible it would be extremely invasive to grizzly bears. Another problem with all telemetry efforts to answer question is that captured and subsequently anesthetized grizzly bears may experience higher mortality rates than non-research-trapped bears 2 (affecting abundance comparisons). Mace and Waller (1997) during the course of their grizzly bear capture program (50 grizzly capture from 1987-1996) classified one death as a research death, where a one-year-old bear was killed soon after it was successfully released. Another grizzly was shot illegally by a hunter while in a research snare. This translates into a range of 2-4% direct capture related morality. Injury can also affect captured bears. An increase in mortality probability for research-trapped bears causes two problems. First, it has the potential to outweigh any differences in abundance rates inside and outside LZs. Second, it can reduce the size of the future population available for sampling and recovery.

Question 3 compares survival rates inside and outside LZs. This information could be indicative of the status of non-LZ areas, demonstrating whether they serve as sinks in a 'source-sink landscape' (Doak 1995). Answering question 3 will be very challenging because grizzly bears use habitat and face mortality risks both inside and outside LZs. In order to control for this, bears would need to be monitored inside LZs, outside LZs, and in undisturbed control areas, such as the Bob Marshall Wilderness complex. It would also be necessary to pair the amount of time spent in

LZs with survival rates to develop usable information. This is not easy to do in a statistically rigorous manner. It appears that GPS collar telemetry results may provide our best vantage into the amount of time spent inside and outside LZs. Without hourly or bi-hourly sampling, confidence in estimates of time spent inside the LZ is quickly lost. However, problems of collaring enough individuals from each age/sex class of each of the two populations (Swan Valley and control) for long enough periods to understand demographically-specific survival rates for these long lived species (20 years) will be problematic. The expense and weight of collars are also both important limitations in any proposed study. Concerns of altering survival rates with a capture program must be raised here as well. For these reasons, we may want to consider using DNA techniques instead to answer question 3. While this technique may be less costly (given that we use at least 7 independent loci for DNA identification) it would certainly be less disruptive to local grizzly bears over the course of a long-term study. The application of DNA techniques to answer question 3 will likely encounter other problems. For example, the diminishing scent attractiveness of snagging station discussed above may cause problems for a long-term study, and long-term reliance on several land owners/managers may cause additional problems. The USGS (1998) is currently using an eight-kilometer-square grid across several land ownerships farther to the north in the NCDE. Results from that study could prove extremely valuable in evaluating the promise of DNA techniques to answer question 3. Beyond the obvious pros and cons of these questions, the statistical realities for sampling and analysis also limits each one, as described earlier in this chapter.

The Big Picture

The variety of challenges presented in this chapter may seem overwhelming to any researcher considering a LZ study. All potential methodologies should be checked with the above sampling and statistical analysis limitations to develop reasonable expectations for study findings. Grizzly bear biology alone presents plenty of challenges to research techniques. In addition, several large landscape problems like the lack of controls, confounding with a design model and landscape variables, an open population, the inability to replicate, and small sample sizes, severely impinge upon any researcher's ability to conduct a statistically-sound LZ study.

It should be expected that any LZ-monitoring researcher will have a battle defending her findings given all the challenges mentioned here. It is also important to remember that research efforts come at a cost to both bears and taxpayers. For both these reasons the focus of any grizzly bear study should be to conduct simulations with data that we can reasonably expect would be garnered using each of the techniques described in the previous chapter. This process involves generating reasonable expectations for data through the review of studies using selected techniques. By incorporating tremendous variation of inputs that reflect data collection possibilities a prospective simulation model can provide upper and lower bounded expectations for real estimates. Work by conservation biologists has recently focused on this simulation work as a means of predicting the usefulness of future ecological studies, see Mills et al. (1999), Boulanger (1997), Zielinski & Stauffer (1996), and Kendall et al. (1992). By conducting this simulation process, an agency such as the USFWS could acquire feedback on what levels of power and confidence will satisfy stakeholders and the public and the study designs required to obtain this information. The audience of the study must be alerted to these challenges, and at the same allowed to decide if these qualified findings will warrant a research experiment. Unfortunately, this task is easier suggested than actually executed by a federal agency. The time, personnel, and budget required to perform environmental impact analyses for proposed studies, with public comment periods, may prevent a study from happening within two years.

CHAPTER V

Applying the General Review to the Swan Valley to select a Study Design

Swan Landscape Problems

This case study illustrates the multitude of challenges to evaluating LZs designed to promote recovery in a real landscape. One unfortunate situation in the Swan Valley is the lack of demographic grizzly bear monitoring prior to the implementation of LZs. This problem of not having a 'before and after' option available creates the need to evaluate the population based on the assumption that any future benefits are at least in part due to LZ protections. Attempts to collect this information in areas slated for future LZs are strongly encouraged, as they will provide a necessary temporal control. However, the Swan Valley likely differs from areas that would be designated as LZs in the future. The Swan Valley has always maintained a population of grizzly bears that use low elevation areas. The intent of the SVGBCA LZs is to maintain connectivity. This differs from future areas, where LZs would likely be protected to encourage demographic restoration through the recolonization and dispersal of grizzly bears through low-elevation areas from existing source areas.

Another control problem exists in the Swan Valley. The home ranges of the local grizzlies are much larger than a size that would allow researchers to study the patches connected to the remainder of the NCDE with LZs as discrete populations.

Bears spend time both inside and outside LZs. Even if we did have the convenience of this feature for a future study, Nicholls and Margules (1991) and Inglis and Underwood (1992) have found that several obstacles that would still prevent solid studies and statistical analyses. These home range sizes will also violate assumptions of a closed population for studies that endure through a full active season. Due to these problems in the Swan Valley, we need to be to clear that we can not perfectly differentiate the value of habitat conservation measure made in LZs and those made simultaneously in the remainder of the valley or in the patches in the mountains beyond the ends of these LZs.

The SVGBCA operates on a rotating timber management / road closure system. This allows flexibility to keep the operations of SVGBCA partners, namely Plum Creek Timber Company L.P. profitable. The USFWS argued that without this flexibility the Swan Valley would be quickly be subdivided, dissolving grizzly bear habitat abundance and quality very rapidly. The challenge to any future monitoring project is to create a study design that observes and incorporates this dynamic timber management program where only 4 of 11 Bear Management Units subunits can be active at any one time. And each subunit must lie fallow for at least 3 years. This will complicate the statistical analysis of any monitoring project, even when each rotation with new roads and timber management activities is fully anticipated. If a disconnect between the monitoring team and the timber planners develops, or timber management becomes contingent on interest rates (discount rates), as is often the case for natural resource management, then an expensive study would surely suffer. This leads to three options. First, one can acknowledge this source of error and work closely with timber planners to develop the most informed schedule of harvest activity to incorporate this landscape variation into a grizzly bear monitoring plan. Second, one can accept that specific road densities and timber harvesting levels will vary, and draw correlation between grizzly bear monitoring findings and the constant overall parameters listed in the SVGBCA. This will weaken the correlation because specific disturbance reductions will not be assessed. Finally, one could admit that this rotational basis is yet another factor that will decimate the power of any proposed study. If power is reduced already because of sampling issues, this further reduction in power may strengthen the argument that the best we can really do for monitoring is to rely on indices.

Public / Management Notions for Research

The degree of disruption that a future grizzly bear monitoring research project will have on Swan Valley grizzly bears and other wildlife certainly needs to be contemplated by land managers and local residents. Although it is impossible to fully anticipate the impacts of a given study protocol, consideration using the descriptions in Chapter III can provide expectations for general impacts of all proposed methods. A recovering bear population estimated at 20-30 adults in the Mission Mountains could be substantially impacted by intrusive designs. On the other hand, all the challenges to developing a statistically-sound study design in the Swan Valley suggest that intense, intrusive, telemetry methods may provide the only truly valuable information on bear use, abundance and interaction levels resulting from LZ protections. A decision must be made. Is the probability of this population persisting and recovering, given the current habitat status, high enough to preclude an intrusive monitoring study to check on the progress (embedded in this question is another question of how much uncertainty can we expect any Swan Valley monitoring project to include.)? If the answer is yes, (the population appears to be recovering), then we should proceed down a similar path as the one we are currently on, relying on solely on non-intrusive sign surveys. This would give us a general understanding of grizzly bear use patterns at a reasonable cost. If the answer is no, then we should step up the intensity of the monitoring effort acknowledging an additive temporary mortality risk to the small population. With this more aggressive monitoring plan and some good fortune, we could possibly develop solid estimates of abundance, density, survival rates, reproductive rates and ultimately finite rate of growths for Swan Valley grizzly bears, presumably benefiting from LZ protections.

Financial Considerations

Perhaps the most important factor in determining which study technique will be used to monitor Swan Valley grizzly bears is the available funding. A large budget for such a project seems warranted considering all the recent discussion of implementing LZs to connect the remnant grizzly population in the lower 48 (e.g. The Yellowstone to Yukon Initiative, The Northern Rockies Ecosystem Protection Act, and the proposed Bitterroot Reintroduction (Servheen 1998; Bader 1991; Mattson et al. 1996). Unfortunately, the budget for this project will likely descrease under the shrinking USFWS Grizzly Bear Recovery Project's budget (Servheen pers. com). Table 1 describes the various annual costs of applying each of the techniques described in Chapter III to the Swan Valley. Currently, there is no estimated budget for this project. It is important to remember that the size of the budget is not the only factor in selecting the best technique. The expected stability of this budget also needs to be considered. Factors like an impending presidential election year, a possible economic correction, etc. should also be included when deriving budget expectations and selecting methods, especially for long-term studies.

Output- Protocol Selection

The selection of a monitoring protocol is the goal of this applying Swan Valley case study to the review included in this thesis. The best I can do is provide guidance, but the final decision should ultimately rely on partner and public decisions. I will attempt to predict these decisions. However, my outcome (asterisked) is only one possible scenario used to illustrate how the choice could be made. While a budget may appear to limit our choices first and foremost, I remind the reader that alternative funding may be available if the other 4 decisions lead to the selection of a technique that has costs beyond the current proposed budget.

Questions of the Public Used to Determine the Output

Given all the challenges described above to answering each of these questions, here is the first question to answer:
Q1. What exactly do we need to know about the linkage zones?

A. The Swan Valley population is not declining rapidly towards extinction.
B. The linkage zones lead to an increasing absolute Swan Valley population size.
C. An estimate of the Swan Valley population finite rate of growth.
D. The linkage zones lead to an increasing Swan Valley population finite rate of growth.
E. SV population mortality is within acceptable limits to maintain a Swan Valley population for 50 years.
F. Verification that no inbreeding depression exists in the Swan Valley population.
G. Swan Valley grizzly bears with a majority of their home range in linkage zones have significantly higher survival rates than Swan Valley grizzly bears with a minority of their home range in linkage zones.*
H. How much time do grizzlies using the Swan Valley spend inside versus outside linkage zones.

Applying all the limitations discussed in this document to the answer to this question will tell us whether we can likely answer our most desirable question with any statistical integrity. Notice that answering monitoring questions A and B can be done using annual population estimates only, while the remainder of these questions require more intense demographic information, which would invoke more intensive sampling and more intrusive techniques.

The second question to answer:

Q2. How many grizzly bears are we willing to risk behavioral disturbance with?

A. 0
B. 50%*
C. 100%

How many grizzly bears are we willing to risk capture injury with?

A. 0%
B. 50%
C. 100%*

This question is very important for the public to answer. If no bears can be behaviorally disturbed then we should not do any study. Regardless of what type of study we attempt, we will certainly affect bears, for example driving roads and hiking trails to maintain a sign survey grid will cumulatively affect grizzly bears. If we decide that we can not only disturb bears, but also risk capture injury to some, then more techniques (e.g., telemetry) can be retained.

The third question to answer:

Q3. What degree of confidence do we desire to set as the critical type I and type II error probability rates, and which is more important to us?

Type I: A type I error is made when the null hypothesis is rejected even though it is true.

Type I is more important, therefore set maximum α at:

1. 5%
2. 10%
3. 20%
4. 40%

Type II: A type II error is made when the null hypothesis is accepted even though it is false, and is termed β:

or Type II is more important, therefore set β at:

5. 5%
6. 10%
7. 20%*
8. 40%

This question addresses the level of statistical soundness that is required to satisfy the audience of any Swan Valley grizzly bear monitoring report. Prospective power analysis may be able to derive error rate expectations for potential sampling regimes. An economic analysis, such as the one recommended for the 'Mapstone Approach,' (described above) where estimating the costs of committing these various errors informs the answer to this question is also recommended.

The fourth question to answer:

Q4. How long of a study do we wish to conduct?

A. 1 year
B. 2 years
C. 3 years
D. 4 years
E. 5 years
F. 10 years
G. 20 years*

Increasing the length of a study will have several effects. First, longer sampling will incorporate more process variation including environmental stochasticity. Longer Swan Valley sampling will also encapsulate variance in demographic rates resulting from changes in the 3-year subunit rotational schedule. Unfortunately, longer studies also require additional staff and resources, increasing their costs.

The final question concerns our Budget.

Q5. Our annual budget is:

A. $5,000
B. $10,000
C. $20,000
D. $40,000
E. $80,000
F. $160,000

Recommended Swan Valley Study Methodology

Based on the information contained in this document, especially the limitations to confidently attributing any detected trends in abundance or vital rates solely to linkage zone protections, I recommend selecting the following answers to the previous questions. We need to know that both, (A) The Swan Valley population is not declining rapidly towards extinction, and (G) Swan Valley grizzly bears with a majority of their home range in linkage zones have significantly higher survival rates than Swan Valley grizzly bears with a minority their home range in linkage zones. Attempts to answer both of these questions must embrace the uncertainty of any future Swan Valley grizzly bear monitoring results, based on a very small sample size and lacking a reference (control) population. Answering the first question (A) would involve a monitoring study to describe if implementation of the SVGBCA is not leading to a rapid decline of the Swan Valley grizzly bear population. Answering the second question (G) would require not only survival rate information but also compositional analysis, and it could provide a long-term evaluation of the direct benefits of the linkage zones.

The first question is not as straightforward as it may appear. All monitoring programs will be subject to the multitude of grizzly bear biology and sampling limitations described in this document. For example, reproductive values vary for different age and sex class grizzly bears. This factor alone, makes using future total Swan Valley population estimates less informative and predictive than might be desirable. Whichever technique is selected would include some sampling bias and it would sample the combination of demographic and deterministic factors affecting bear numbers. Human-caused mortality and natural mortality, will combine with typical variability in grizzly bear vital rates each subsequent year to determine the future numbers of grizzly bears in the Swan Valley. Therefore, the best way to evaluate the probability of a rapid decline is by using not only actual population estimates or finite rate of growth (lambda) estimates but also their confidence intervals. The standard deviation and skew of the confidence intervals will yield valuable information regarding the precision of any estimates. A manager should consider what percentage of a given population estimate or finite rate of growth estimate's confidence interval (e.g., 95%), from monitoring results, lies on either side of a lambda of 1.0. This confidence interval-based approach would alleviate the need to focus on point estimates, which are criticized above.

Although several factors will influence a researcher's ability to define a 'rapid decline', some quantitative definition must be generated before a monitoring study is undertaken. A 'rapid decline' could be observed in three ways. The first two rely on population estimates and the last relies on a finite rate of growth estimate. First, future total Swan Valley population estimates (reported with confidence intervals) might indicate that Swan Valley grizzly bears are suffering higher than 'natural' levels of mortality, leading to lower absolute numbers. Secondly, more detailed population estimates may suggest a changing age and sex class distribution of the

Swan Valley population, which would likely lead to a rapid decline in bear numbers. Consider that the total population numbers may remain stable in the short-term, although adult female Swan Valley grizzlies (with possibly the greatest influence on population finite rate of growth (Eberhardt et al. 1994)), could experience unnaturally high levels of mortality, leading to decreasing future numbers of grizzlies.

Alternatively, a finite rate of growth estimate with confidence intervals could be obtained using a Leslie matrix approach, which incorporates survival and reproductive rates. This finite rate of growth approach (with confidence intervals), which requires more intensive data collection, could then be compared to 'natural' levels of variability in the NCDE grizzly bears' finite rate of growth. The problem with all of these definitions is their dependence on a comparison with some 'natural' level of survival or mortality. Since no systematic monitoring has been conducted to date in the Swan Valley, a researcher would be forced to use a reference population, such as the nearby Swan Mountain population – South Fork Project data. Problems with defining and using a reference population are described above, and include the fact that currently no comprehensive monitoring data is available for the entire NCDE grizzly bear population (Mace and Waller 1997). However, even by using telemetry monitoring techniques on 29 female grizzly bears in the Swan Mountains, Mace and Waller (1998) derived a finite rate of growth estimate of 0.977 with a 95% confidence interval that ranged broadly from 0.875 to 1.046. This estimate was then used in a computer simulation to derive probabilities that the population is decreasing (69%), stable to increasing (31%) or increasing (27%). Assuming that there are currently between 15 and 40 grizzly bears using the Swan Valley during the spring, one might expect two future scenarios. First, the small number of females that could be sampled to obtain vital rate data needed for a finite rate of growth estimate, would yield a much wider confidence interval than Mace and Waller's South Fork Project. This will likely prevent a researcher from confidently ascribing a population trend to the Swan Valley population. Secondly, 'natural' mortality rates for Swan Valley bears would lead to some annual mortality. By using 95% confidence interval extremes for mortality rates from Swan Mountain grizzly bears (the most proximate population with available data), one could develop expectations for annual mortality figures for the bears using the Swan Valley. With a total mortality rate estimate of 13.62 and with extreme confidence interval values of the total mortality estimate ranging from 8.52 to18.44%(Mace & Waller 1998) one would expect that these mortality rates might lead to the death of 1 to 8 of these 15 to 40 bears each year. One swould also expect that the effect these mortalities would have on the Swan Valley population should be naturally mediated by new cubs surviving through each year. However, as part of this total mortality, the human-caused mortality rate was estimated at 7.33%, with confidence intervals ranging from 3.42 to 12.90% (Mace & Waller 1998), which suggests that human influences might lead to half of these 1 to 8 bears dying annually. Therefore, one would not expect natural reproduction to annually replenish all of the populations losses due to human influences.

After determining which technique will be used to ascertain a rapid decline, setting an apparent threshold or yardstick of decline, which triggers management review of the Swan Valley Grizzly Bear Conservation Agreement rules must be accomplished. Typically, a 4 percent allowable mortality limit is applied to each grizzly bear recovery area's (3-year summation) females with cubs-of-the-year calculation (USFWS 1993). This figure is used to prevent grizzly bears, with slow reproductive rates from declining rapidly. While a 4 percent annual decrease in estimated population may, in the opinion of some, be too risky for a 'threatened' species with a very low reproductive rate, it may also be too small to detect with available monitoring techniques. For example, sign survey sampling may only be capable of detecting a 20 percent annual decline (Kendall et al. 1992). More intrusive techniques with aggressive capture programs and Leslie matrix-based finite rate of growth estimates may be able to detect a decline in numbers between these two figures (4-20%). Additionally, telemetry monitoring may allow investigation into the causes of bear mortality. For example, Mace and Waller (1998) evaluated 91% of mortality causes during the course of their South Fork Telemetry Project. By determining how many bear deaths appear to be human caused one could gain a better understanding of the value of SVGBCA protections.

Ultimately, the determination that the population is declining will depend on estimates derived from several of these methods and interpretation of the results in light of certain decision rules. If conservation of the grizzly is the ultimate goal of the SVGBCA and its linkage zones, then management rules should be reviewed when a decline is likely to be occurring. Decline may not be detectable within standard statistical methods until it has reached a proportion from which the bears cannot recover. As a result, if point estimates of adult mortality levels rise above those observed in the South Fork population, or the estimated finite rate of growth has 95% confidence intervals that include a distribution of say 30% or more of the potential error below 1.0; then management standards should be revisited. Other combinations of these factors, such as an observed marked future reduction in the use of low-elevation spring habitat, could also warrant review of conservation area and linkage zone management. These yardsticks are suggested, however, as a way of dealing with uncertainty in the management of small populations with slow reproduction. Uncertainty should not prevent taking action, but should enter into the consideration of whether to continue or alter management standards in the face of multiple indicators of decline, even when these indicators are lacking traditional statistical significance.

Moving on with the remainder of recommended answers, researchers should risk injury to only 50% of the Swan Valley grizzly bears, but can behaviorally disturb all if necessary. This would allow researchers to collar the recommended minimum number of bears during a monitoring study. I think that the maximum probability of a committing a type II error for studies answering questions (A) and (G) should be set around 20%. This would create studies that have an estimated 80 percent probability of detecting a decreasing trend and difference due to linkage zone treatment effect, respectively. Researchers should conduct a twenty-year Swan Valley project to adequately sample process variation (environmental and temporal stochasticity). This combination of answers leads me to recommend the selection of an annual background two-tailed, non-intrusive sign survey (spring and fall) or minimum count, with additional GPS telemetry collars, and a large DNA hair-snagging grid for the three intense study periods, with one-tailed tests. These intense sessions should include spring season DNA studies, with 3, overlapping 2-year intense GPS telemetry studies at the beginning (years 1-2), midway point (years 10-11) and end (years 19-20). That way each will be separated by eight years to create high power to detect a decreasing trend in the SV population, corroborating the results of the annual sign survey-based trends. By designing a multiple-stage study a researcher can use both open and closed models to determine abundance trends, and vital rates needed to model the finite rate of growth to answer question (A). Use of GPS collars (with adequate sample sizes) in conjunction with DNA hair snagging will allow the compositional analyses necessary to answer question (G). This study protocol should give the best chance of detecting a rapid decline in Swan Valley bear numbers while concurrently answering the three ideal questions, described above in chapter IV, that can collectively assess the effectiveness of linkage zones. In conclusion, I most strongly urge that the questions (Q1-Q5) used to arrive at my suggestions be used in a mix of partner and public forums to ultimately select study techniques and a sampling protocol.

CHAPTER VI

Management Recommendations for Implementing Study Protocol

Certain suggestions are made no matter whichever study design is selected for monitoring grizzly bears in the Swan Valley. They are intended to improve the efficiency of the selected study design, increase the comparability to other grizzly population studies, maintain public support for grizzly recovery and leave options open for intensifying monitoring efforts in the future.

Public Support

The value of public support cannot be overstated for grizzly bear recovery. People are increasing their presence annually in grizzly bear country. Grizzly bears are living on both public and private lands. The agencies that protect their habitat, enforce bear protection, and conduct bear studies are all publicly funded. Maintaining public support is therefore tantamount to successful grizzly bear conservation. Although the public will never understand all the ramifications of habitat conservation measures and monitoring projects, it is important to make strong efforts to explain them. We should embrace the uncertainty inherent in any future monitoring program. Uncertainty from the application of various techniques in a real landscape needs to be reported with any monitoring results.

This open approach of reporting may tend to reduce public support in the short-term, but it will pay off with respect in the long-term. If we lose public support for bear recovery, then we will lose grizzly bears in the lower 48!

Several steps should be taken to maintain public support when monitoring grizzly bears. Human mortality needs to be prioritized over grizzly bear survival. If people feel that their lives are not valued as much as bear lives, they will immediately stop supporting bear recovery. All area closures for bear habitat security need to be clearly demarcated and explained to the public. A reasonable timeframe for the closure should also be posted for temporary closures. The public should be given the opportunity to share their ideas about grizzly bear management, especially in closure areas. The public opinion should be solicited and included in all decisions about what monitoring plan to pursue. Fortunately, a mechanism to incorporate public opinion is already in place in the Swan Valley. The Swan Ecosystem Center, a Condon-based non-profit organization, was developed for just this purpose. Finally, all information that does not sacrifice the security of individual bears should be released to the public immediately upon preparation, as described below.

Database Management / Information Availability

International database management has been touted by Canadian bear biologists as a necessary step in grizzly bear conservation (Boulanger 1998; Woods et al. 1997). All marks, natural and artificial that permanently label bears should be recorded in a standardized database. This database should include all relevant findings for these bears, including biographical information, capture histories, estimated home range, etc. This geographic information contained in each bears file should be available only to people at risk of danger or scientists incorporating this data into their own studies. This is to prevent inappropriate information disclosure, which could potentially lead to bear deaths or high levels of disturbance of these charismatic but dangerous mega-fauna.

The future monitoring project should make all quantitative information, and the techniques used for collecting this data available, available over the world wide web. This is being done for several other studies, and it leads to two desirable consequences. Public moral and financial support is garnered. Researchers battling with similar challenges around the globe will be able to quickly find text and analysis which will help them select the most appropriate techniques for their study area / population.

Ancillary Information Collection

The collection of additional habitat information should be actively pursued. New satellites with continuous improvements in spatial and spectral resolution are continually being launched. These will definitely be a good source of habitat information. Fortunately, as mentioned above the Swan Ecosystem Center will be collecting all available spatial information for the Swan Valley. In addition, all anecdotal data that can be collected in efforts incidental to any demographic study will help expand our understanding of existing patterns of behavior and habitat selection.

Simulations and Diffusion Models

The use of simulation and diffusion models has been described recently by several bear biologists. Prospective use of these models accomplishes two previously mentioned goals. First, it would help scientists design sampling regimes adequate to test future hypotheses and conduct trend monitoring. Second, it would also be very interesting to compare to actual field data for testing purposes. It may be possible to collect information regarding the use of certain habitat types inside linkage zones. If this valuable information can be collected, then it can be used to test and inform diffusion models. Then all future studies attempting to evaluate potential linkage zones, such as those in the NREPA, suggested to connect all US grizzly bear recovery areas (Bader 1991), would benefit from better diffusion-modeling. A study deign evaluating the SVGBCA linkage zones could also test the prediction abilities of a diffusion model applied to the Swan Valley. For example, Boone and Hunter (1996) developed a model that broke a potential linkage zone, between the GYE and NCDE populations, into cells and assigned permeability values to each cell. Realistic length grizzly bear movements through ranked cells were then simulated using random selection from 8 possible directions (Boone & Hunter 1996). If these models are eventually proven to perform well, they may eventually allow us to make accurate statements about grizzly bear populations and their anticipated dispersal patterns in the future, without imparting any disturbance to these wild animals. A refined simulation-based model of increased grizzly bear travel through linkage zones, such as the one reported by Boone and Hunter (1996) could then more realistically be weighed against the economic costs to implement these relatively new conservation tools.

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Table 1. A Comparison of Grizzly Bear Study Techniques

Technique	*Level of Intrusion*	*Pros*	*Cons*	*Min. Sample Size*	*Cost*
Intrusive Techniques **Telemetry**					
Radio Telemetry	High	Habitat Preference Studies Survival / Reproductive Information Spatial Interaction Studies	Risk of Injury	15-20 bears	$2,000 bear/year
GPS Telemetry	High	Accuracy <15 m Hourly location data	Risk of Injury Battery demands mean that you Must capture bears annually Lacking early spring data	5 bears	$4,000/bear years
Photographic Detection	Med.	Inexpensive Presence /Absence	Poor Information w/out marking Diminishing visitation rates	>0	$14-34,000/ session
Non-Intrusive Study Techniques DNA Techniques					
Hair Snagging	Low	Individual identification	Probability of identity		$40- 60/sample
Scat Analysis	Low	Easy sexual distinction	Shadow Effect	>0	$40- 60/sample
Sighting Indices	Low	Low costs, Aggregation-based Minimum counts	Confusion with black bears Effort dependent	>0	Variable
Observations	Low				
Sign Surveys	Low	Enduring samples	Variability of scat volume		Variable
Track Surveys	Low	Presence /absence	Confusion with black bears Limited tracking conditions	>0	Variable 0- -$52,000 / Year
Den Surveys	Low-High	Aerial census abilities	Inability to calculate area used by denning bears Possible disturbance of dens	>0	Min $4,000 (min. 1 flight)

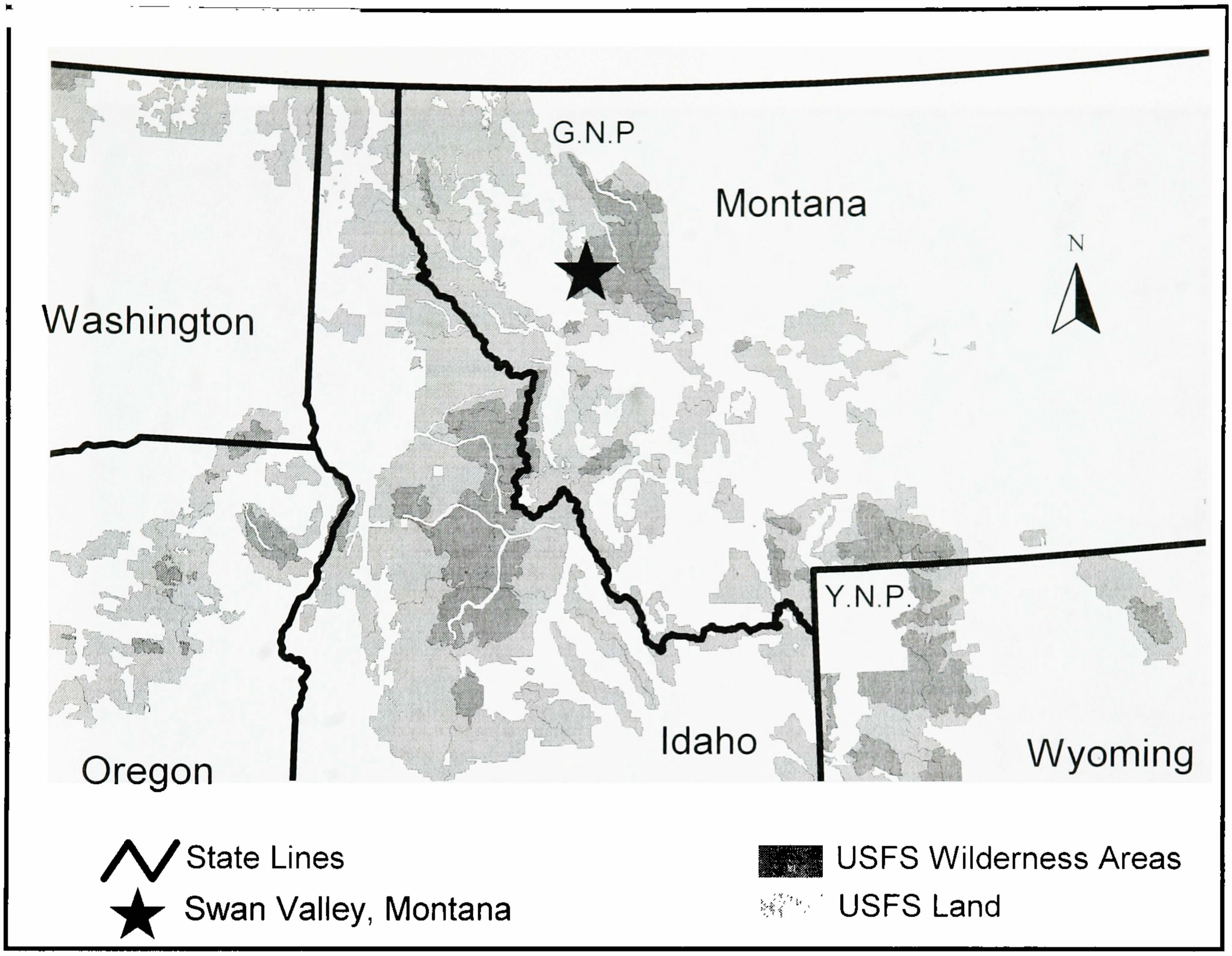
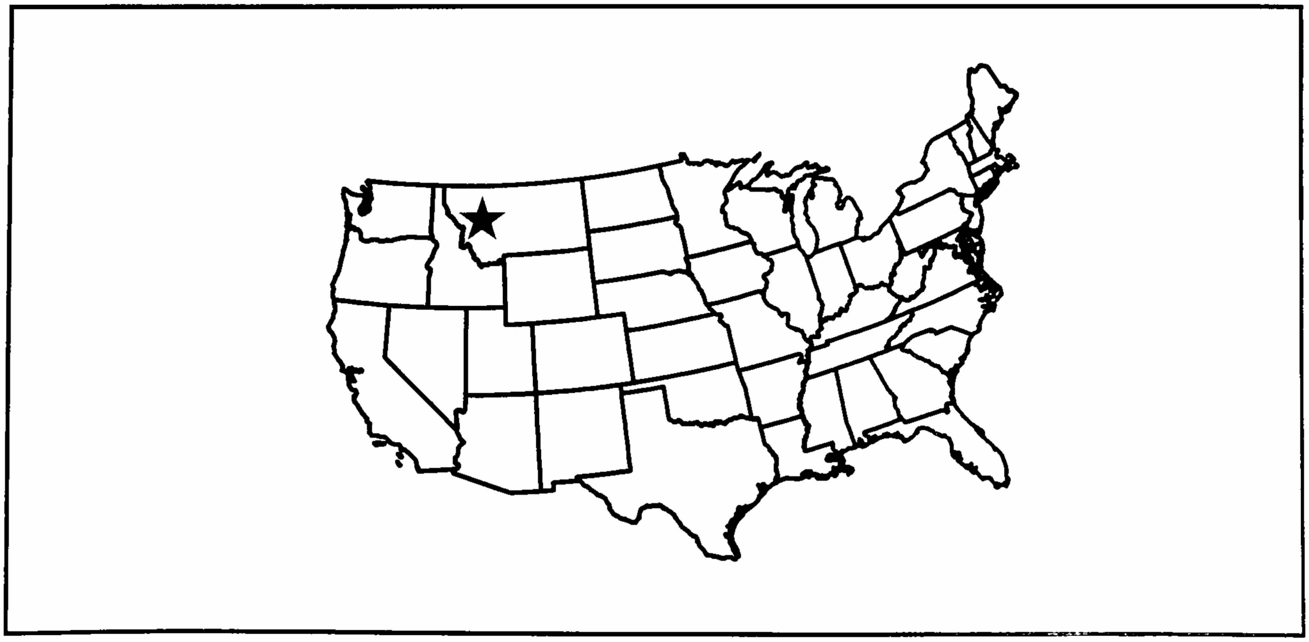


Fig. 1. Swan Valley Locator Map, Western Montana, United States of America



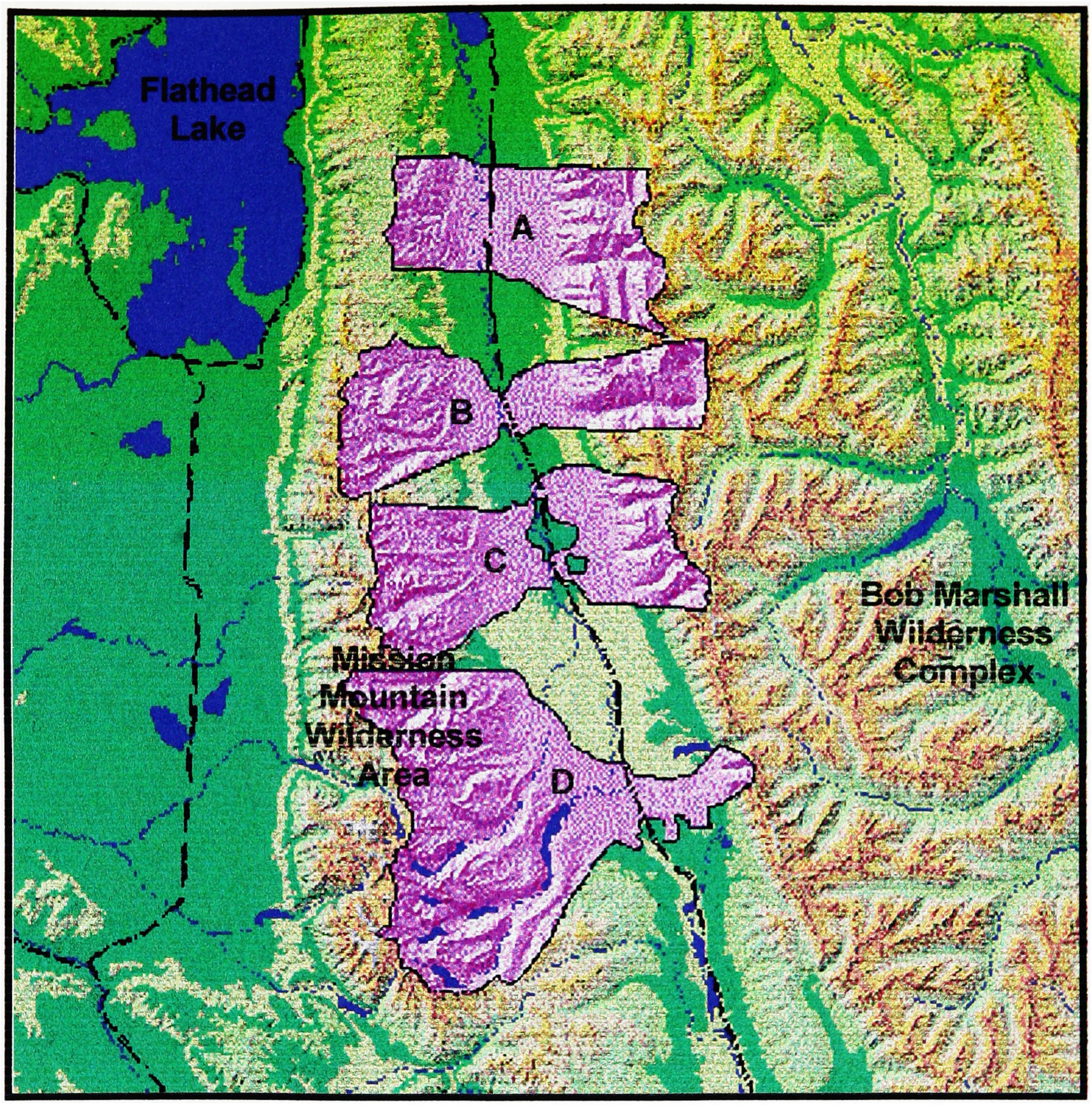


Fig. 2. Swan Valley Grizzly Bear Conservation Agreement Linkage Zones