MANAGEMENT OF GRIZZLY BEARS IN BRITISH COLUMBIA: A REVIEW BY AN INDEPENDENT SCIENTIFIC PANEL

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I. INTRODUCTION

A. Importance of grizzly bears (*Ursus arctos*) to society and in natural systems

Conserving the natural diversity, distribution, and viability of indigenous wildlife populations is one of the highest management priorities of the Ministry of Water, Land and Air Protection (MWLAP, B.C. Government 1996). Although agreement on this general objective is certainly not universal, we suspect that the majority of British Columbians strongly support it. First Nations peoples have long had favorable attitudes toward grizzly bears (Rockwell 1991). For most other British Columbians, favorable attitudes toward grizzly bears evolved during the last five to six decades. Prior to this era, grizzly bears were widely viewed as such serious threats to human life and property that they were destroyed at every opportunity. Most people held similar attitudes about wolves and other large predators. During the last half of the 20th century, an ecological consciousness has largely replaced these attitudes in North America, Europe, and other areas of the world.

This ecological consciousness recognizes the value of functionally intact ecosystems that includes the full complement of native species of flora and fauna. Grizzly bears, as well as wolves, are becoming the poster children for this consciousness, which recognizes that the presence of these species augments rather than undercuts human welfare. By helping to replace myths about grizzly bears with facts (Herrero 1985, Schwartz et al. 2002), the science of wildlife biology augments the rehabilitation of the grizzly bear image. In addition to the emerging recognition of their ecological value, there is growing recognition that grizzly bears are an important economic asset, valuable to hunters as well as to tourists with cameras. The laws of supply and demand hastened this recognition as areas where grizzly bears remained relatively abundant became increasingly scarce in North America. Since 1975, when grizzly bears were listed under the U.S. Endangered Species Act, there has been no place south of Canada where hunting them was legal, except for a limited hunt in Montana between 1975 and 1991. Moreover, opportunities for hunting grizzly bears south of Canada were extremely rare for the 25 years prior to 1975. Today, hunting of grizzly (brown) bears continues in Alaska, Canada, and parts of Europe and Asia. For example, hunters harvest over 1000 grizzly bears per year in Alaska from an estimated population of 32,000 bears (Miller 1993).

Grizzly bears are a particularly appropriate species to exemplify the emerging ecological consciousness of the 20th century. Grizzly bears are a large and occasionally dangerous species whose behavior is not always predictable. Grizzlies may cause real damage to specific economic interests and injuries to individuals. Implicit in efforts to conserve grizzly bears is the acknowledgement that these are costs that society is willing to accept for the benefits of having bears.

Healthy populations of grizzly bears require large landscapes where habitat is managed in ways compatible with their needs (Schoen 1990). Grizzly bears are a classic "umbrella species" because landscapes adequate to maintain long-term viable populations of this

species are *ipso facto* adequate to maintain a host of other species with similar requirements for large landscapes. Such species include gray wolf, lynx, wolverine, marten, and mountain caribou. From the umbrella role of grizzly bears, it follows that in some of the areas from which grizzly bears have disappeared, the human footprint has become too large to assure the perpetuation of grizzly bears as well as a host of other species. There remain other areas from which grizzlies have disappeared due to excessive killing but where habitat is adequate to support populations.

In addition to their umbrella role, grizzly bears help perpetuate natural systems. Through their feces, they transport and disperse seeds of berries and other plants. In recent years evidence has developed that bears have played an important role in maintaining forest health by transporting and depositing nutrients from salmon far from streams where the salmon had been consumed. This phenomenon represents an important net import of nutrients to inland ecosystems from marine ecosystems (Hilderbrand et al. 1999a). Under some circumstances, bear predation on neonatal ungulates (moose, elk, deer) may lower survival of these species and reduce their abundance below levels expected without predation (Ballard and Larsen 1987), but these relationships are complex (Miller and Ballard 1992). Grizzly bear predation may also influence avian biodiversity in riparian habitats damaged by overuse by ungulate prey (Berger et al. 2001). Grizzly bears are excellent excavators, using their long claws as shovels to overturn large areas of earth in search of edible roots, tubers, and ground squirrels. These sites enhance vegetation diversity by providing fertile ground for pioneering plant species.

We recognize the functional values that grizzly bears have in ecological systems. However, we do not have to justify their existence by demonstrating these values. It should suffice that grizzly bears are an apex carnivore and a symbol of ecological integrity that represents the current expression of untold millennia of evolution. If we fail to nurture grizzly bears and the conditions necessary for them to thrive, there can be little hope that functionally intact ecosystems will continue to support the diversity of life forms that enhance our lives and the human spirit.

B. Purpose of review

Grizzly bear hunting in British Columbia (hereafter B.C.) has become a contentious and politically charged issue. In response to claims that the current strategy for estimating grizzly bear numbers and for setting harvest quotas was inadequate to prevent widespread overharvests (e.g., Horejsi et al. 1998), the then government of B.C. declared in February 2001 a three-year moratorium on grizzly bear hunting. The government announced that during the hunting moratorium an independent panel of bear experts would be appointed to review the harvest management strategy. The moratorium was in existence during the spring of 2001. In July 2001, the new B.C. government lifted the hunting moratorium, but supported the continuation of the independent review panel (hereafter Panel) called for by the previous government. The composition of the Panel was based on recommendations from the International Association for Bear Research and Management (IBA), the professional association for scientists and managers working with bears around the world (www.bearbiology.com). The only constraint placed on the IBA's selection was that

panelists could not be employed by government agencies in B.C. or financially linked to such agencies. This constraint was to ensure that the Panel would deliver an unbiased and independent analysis. The membership of the six-person Panel was announced in July 2001, and the Panel held its first meeting in October of that year.

The Panel was not the first effort on the part of a B.C. government to review and recommend improvements for managing grizzly bear hunting in the province. A government-appointed Grizzly Bear Scientific Advisory Committee was formed in 1995 to advise the B.C. government on the conservation needs of grizzly bears. The establishment of this committee was specified by the British Columbia Grizzly Bear Conservation Strategy, published in 1995 with a companion background report on grizzly bear conservation in B.C. (B.C. Government 1995*a*, *b*). The advisory committee met periodically for several years and in 1998 provided the government with a "Three-Year Report Card", which contained sharp criticisms regarding the lack of implementation of the Grizzly Bear Conservation Strategy. That same year, three independent bear biologists published a lengthy, critical review of B.C. bear management (Horejsi et al. 1998). Several similarly critical reports followed over the next few years by the same senior author (Horejsi 1999, 2000a, b) and others (deLeeuw 1997, 1998, 1999, 2001). Some criticisms relate to the implementation of the Grizzly Bear Conservation Strategy, while others simply oppose any hunting of grizzly bears.

M. K. Taylor, a polar bear biologist currently employed by the Nunavut Government conducted another review of grizzly bear hunting in B.C. Taylor produced but never finalized a draft report ("Social, biological, economic and political factors affecting grizzly bear hunting in British Columbia") for the Safari Club International. The draft report followed Horejsi et al. (1998) in criticizing the approaches taken to managing grizzly bears in B.C. and focused especially on problems in delineating populations and estimating population size. In contrast to other critical reports, Taylor's asserted that sustainable hunting was the quintessential indicator of a healthy population: only large, healthy populations can be hunted, whereas depleted populations must be totally protected. Taylor insisted that hunting should thus be the ultimate goal in grizzly bear conservation because it would ensure that populations are large enough to produce a yearly "surplus".

Apparently basing its actions on these criticisms and on the presumption that the hunt was not sustainable, in 2002 the European Union banned the import of grizzly bear trophies from B.C. to European Union member countries. The European Union took this action without knowledge that a scientific panel had been convened to review the management strategy for B.C. grizzly bears and without information directly from the B.C. government biologists responsible for managing the hunt. Following the submission of additional information from the B.C. government, the European Union reversed its decision pending the results of this Panel's review.

The terms of reference for the Panel are attached as Appendix I. The Panel's overall purpose was defined as follows:

> *"To conduct a review to ensure that hunting, as it is currently managed, does not threaten the long-term conservation of grizzly bears in British Columbia and, if necessary, to make recommendations for improvements to the existing harvest management regime."*

The Panel was asked to investigate and provide recommendations regarding the following three issues:

> *(1) the methods currently used to estimate grizzly bear populations in British Columbia;*
> *(2) provincial management strategies and harvest procedures regarding grizzly bear hunting; and*
> *(3) related issues deemed by the panel to be significant to grizzly bear conservation*

The specific mandate of the Panel focuses on strategies for managing hunting although under issue (3) the Panel is empowered to look at related issues. The Panel recognizes that hunt management is certainly not the only issue affecting the persistence of healthy populations of grizzly bears in B.C. Indeed, we recognize that habitat management (including managing road access) is likely to be of greater significance than harvest management to long-term grizzly bear persistence. Although we acknowledge the ultimate importance of habitat issues to grizzly bear persistence, the resources, information, and time allocated to address habitat issues were inadequate for us to do much more than acknowledge their importance. Analysis of the affect of habitat issues on grizzly bear conservation in B.C. will require a joint commitment from the Ministry of Sustainable Resource Management, Ministry of Forests, and the MWLAP.

In January 2002, the Panel presented an interim report consisting of an outline of the topics that would be covered in our final report.

C. Bear management in North America

1. Patterns and causes of bear declines in North America

During the exploration and colonization of North America by Europeans, grizzly bears were considered to be dangerous impediments to progress and were destroyed as public nuisances and threats. This attitude led to the extirpation of grizzly bears from 98% of their range south of Canada and from the eastern portion of their range within Canada (Mattson et al. 1987, Mattson and Merrill 2002). Declines in bear abundance continued south of Canada until grizzly bears were federally listed as a threatened species in 1975 under the US Endangered Species Act. As a consequence of recent protective measures, grizzly bears appear to have increased in portions of Montana (Glacier National Park and vicinity) and in the Yellowstone ecosystem. However, three additional small populations in northwestern Montana, northern Idaho, and Washington State have either declined or, at best, remain unchanged since early 1980. The historic decline in grizzly abundance in the

U.S. is also mirrored in the southern portions of their Canadian range in recent decades, especially in B.C.

In North America, Europe, and Asia, grizzly (brown) bears are likely to persist in greatest numbers in areas where management strategies give a high priority to the maintenance of naturally functioning ecosystems. Such places tend to be designated as national parks or wilderness areas where the maintenance of naturally functioning ecosystems is given a high priority for management. In areas where multiple uses such as human housing, agriculture, animal husbandry, and resource extraction (including logging) have a high priority, grizzly bear populations are typically more at risk than in areas where multiple use policy is not a priority. This pattern occurs not because grizzly bears are incompatible with these human activities but rather because humans conducting these activities are intolerant of grizzly bears and other large carnivores (McLellan 1998, Woodroffe 2001). Bears are killed in excess of sustainable levels because of the risks, or perceived risks, they pose. In spite of very intensive forestry practices, grizzly bears in Sweden have increased and expanded their range during the last several decades (Swenson et al. 1995). In part, this response may be due to the paucity of guns in the hands of those who use bear habitat for recreation (J. Swenson, personal communication to S.D. Miller, July 2002).

There is also significant evidence that grizzly bears may selectively avoid some areas where they are likely to encounter humans. This avoidance reduces the amount of habitat available to bears. For example, grizzly bears tend to select lowland foraging areas along riparian corridors preferentially in the spring (McLellan and Shackleton 1988, 1989, Schwartz et al. 2003). These are areas where phenology is most advanced and carcasses of winter-killed ungulates are most common. However, these habitats are also where roads are typically constructed and vehicular activity may dissuade bears from using the area (McLellan and Shackleton 1989, McLellan 1990).

2. Management principles used to restore grizzly bear populations

Where bear populations have been exterminated or have declined to precariously low levels, management efforts could focus on reducing human-caused mortality, restoring habitat, and augmenting or reintroducing bears. For the population of the Yellowstone ecosystem, management practices designed to minimize mortality pursuant to the closure of dumps in the early 1970s have resulted in increased numbers of bears and expansion into historical but recently unoccupied habitats outside of the designated recovery zone (Boyce et al. 2001). Changes in road management and other habitat improvements within the recovery zone have facilitated this improvement. In the U.S. Northern Continental Divide Ecosystem, similar efforts to reduce mortality and improve habitat conditions are correlated with an expansion of bears outside of the recovery zone into historical but recently unoccupied habitats

In contrast, small populations in the southern Selkirks and the Cabinet-Yaak in the U.S. and in the “North” Cascades of south central B.C. have remained stable or have declined during the same period. The failure of these populations to recover is likely due both to the small number of bears present and to a lesser emphasis on management because these

populations occur in habitats that are designated as multi-use and that do not include a National Park or large designated wilderness area as a focus for recovery efforts. The North Cascades in Washington State include these more intensely managed features but, so far, the grizzly bear population on the B.C. side of the border is too sparse to provide for re-colonization into Washington through natural dispersal. The small population in the Cabinet-Yaak was augmented by translocation of bears from Canada (Kasworm et al. 1998) and plans are underway to similarly augment bears in the North Cascades of B.C. Remnant populations of grizzly bears are difficult and expensive to rehabilitate (Servheen 1998). To date reintroduction of bears through translocation to areas of vacant but suitable habitat has not occurred in North America, although such reintroductions have been accomplished in Italy, France, and Austria (Clark et al. 2003). An effort to restore grizzly bears to two huge areas of designated wilderness in central Idaho and western Montana (Fischer and Roy 1998) is currently stalled due to political opposition. It is far easier politically and economically to maintain healthy populations of grizzly bears than to attempt to restore depleted or extirpated populations.

3. Methods of population estimation

Techniques to estimate the abundance of bears are typically imprecise, expensive and time-consuming. Specific methods vary based on the visibility of bears (i.e., a function of density and vegetative characteristics), available funds, and institutional and social constraints on activities such as capturing and marking bears. A number of investigators have used variations of mark-recapture techniques. The general procedure involves marking a known number of bears and then recapturing a sample to obtain an estimate of the proportion of animals marked. Some investigators have used photographic samples as the "recapture" (Garshelis et al. 1993, Mace et al. 1994, Martorello et al. 2001). A mark-resight approach with radio-collared bears was developed and widely used in Alaska, where relatively open habitats enabled investigators to see bears from the air (Miller et al. 1998). Currently, Alaskans are experimenting with a double-blind method of survey that uses differences in number of bears sighted by independent observers in the same aircraft to estimate the number of bears missed (E. Becker personal communication; Crête et al. 1991). This technique may not be practical in forested habitats because of low visibility.

Mark-recapture or resight estimates are generally limited by costs to areas smaller than a harvest management area. This limitation results in a necessary extrapolation from the area where the research was conducted to a larger geographic area, thus introducing subjective judgment and the potential for error. Results of mark-recapture studies also may be biased by a failure to meet assumptions associated with the models used to estimate population size. Such biases are seldom measured, often because they are not measurable.

Currently, there is no practical method for estimating bear numbers in an area as large as B.C. In Minnesota and part of Michigan, a direct estimate of the number of American black bears was accomplished by marking bears with tetracycline ingested from systematically situated bait stations and then examining bones and teeth from hunter-harvested bears to estimate the proportion of the population that had been marked

(Garshelis and Visser 1997). This method would be inappropriate for B.C. grizzly bears because the density of bears is too low to mark an adequate sample and the number harvested is insufficient to obtain a reliable estimate of the proportion of animals marked.

Population estimation techniques based on hair samples snagged from barbed wire were developed in B.C. (Woods et al. 1999, Mowat and Strobeck 2000, Boulanger et al. 2003) and have become widely utilized for a number of species, including both grizzly and black bears. DNA from these hair samples is analyzed to differentiate individuals. These data can be used to generate population estimates without the need to physically capture and mark bears. A common problem with this technique is correctly identifying the geographic area utilized by bears from which hair samples were obtained (Boulanger et al. 2003). To calculate density, the surveyed area must be identified correctly. Potential problems also exist with analysis of the DNA, which can result in misidentifying hairs from the same individual as being different or misidentifying different individuals as being the same (Waits 2002). Finally, some age groups, like cubs-of-the-year may be under-represented in the DNA samples.

A large-scale application of the hair snaring technique was conducted in the northern portion of the Northern Continental Divide Ecosystem during 1999-2001 (K. Kendall unpublished data). An effort is currently being planned to estimate the number of grizzly bears in the entire U.S. Northern Continental Divide Ecosystem (24,800 km^2, 9,600 mi^2) utilizing hair snaring and subsequent DNA analysis techniques. Preliminary planning for this effort indicates that it will cost $2.5-$3.0 million (US$). Because of these high costs, in B.C. and elsewhere, estimates for metapopulations of bears are usually derived by subjectively extrapolating density estimates from small study areas (typically <1,000 km^2) to larger management areas.

In the Yellowstone Ecosystem, estimates have been obtained from unduplicated sightings of females with cubs-of-the-year (Knight et al. 1995), adjusted upward to account for the proportion of the population other than females with young cubs (US Fish and Wildlife Service 1993). However, this method is used more as an indicator of population trends than as an estimator of population size.

4. Methods of trend assessment

Methods for assessing trends in grizzly bear populations are perhaps even more poorly developed than the procedures for estimating populations. Harris (1986a) reviewed early population and trend assessment methods for grizzly bears. There have been attempts to estimate trends in black and grizzly bears using unduplicated counts of females with newborn cubs, counts along salmon streams and other concentration sites, track counts, bait station visitation, the frequency of nuisance bear complaints, and analysis of harvest data (number and sex/age composition). Trends also have been estimated by comparing sequential population estimates obtained by one of the techniques discussed above (e.g., Miller 1990b, Reynolds 1997). Probably the most widely used trend indicator is analysis of the sex and age composition of the harvest. These data may be useful as signals of abrupt or long-term population change (Harris and Metzgar 1987b) but results are

frequently ambiguous and subject to conflicting interpretations (Garshelis 1993) and confounding factors (Noyce and Garshelis 1997).

5. Concept of sustained yield

Sustained-yield harvesting refers to the concept that, after an initial adjustment period, systematically removing a certain number of individuals (the yield) from a population of animals will not cause a permanent reduction in the population size. Sustained yields are possible whenever the number of births into a population exceeds the number of deaths. Immigration may act to increase sustained yields (conceptually equivalent to increasing births), while emigration (equivalent to deaths) will decrease sustained yields.

By definition, populations that are held stable by environmental constraints and that exist at the carrying capacity (KCC *sensu* Macnab 1985) of their environment have no sustained yield because births and deaths are balanced. If animals are removed from such a population, then the population will decline, but theoretically a sustained yield will become available because, at this lower population size, more food (or other limiting factor) will be available per capita, enabling the population to grow. The sustained yield is equal to the amount by which the population would grow -- the difference between births and deaths -- assuming a nonselective harvest regime. Whereas birth rates continue to increase and death rates decline as populations become lower, the population size that will support the largest sustainable yield will vary with the nature of the density-dependent relationships for that species or population. If the relationship is linear (for every unit of increase in density there is a corresponding decline in natality or increase in mortality) then maximum sustained yield (MSY) will occur at exactly ½ KCC. If density-dependent effects are non-linear (e.g., disproportionately more mortality or less reproduction the closer the population is to KCC) then MSY will occur somewhere between ½ KCC and KCC. Bears and other long-lived species exhibit non-linear density functions. In these species, the highest sustainable harvests will occur at densities close to the carrying capacity of the environment.

The effects of harvests on population growth rate depend on whether removals are mainly additive or compensatory. Compensatory harvests occur when the harvest mortality simply replaces, rather than adds to, natural mortality. Obviously, managers desire to maintain populations of sufficient size that harvest mortalities are more compensatory (due to density changes) than additive. Assuming that bears have non-linear density dependent functions, then harvest will have more compensatory potential near KCC and more additive effects well below KCC. Taylor (1994) and Taylor et al. (1987) suggested that for bears, MSY might occur in the range between 75% and 90% of KCC. However, no empirical data exist for bears on the location of MSY with respect to population size.

6. Estimation of sustainable harvest

A model involving the sustained yield concept discussed above may be used to estimate sustainable harvest rates, and then these rates can be applied to a population estimate to obtain an estimate of sustainable hunting mortality. Outputs from such models vary with

the assumptions used. The B.C. government relies on results of a modeling exercise performed by Harris (1986b) that estimated maximum sustainable harvest mortality at 6%. This model used reproductive and mortality rates believed typical of "southern interior" grizzly bear populations and included density-dependent effects resulting from the increased survival of young in response to the removal of males. Miller (1990a) estimated the maximum sustainable harvest of Alaskan grizzly bears at 5.7% based on a model that did not include density-dependent effects. In all likelihood, differences between models used to estimate sustainable harvest rates for bears are insignificant compared to the typical magnitude of error in estimates of total population size. We note, however, that both the Harris and Miller models did not consider the effect of sampling error on the estimations of population size or demographic parameters on the estimated harvest rate.

7. Assessment of harvest data

Reliable information on the number and sex and age composition of harvested bears is an important component of harvest management for bears although these data seldom yield unequivocal interpretations. A decline in the mean age of harvested males, for example, can be interpreted as either a young expanding population or as a population harvested so heavily that few old males remain. Considering that males are generally more vulnerable to harvest than females, a shift to a higher proportion of females in the composition of the harvest may be an indicator of over-harvest, which should raise concerns on the part of the managers (Harris and Metzgar 1987a,b). Taylor et al. (1987) demonstrated that harvest rates of adult female polar bears had the greatest effect on growth rates of populations. Grizzly bears have life histories very similar to polar bears and are doubtless equally sensitive to the exploitation of adult females. For this reason, it is prudent to set specific harvest quotas for adult females.

Information on the location of the kills may be useful in assessing how clustered the harvest is. Populations where harvests are highly clustered may be more resilient to widespread over-harvests, but more susceptible to localized population depletions. Also, areas where harvests are highly clustered are likely to show sex and age composition patterns that are less representative of the whole population and from which it will be more difficult to infer trends based on harvest data.

8. Significance of human-induced changes in habitat

Human-induced changes in habitat for grizzly bears may affect the availability of food for bears and their rates of reproduction and mortality, or they may affect mortality directly through increased vulnerability to killing by humans (legal or illegal). Some human-induced habitat alterations may result in increases in natural foods such as berries, fish, carrion or prey. Conversely, many changes such as road building or other development activities, which result in increased human presence, reduce the amount or accessibility of food resources and increase the potential for direct killing (McLellan 1989b, 1998, McLellan and Shackleton 1988, Mace et al. 1996, 1999). Some actions can cause both positive and negative effects, the net result of which may be difficult to assess. For example, elk hunting in areas surrounding Yellowstone National Park produces gut piles

available to bears. These gut piles are an important food source that attracts bears from within the park, but this attractant puts an increased number of bears in proximity to hunters. Similarly, decommissioning roads in managed habitats can reduce human-caused mortalities to bears.

9. Role of refugia

Refugia that are not hunted can be an important component in managing bear populations or sustainable harvests. There are many uncertainties associated with estimating bear abundance, population trends, and sustainable harvest rates. These uncertainties mean that errors leading to localized over-harvests are likely to occur even when harvests are designed to be conservative. Refugia that are closed to hunting, where bears occur at near carrying capacity, can be important sources of emigrants that can buffer over-harvesting in surrounding areas. The importance of refugia is illustrated by the increasing number of bears in the Greater Yellowstone Ecosystem, which is centered on Yellowstone National Park, and in the Northern Continental Divide Ecosystem which is centered on Glacier National Park in the U.S. and Waterton National Park in Canada. Human-caused mortalities (unrelated to bear hunting) still occur in and along the border of these refugia. However, intensive efforts to reduce bear mortalities in these two ecosystems have enabled grizzly bear populations to expand into recently unoccupied habitats adjacent to the refugia (Gniadek and Kendall 1998).

A key consideration of refugia is their size. For example, grizzly bears in the Cabinet-Yaak, Selkirks, Purcells, and North Cascades have declined in recent decades even in the absence of sport hunting. Small refugia may not only be inadequate for sustaining nearby hunted areas, but also may be depleted by nearby over-hunting. Studies suggest that many small, isolated populations are more prone to extinction than larger populations occupying the same total area (Brown 1971, Bolger et al. 1991, Woodroffe and Ginsberg 1998). Establishing buffer zones around protected areas and connectivity between protected areas enhances the probability of long-term persistence (Beier 1995, Woodroffe 2001).

10. Costs of research associated with managing bears on a sustained basis

Research is an essential component of grizzly bear management in an environment where significant habitat changes are occurring and where a great deal of uncertainty exists in estimates of population parameters. Habitat changes that mandate an active research program include logging and other activities that fragment habitat and/or increase bear mortalities. In more stable habitat conditions, it may be possible to set conservative bear harvest quotas, but periodic monitoring of population status will still be necessary to evaluate the effectiveness of the management program.

Even more difficult is managing harvests near the maximum sustained yield, because of the increased risk of over-harvest. In this case, very reliable habitat and demographic information is needed to ensure long-term conservation. For rare and wide-ranging species like grizzly bears, obtaining such information is exceedingly costly. Moreover, obtaining such information may necessitate the development of new techniques.

Management agencies must weigh this high cost of management against the benefits of harvesting at the chosen level; it is legitimate to question whether such harvesting is worthwhile. An ironic benefit of harvesting is that it prompts agencies to conduct research and monitoring that they otherwise might not do; some non-harvested bear populations may be in jeopardy from human-imposed alterations to their habitat but monitoring of these populations is often inadequate.

D. Overview of management of grizzly bears in B.C.

1. Historical perspective

The grizzly bear in B.C. holds recreational, economic, and cultural significance for the people of the province. A status review of grizzly bear populations and habitat by the Committee on the Status of Endangered Wildlife in Canada suggested that the province contained half of Canada's remaining grizzlies (Banci 1991, Banci et al. 1994). Grizzly bears were an important part of the culture of natives living in B.C. prior to European settlement (Hamilton and Austin 2001) and remain an important cultural symbol to native (First Nations) people.

B.C.'s total land and freshwater area (950,000 km^2) comprises approximately 10% of Canada's land surface. B.C. has a wide variety of landscapes ranging from temperate wet mountains on the coast to drier interior mountains and plains. Historically, grizzly bears have occupied the entire province except for Vancouver Island, the Queen Charlotte Islands, and other smaller coastal islands (Hamilton and Austin 2001). Grizzlies still occur in about 80% of the province. The B.C. government currently estimates that there are about 14,000 grizzlies occupying a land area of 744,000 km^2 (Hamilton and Austin 2001). Hamilton and Austin (2001) reported that grizzly bears have been extirpated from 11% of their historical range in B.C., corresponding to concentrations of private land, high road densities, and human population centers.

Seasonal distribution of grizzly bears in the province is influenced by distribution of food, including salmon in coastal areas, ungulates, and smaller prey such as beaver, marmots, ground squirrels, forbs, berries, whitebark pine nuts and skunk cabbage (Hamilton and Austin 2001). This broad range of food sources periodically brings the grizzly in contact with humans. Fortunately, low road density and low human populations characterize most of the province, enabling it to support viable grizzly populations. Less than 10% of the province's land can be used for grazing or cultivation, while nearly 75% is covered with forests. The fact that more than 90% of B.C.'s forest lands are publicly owned and managed by the provincial government ensures that the management of bear habitat will be a matter of public concern.

Human demographics are changing in B.C. According to the 2001 census, B.C. was the third fasting growing province in Canada, increasing 4.9% between 1996 and 2001. The 2001 population of B.C. was tabulated at 3.9 million, with 85% of the population occupying urban areas in the southern and south-central mainland and Vancouver Island. This area of high human occupancy corresponds to the area within the province where

grizzlies have been extirpated or significantly reduced. In contrast, the northern and Kootenay regions registered human population declines during the last five years and the persistence of grizzly bear populations and their habitats in these areas seem more secure. However, with further expansion of human activities the economy of the province will continue to grow, bringing more pressure on grizzly bear habitat and more opportunity for human-caused mortalities.

Attempts to regulate hunting of grizzly bears have occurred throughout most of their range in the province for at least 150 years. Grizzly bear management has involved specific harvest regulations, enforcement of regulations, and measures of habitat protection on private and public lands. Because of concerns over the perceived over-harvest of local populations, the province imposed more conservative hunting regulations beginning in the mid to late 1960's. By 1968, hunting with the use of bait was prohibited, seasons in the southern two thirds of the interior of the province were either closed or opened only during the spring and females with young and their young were protected by law. By the mid-1970s, the province had begun limited entry hunting (LEH) in selected areas in the southern portion of the province.

In 1996, all grizzly bear hunting in the province had been placed under a limited entry system (LEH; B.C. Government 1995b). Recently, 1200 to 1400 provincial residents and 500 to 700 non-residents annually have purchased grizzly hunting licenses (B.C. Government 1995a). Non-resident hunters support an economically important guide/outfitter business (Guide-Outfitters Association of British Columbia 2001). The B.C. government (1995a) estimated that resident and non-resident hunters spend $2.83 million annually. Bear viewing is also considered an important non-consumptive use of grizzly bears and a growing group of licensed guide/outfitters are providing bear viewing opportunities.

2. Grizzly bear conservation strategy

The MWLAP controls grizzly bear management policy in B.C. under the British Columbia Grizzly Bear Conservation Strategy (B.C. Government 1995b). The Conservation Strategy identifies four management goals:

- To maintain in perpetuity the diversity and abundance of grizzly bears and the ecosystems on which they depend throughout British Columbia.
- To improve the management of grizzly bears and their interactions with humans.
- To increase public knowledge and involvement in grizzly bear management.
- To increase international cooperation in management and research of grizzly bears.

To accomplish the first management goal, the Conservation Strategy calls for establishing grizzly bear management areas that are closed to harvest and managed to ensure long-term survival of the bear population. Conceptually, the grizzly bear management areas would be relatively large, intact ecosystems that would be managed to protect the population and its habitat (B.C. Government 1995a). The MWLAP must coordinate implementation of these goals with other provincial ministries, primarily the Ministry of Forests and the

Ministry of Sustainable Resource Management. While a number of potential grizzly bear management areas have been identified, none have been protected to date. Approximately 6% of the province is protected by provincial parks that are permanently closed to grizzly bear harvest.

To meet the second goal, the Strategy calls for the appointing a Grizzly Bear Scientific Advisory Committee to advise the provincial government on the conservation of grizzly bears; increasing research on grizzly bear ecosystems; changing all grizzly hunting to LEH; and establishing a Habitat Conservation Fund to help pay for grizzly bear research. The strategy also calls for increased enforcement to deal with violations of the British Columbia Wildlife Act, and increased penalties for violations.

To meet the third goal, the Strategy calls for a comprehensive environmental education program to increase public awareness about grizzly bears, bear safety, and ways to avoid bear/people conflicts. The Strategy also includes the development of policies to minimize conflicts between people and grizzly bears, including regulations to dispose of garbage and other food attractants. The Strategy encourages partnerships with the private sector to help promote the conservation needs of grizzly bears.

To accomplish the goal of increasing international cooperation, the Strategy calls for cooperation of all jurisdictions where grizzlies occur. The province has allowed its biologists to participate in international scientific organizations (e.g., IBA), and to pursue discussions with the U.S. regarding grizzly bear management in populations shared by both jurisdictions. The province signed an agreement with the Interagency Grizzly Bear Committee in 1986 to coordinate management of shared populations; this cooperative effort is still in place.

3. Genetic considerations

Genetic variation associated with small populations is an important consideration in wildlife management. Shaffer (1987) summarized the extensive information on the principles of genetics (e.g., Soulé and Wilcox 1980, Frankel and Soulé 1981, Schonewald-Cox et al. 1983) relative to population viability. Preliminary information on genetic variation in grizzly bears (Knudsen and Allendorf 1985) enabled Shaffer (1986) to evaluate the implications of genetic variation on both short and long-term population viability. He concluded that a population of approximately 50 effective breeding adults and 500 total individuals was necessary to maintain short-term genetic viability and long-term adaptation, respectively.

These estimates of population viability were based on simulations of population persistence over >100 generations. It is important to recognize that these estimates of viability based on population size should not be used as a basis for concluding that small populations are inevitably doomed and efforts to preserve them without merit. Small populations have persisted in central Italy for many decades and four small populations in Sweden have expanded into a population of about 1000 bears over the last half century. Similarly, the population in Yellowstone National Park and surrounding areas was

reduced to <300 individuals in the late 1960s but has increased about two-fold. Grizzly bear populations numbering less than 50 have persisted for decades in the Cabinet-Yaak and southern Selkirks, and in the Himalayas of the northern territories in Pakistan. Unquestionably, populations of less than approximately 100 bears should be considered highly endangered but no population is too small to make recovery efforts inherently futile from a genetic standpoint. The healthy population of grizzly bears on Kodiak Island exhibit low levels of genetic diversity (Paetkau et al. 1998).

The province's policy is to protect small populations, particularly isolated ones, from harvest, in part because of the importance of genetics in the management of grizzly bears. Recently, Proctor et al. (2002) documented what appears to be genetic isolation due to habitat fragmentation in southern B.C.

4. Current regulations (seasons, reporting, bags, guides, administrative structure)

The MWLAP administers the B.C. Wildlife Act through biodiversity and wildlife programs in Victoria and in seven regions. Hamilton and Austin (2001) discussed B.C. grizzly bear harvest management. In addition to the Conservation Strategy, management of the grizzly bear harvest is influenced by the policies contained in the Wildlife Harvest Strategy (B.C. Government 1996) and guided by the Grizzly Bear Harvest Procedure (B.C. Government 1999).

Population management is accomplished through a combination of limited entry hunting seasons, agency control of problem bears, and area closures. Under the LEH system, an allowable harvest is estimated for each LEH zone and hunting authorizations based on the allowable harvest are issued as guide-outfitter quotas and to First Nations. Resident hunters apply to a lottery for authorizations. The number of authorizations available for each area is established by the Director of the Fish and Wildlife Recreation and Allocation Branch in consultation with regional staff. Non-residents must hunt with a licensed guide-outfitter. Guide-outfitter quotas as well as allocations to First Nations are established by the regional managers of environmental stewardship based on recommendations from regional staff. The annual bag limit for grizzly bears is one. Grizzly hunting is closed in all national parks and some provincial parks.

In the southern interior of B.C., grizzly hunting is limited to spring seasons. In northern and coastal areas, hunting occurs during both spring and autumn. Hunting is closed indefinitely in 24%, and temporarily in another 13% of the species' historic range (Hamilton and Austin 2001).

Annual harvest is determined through compulsory inspection of all legally harvested bears. Hunter success and hunter effort are tracked through guide-outfitter reports and a LEH questionnaire.

The province uses an array of area designations for grizzly bear management including wildlife management units (MU), grizzly bear management areas (GBMA), grizzly bear population units (GBPU), and limited entry hunting (LEH) zones. The GBPU is the

planning unit and the MU and LEH are harvest allocation units. The MU system is a common set of management units used for all big game species. The GBPU areas are considered sub-populations of bears and serve as the units for setting population objectives and determining mortality thresholds and are considered during strategic land use planning (Hamilton and Austin 2001). Originally the boundaries of the GBPUs were a combination of MU boundaries and natural features (e.g., representing potential barriers to the movement of bears between units). However, to resolve inconsistencies with the already well-established administrative boundaries of the MUs, the GBPU boundaries were modified to coincide with MU boundaries where they differed. Currently the GBPU consists of one or more MUs, and the MUs consist of one or more LEHs; however, a few LEH zones include all or portions of more than one MU (M. Austin, personal communication).

Wildlife managers determine the allowable grizzly bear harvest based on an estimate of population size derived from the estimate of the number of bears the habitat in particular area should be capable of supporting, modified through the application of the Fuhr-Demarchi (1990) step-down process that incorporates evaluations of habitat condition and past human-caused mortality. Based on this estimate of population size and an estimate of allowable harvest, managers ultimately make a recommendation for the number of licenses available for grizzly bear hunting, which are adopted through the provincial process for establishing regulations. Generally, harvest allocations are designed to meet GBPU-specific objectives, which are usually to maintain or increase the current number of bears, unless high levels of human-grizzly bear conflicts indicate that bear numbers should be reduced. The overriding parameter controlling harvest is total allowable human-caused mortality, particularly female mortality. Harvest is allocated for three-year periods and is evaluated annually.

5. Educational program

The province's Grizzly Bear Conservation Strategy calls for a comprehensive educational program for intermediate and senior secondary level students. The Strategy also calls for an effort by the general public in the area of bear safety, waste management, bear ecology, and current wildlife regulations. The Strategy calls for delivery of this program through the existing education programs, Project Wild, and The Green Team. A Grizz Ed program was launched in 1997 and included a traveling educational team for grade 4-7 students. Project Wild includes a grizzly bear biology program, that began in 1998. The program is available for sale to teachers and delivered through workshops. The province and the Vancouver Grizzlies professional basketball team introduced an educational program for high school students in 1999.

In June of 2002, the province developed a community based program called Bear Smart that is intended to reduce conflicts between bears and people. Designed for communities and municipalities in bear country, the program certifies communities as Bear Smart when they have met specific standards. The MWLAP recently provided a one-time grant of $290,000 for the province-wide Bear Aware program and another $10,000 for the

Northern Bear Awareness Program in Prince George. Funding for the Bear Smart program came from surcharges on all black and grizzly bear hunting licenses.

II. METHODS

A. Review of written information

A substantial body of literature directed at grizzly bear conservation in B.C. is available from agency and non-governmental sources. The Panel became acquainted with the issues through meetings with personnel of the MWLAP, discussions with groups and individuals, and the acquisition of pertinent reports and publications. Particularly key was a background report (Hamilton and Austin 2001) and an associated oral presentation on the methods of population estimation and harvest allocation that the MWLAP presented to us shortly after the Panel was established, and a self-critique presented to us both orally and in written form (Austin and Hamilton 2002) in April 2002.

The Panel met five times during the review. We meet three times in Victoria, B.C. (9-10 October and 7-8, December 2001 and 23-26 April 2002), once in Spokane, Washington (30-31 January 2002), and once in Missoula, Montana (7-11 October 2002). We also consulted via conference calls and email.

The Panel requested written input from individuals and groups that have expressed concern about grizzly bear management procedures in B.C., and from scientists who have worked on grizzly bear management and research in B.C. In response to these requests, we received an array of materials from several groups and individuals, including reports critical of B.C. grizzly bear management. The published and unpublished literature relating to bear management in B.C. used in our review is cited herein or listed in section VII.

The Panel circulated an interim report in February 2002. The report briefly summarized our purpose and approach and provided a detailed outline of this report. The Panel anticipated additional comments as a result of the circulation of this interim report and we invited written comments and testimony pertinent to our mandate.

B. Independent analyses

In addition to reviewing the published and unpublished literature, we completed several independent analyses.

1. Fuhr-Demarchi population estimation and calculation of allowable harvest

Our review of the Fuhr-Demarchi models and the calculations of allowable harvest were restricted to a conceptual review of the method, as spreadsheets for individual populations were unavailable.

2. Harvest data and harvest strategies

The Panel analyzed numerical harvest data organized at the level of management units (MUs). Typically, numerous MUs needed to be combined to obtain sufficient numbers of killed bears to enable us to perform a meaningful analysis. We did not analyze data based on actual point locations of reported kills. These data were offered to the Panel but we considered analysis at this level of detail to be unproductive.

3. Risk assessment in grizzly bear management

We assessed the degree of risk associated with provincial harvest management strategies for selected grizzly bear populations using model-based "population viability analyses" (Boyce 1992). We did this in collaboration with Dr. Philip D. McLoughlin, Department of Biological Sciences, University of Alberta, Edmonton. The report of McLoughlin (2003) has been submitted to the B.C. government as a companion to this report. The report focuses on three objectives: i) the relative contribution of error in initial population size versus error in demographic parameters to risk of population declines, ii) an assessment of thresholds of human-caused mortality on the viability of grizzly bear populations, and iii) risks of population decline for grizzly bear populations based upon documented population sizes, documented harvest rates, and vital rates assumed for each targeted population. Appendix II provides a summary of this work.

4. Trends in habitat

Habitat information for British Columbia was acquired from publications, reports, and unpublished documents. Interviews with biologists, guide-outfitters, foresters, and other people knowledgeable about grizzly bear habitats provided information not available in the written record. Correspondence with the B.C. Ministry of Forests provided essential information on forest management and the legal and administrative basis for land management that affects grizzly bears.

III. RESULTS AND DISCUSSION

A. Population estimation

1. Historical overview

Population estimates are the foundation for the management of B.C. grizzly bears. For this reason, government estimates have raised substantial contention among critics and concern among those interested in ensuring perpetuation of viable grizzly bear populations. Hamilton and Austin (2001) discussed B.C. grizzly bear harvest management, including population estimation procedures. This information is briefly reviewed here.

The first official estimate of grizzly bear numbers appeared in the MWLAP's (1972) Management Plan. Based on subjective assessments of bear density in different physiographic areas, the total provincial population was estimated at 5000–8000 bears (Spalding et al. 1972). At about this same time, Cowan (1972) reported 6800 grizzly bears in B.C., noting that this population size was "estimated by the author". A very similar estimate of 6600 bears was produced in 1977 by Blower (1977), inventory biologist for the MWLAP. This value was derived by extrapolating density estimates, ranging from 2–19 bears/1000 km^2, to different geographical areas based on topography and climate. The similarity of these three estimates may not be coincidental given that the people responsible for them probably corresponded with each other and also relied on the same baseline information, including grizzly bear literature that was available at the time.

Grizzly bear studies in the early 1970s provided estimates of about 25-45 bears/1000 km^2 for unhunted grizzly bear populations in inland North America (Mundy and Flook 1973, Martinka 1974, Pearson 1975, Dean 1976). These early estimates were generally derived from counts of bears, sightings of unmarked bears, or sightings of unmarked bears combined with telemetry records; inasmuch as some bears were undoubtedly not counted and some were counted more than once, these estimates could have been biased, but to an unknown degree or direction. Moreover, these researchers (except Pearson) generally ignored the issue of geographic closure (i.e., movements of bears in and out of the delineated area for which density was estimated), which would inflate their estimates of density. Adding to the confusion, these reports generally did not clarify whether cubs or other dependent young were included in the estimates. For these reasons, we do not consider estimates of grizzly bear density from this period of time (pre-1980s) reliable.

More recent estimates of total bear numbers in B.C., based on different methodologies, are significantly higher. This increase represents only a revision in the estimate, not a change in population size. It is certainly worth examining whether the revised estimates are reliable (see below). However, we take issue with critics who continue to endorse estimates of about 6000 bears (or even 4000), based on long-defunct data, claiming that such values are just as likely as the newer estimates. The only basis, insofar as we can discern, for these low values are the old estimates, which are biologically unrealistic in that populations that low could not have sustained the decades of known harvest that have already occurred. Although these low estimates — which have been widely cited in the public media — make an appealing argument for those concerned about over-harvests of bears and inherent uncertainties in bear management, they do little more than unfairly muddle the picture. If these old estimates had been higher than current estimates, it is likely that they would have faded from memory, which should be the situation in any case.

2. Population estimates from recent telemetry projects

As mentioned above, early researchers produced density estimates by tallying bears that were seen or captured in a specified area. If all bears are accounted for, one obtains an estimate of the number that are using an area (i.e., the "superpopulation" *sensu* Kendall 1999), but bear densities will be over-estimated because the tally represents a cumulative sum over time rather than the number of bears simultaneously present within the area

(Eberhardt 1990a). For example, McLellan (1989a) figured that Russell et al's (1979) estimate of grizzly bear density in Jasper National Park, Alberta, was overestimated by 100% because they did not account for bears being only part-time residents of the study area. McLellan's (1989a) own density estimate for the Flathead River Valley of southeastern B.C. accounted for part-time residency by weighting bears by the proportion of their home range within the selected study area (i.e. by summing "bear-equivalents"). Home range data were collected using radio telemetry. Wielgus et al. (1994) used data on radio-collared animals to estimate grizzly bear density in the B.C. portion of the Selkirk Mountains, but they did not apply McLellan's weighting scheme and hence likely obtained a biased estimate.

McLellan's (1989) and Wielgus et al.'s (1994) density estimates were both based on the assumption that all bears that used the study area extensively were caught and radio collared. In McLellan's study, some uncollared bears were seen in the study area, but because they were not collared, he could not determine whether they used the area very much; however, he did not catch these animals during the course of many years of trapping, so he concluded that they did not spend much time there and hence did not contribute much to the density of bears.

MacHutchon et al. (1993), in contrast, added uncollared bears into their population estimate for the Khutzeymateen Valley of coastal B.C. They saw and photographed (using remote cameras) bears frequently enough to distinguish many individuals that were not collared, thereby obtaining an estimate of the minimum number present. However, they had trouble generating a meaningful density estimate because they did not determine the bears' proportional use of the study area; such a determination was especially difficult due to seasonal and sex-specific movements, which caused real fluctuations in bear density.

Like MacHutchon et al. (1993), Raine and Riddell (1991) based their estimate of grizzly bear numbers in Yoho and Kootenay national parks on a combination of collared bears and sightings of unmarked bears. They tried to take into account the percentage of time the bears resided in the designated study areas, but their sample of collared bears was too small to do this effectively. Moreover, since they relied on second-hand reports of bear sightings, their estimate of the number of unmarked bears was prone to significant error.

Mark–recapture methods were devised specifically to provide a rigorous estimate of numbers of unmarked animals, thus avoiding the assumption that nearly every animal was accounted for (i.e., captured or seen). The basic methodology involves capturing and marking a sample of animals and subsequently obtaining a second sample to determine the proportion of the population that was marked. Garshelis (1992) incorporated bear-weightings, like those used by McLellan (1989a), into a mark–recapture procedure to obtain density estimates for American black bears. Like McLellan, he found that mark–recapture density estimates obtained using unweighted values were significantly inflated. For animals like grizzly bears, with home ranges that approximate or exceed the size of most study areas, unweighted density estimates may be severely inflated because many animals spend significant time outside the designated area. This problem, referred to as a

lack of geographic closure, has unfortunately not been adequately dealt with in many mark–recapture bear studies. In Alaskan grizzly bear population studies, closure was corrected for using a modification of the mark–recapture approach wherein radio-collared bears were resighted instead of recaptured (Miller et al. 1997).

There is at least one other important consideration in population estimation that, until recently, has not drawn adequate attention: basic mark–recapture procedures assume that marked and unmarked animals have equal probabilities of being recaptured or resighted. Variation in the probability of being caught or seen, due for example to sex, age, individuality, or habitat occupied, can bias population estimates. Some mark–recapture models make adjustments for this variation (Boulanger et al. 2003, Taylor et al. 2003), but until very recently such adjustments could not be included coincident with adjustments for lack of geographic closure. Future studies can take advantage of these improvements in the collection and analysis of mark–recapture data.

3. Population estimates from hair-sampling projects

Major initiatives to estimate grizzly bear density in B.C. have been conducted since the mid-1990s using DNA-identified hair samples collected at baited sites within a grid. This method was first employed on a study site in the upper Columbia River Basin near Golden during 1996–98 (Woods et al. 1999). Over a dozen additional DNA-based studies have been conducted in B.C. since then, although not all of them yielded useable density estimates (Boulanger and Hamilton 2002).

Boulanger and McLellan (2001) devised a non-telemetry-based method of adjusting DNA-derived population estimates for lack of geographic closure. They delineated a core group of bears that mainly resided on the study area grid; these were bears whose average location (based on visits to hair snag sites) was in the central part of the grid. Some of these "core bears," however, likely made occasional movements off the grid, but in the absence of radio collars, such temporary movements cannot be detected. Hence, the method probably underestimates the true extent of movement off the grid and thus may overestimate density (although results of the method have never been compared to those adjusted using data from radio-collared bears).

4. Development of Fuhr-Demarchi population estimation

Research projects produce estimates of grizzly bear numbers for small study areas. To manage bears over larger areas, B.C. biologists developed a method to estimate bear density from knowledge of the existing habitat, based upon the ecological land classification system. This method was initially employed by Ben van Drimmelen in the mid-1980s, but formalized by Brian Fuhr and Dennis Demarchi in 1990 (Fuhr and Demarchi 1990). It has since come to be called the Fuhr-Demarchi (F-D) method. Similar habitat-based techniques have been used elsewhere to estimate population size and to calculate allowable harvest levels (Berg et al. 1983).

The F-D method is based on the premise that animal density is related largely to habitat capability, so if one knows enough about the habitat requirements of a species, then conceivably one could roughly estimate the carrying capacity by examining the habitat conditions of the landscape. Accordingly, the accuracy of such estimates of carrying capacity would be related to knowledge of habitat requirements and habitat availability and the ability of experts to scale density to habitat. Other potentially confounding factors include seasonal and yearly fluctuations in availability of food and inter- (e.g., black bear) and intra-specific competition and predation.

The map scale used to assess habitat availability is another confounding issue related to this technique, and has been the subject of criticism (Horejsi et al. 1998). As the scale of a habitat map becomes finer, small patches of very good and very bad habitat become more visible, so the range of animal densities increases. Whereas only a three-level ranking of habitat capability — high, moderate and low — might be discernible on a very coarse map scale, greater habitat resolution on a finer map scale might enable rankings above and below these. The MWLAP has finer-scale habitat mapping for grizzly bears in some areas of the province that has not been used to develop population estimates.

At the time Fuhr and Demarchi (1990) reported their method for estimating numbers of grizzly bears, several grizzly bear studies (besides those already cited above) had been conducted. MWLAP staff considered available information on grizzly bear density from other jurisdictions but chose McLellan's (1989a) density estimate from the Flathead Valley as the only "benchmark" value. McLellan provided not only a density estimate and detailed habitat maps, but assisted in developing the F-D method.

Since that time, the F-D density estimates have been rescaled, due to updated information from the Flathead (McLellan 1994, B. McLellan, personal communication), plus MacHutchon et al.'s (1993) density estimate from the Khutzeymateen. Both of these studies yielded estimates of grizzly bear densities that were believed to represent the high end of the scale, falling in the range of 75–100 bears/1000 km^2. From that starting point, a scaled progression of lower densities was established and matched to habitats that were considered less productive for grizzly bears. It is an acknowledged weakness(Austin and Hamilton 2002) that no other benchmark areas were available to calibrate the density ranking scale, especially none with lower grizzly bear densities. The five-level scale that was developed (75–100, 50–75, 25–50, 5–25, and 1–5 bears/1000 km^2) was based on expert, but subjective opinion. Importantly, this scale represents potential carrying capacities in the absence of human impacts (termed "habitat capability"), not actual densities of bears.

5. Application of Fuhr-Demarchi estimation of habitat capability

The MWLAP uses base maps for the province that combine the Biogeoclimatic Ecosystem Classification (BEC, Pojar et al. 1987) with the Ecoregion Classification (EC, Demarchi et al. 1990). The BEC scheme groups together areas with similar climate, soils and vegetation into 14 zones, which are further divided into subzones, variants, and phases. The Ministry of Forests created and maintains BEC maps for the province.

Because of its mission, the Ministry of Forests focused its early data collection and mapping efforts on commercial forests. The data used to create the BEC maps are continually updated, now including information on non-forested areas (grasslands, wetlands, and alpine) and forests with little commercial value. Updates are based on field sampling, air photo interpretation, over flights and professional judgment.

Province-wide habitat categorization for the F-D process is currently performed using small-scale maps (1:500,000 and 1:250,000). The original F-D description referred to medium-scale mapping (1:50,000–100,000) for finer habitat categorization, including seasonally scaled habitat rankings, but this has not been used. Estimation of habitat capability at this finer scale requires not only better maps, but also a better understanding of grizzly bears. For example, it is as yet unclear how bear densities respond to limited availability of good habitat during only one season, or exceptionally good food conditions during one season.

In order to be conservative in estimating numbers of grizzly bears available for harvest, the MWLAP uses the minimum value within the range of habitat capability estimates for each of the five levels on the F-D scale (i.e., 75, 50, 25, 5, and 1 bears/1000 km^2; hereafter referred to as minimum F-D ratings). Applying these values to habitats within each Management Unit (MU), or within each Grizzly Bear Population Unit (GBPU) yielded a present, province-wide (minimum) habitat capability of 18,800 grizzly bears, which is close to Fuhr and Demarchi's (1990) estimate of about 20,000 animals. Historical habitat capability was estimated at 20,000 – 37,000 bears. The difference between historical and current habitat capabilities reflects permanent habitat loss due mainly to urbanization and agriculture. Grizzly bears no longer occupy 11% of their historic range in B.C.

6. Step-down of Fuhr-Demarchi estimates

Historically, B.C. grizzlies occupied all portions of the province except the coastal islands and ice fields. They apparently occurred at fairly low density in montane forests and grasslands of south-central B.C., but because of extensive landscape alteration in this area, they have been largely extirpated. Small grizzly bear populations still exist in portions of southern B.C. where they are considered threatened. Although F-D estimates suggest habitat capabilities in GBPUs in this area in the range of 100–300 grizzlies, logging, road building and high historic hunting pressure have reduced these populations to 20–100 bears. Reduction of population estimates derived from habitat capability to current estimates of bear numbers (used for harvest allocation) involves a multi-stage "step-down" process.

A formalized "step-down" process was incorporated in the F-D method in 1996 to account for the effects of increasing human impacts on the landscape plus historic human-caused mortality. The procedure involves five potential step-downs of habitat capability related to (1) habitat loss (e.g., urbanization), (2) habitat alteration (e.g., logging), (3) habitat displacement (human activities, such as traffic, that displace bears), (4) habitat fragmentation (partitioning of home ranges), and (5) human-caused mortality. For each of the first four steps, the impact is first quantified by the proportion of the area that was

impacted, then by the degree of impact, and finally by the relative habitat value of that parcel of land. Degree of impact is rated on a scale of 0–1.0, related to the loss in ability to support grizzly bears (1.0 = 100% loss). Relative habitat value refers to the habitat capability of that parcel of land compared to other parcels in the same MU. A value of 1.0 would indicate that the habitat capability density of that parcel was the same as the average for that MU. Each of the four habitat step-downs is calculated by multiplying the values of each of these three factors. The first factor is measurable, and the third can be calculated from the habitat capability ratings. However, the second factor, related to degree of impact, is highly subjective; whereas there have been various studies related to impacts of roads and other human disturbances on grizzly bear behavior, studies have not quantified the effects of disturbances on grizzly bear demographics. Moreover, for the step-down process, if an impact were considered to be twice as great, the step-down would be twice as much because the process is multiplicative. Of the four habitat-related step-downs, only the first (habitat loss) is fairly straightforward; steps two, three, and four are not easily measured and because bear reaction to these disturbance factors is less well understood, application of these steps is a subjective process.

The step-down for human-caused mortality (step five) is the most subjective, but often the most important element in the process. Bear populations in areas with little human-caused habitat alteration but which have been heavily exploited over a long period of time could exist at densities well below habitat capability. The difficulty is in determining the magnitude of this step-down from historical human-caused mortality data.

The step-down called for in the F-D process uses kill data for the previous 20 years or longer where information is available. It includes factors related to the killing of too many bears (regardless of sex and age), too many females, and too many bears in a concentrated area. These three subjectively derived values, expressed as proportions, are added together and are thus weighted equally. Conceivably, these could total 1.0, which would result in a 100% step-down, or a population estimate of zero.

A particularly troubling aspect of the human-caused mortality step-down is that it should be related to estimated population size, but such estimates are themselves derived from the F-D method. For example, a given number of kills out of a population of 100 should have half the effect as that same number removed from a population of 50 — indeed the first situation may be sustainable, resulting in no long-term change in population size, whereas the second may cause severe population decline. A manager employing this step-down would thus have to know which scenario applies. Likewise, it would be important to have knowledge of the population trend to gauge impacts of the kill: a fixed kill taken from a population that is already declining due to habitat degradation would speed the rate of decline. These complexities are by no means trivial, and are not easily resolved because a manager, having no independent information on population size, would need to be able to estimate population size and trend 20 years (at least) in the past.

To alleviate some of the subjectivity in this step, one B.C. regional manager developed a simple demographic model to ascertain the impacts of historic human-caused mortality (D. Heard, personal communication). However, this model has not been approved for

general use by the MWLAP, mainly because of disagreements regarding the specifics of how it functions (A.N. Hamilton, personal communication). The Panel did not examine this model.

7. Density estimates from Fuhr-Demarchi compared to research projects

Boulanger and Hamilton (2002) compared density estimates derived from the F-D method to closure-corrected estimates obtained from DNA mark–recapture research projects. Their regression analysis indicated that F-D estimates reliably predicted DNA-based estimates of grizzly bear density. Notably, the "conservative" F-D estimates, as used by the MWLAP — that is, those derived from the minimum density values within each habitat capability step — matched the DNA point estimates better than the midpoint F-D estimates. This suggests that the so-called minimum F-D estimates employed in bear management are not underestimates of bear density.

F-D estimates are meant to include cubs-of-the-year whereas DNA analyses of hair samples may underestimate cubs because they can pass under the strand of barbed wire without their hair being snagged (Boulanger et al. in prep). If DNA estimates were increased to account for missing cubs, they might better match the midrange of F-D estimates. More study is needed to assess the under-representation of cubs in DNA-based estimates.

A potentially troublesome point in the analysis done by Boulanger and Hamilton (2002) is the bear population estimate for the Flathead, which although originally used to benchmark the F-D scale, appeared to be somewhat of an outlier in the regression. Whereas the minimum F-D density estimate for the Flathead of 64 bears/1000 km^2 fell within the wide DNA-based confidence interval of 30–92 bears/1000 km^2, it was higher than the DNA point estimate of 48 bears/1000 km^2. This is disturbing in that the Flathead F-D density estimate is more than twice that of any other area in the regression, and thus is the sole representation of bear density in prime habitat. Notably though, the 1997 DNA-based point estimate is substantially lower than McLellan's (1989) original telemetry-based estimates (averaging 64 bears/1000 km^2). If cubs are considered missing from the DNA estimate and are thus added back in (using 22% cubs from McLellan 1989), the corrected estimate becomes 62 bears/1000 km^2, nearly matching both the F-D estimate and McLellan's original telemetry-based estimate. This may be somewhat of a coincidence, as the Flathead population was believed to be increasing by about 8%/year since McLellan's original estimate from the mid-1980s (Hovey and McLellan 1996), and more recent telemetry-based estimates exceed 80 bears/1000 km^2 (McLellan 1994, personal communication). McLellan (personal communication) has suggested that his telemetry estimate is for a portion of the Flathead where bear density may be greater than the larger area covered by the DNA grid. However, the F-D estimate was specifically for the DNA grid, and so within that area, the F-D estimate *appears* to be too high; nevertheless, the broad confidence interval around the DNA estimate and its potential under-representation of cubs render any conclusions about the reliability of the Flathead F-D estimate tenuous.

Because the Flathead DNA estimate had such a wide confidence interval it was given relatively less weight in the Boulanger and Hamilton regression, as points were weighted by the inverse of the variance of the DNA estimate. The nine-point regression included three points from one study area (Upper Columbia River) in different years (although a somewhat different area was sampled), one point from the unhunted and threatened Kettle-Granby population and one point from the Prophet River area where the F-D step-down resulted in a population *increase* (due to the presence of a high ungulate population as potential food for bears); moreover, this "step-up" adjustment was made after obtaining results of the DNA study. These cases do not necessarily negate the conclusions, but they add more uncertainty that confounds the issue.

Mowat et al. (2002a) conducted a similar comparison of F-D and DNA-based grizzly bear population estimates on two portions of each of two B.C. study areas. In contrast to Boulanger and Hamilton (2002), Mowat et al. (2002a) found a better match between DNA estimates and the midpoint of the F-D scale rather than the minimum F-D estimates. However, the closure correction procedure that they used differed from that of Boulanger and McLellan (2001) and likely resulted in somewhat higher DNA-based density estimates. Moreover, they performed their own F-D estimates and step-downs, which may have differed from those that the MWLAP would have obtained, because the process includes a good deal of subjectivity. In fact, after Mowat et al.'s step-down, minimum F-D grizzly population estimates on three of four areas were close to zero, indicating that their step-down was too large. Two of these three near-zero F-D estimates were for two halves of the Prophet River study area, where Boulanger and Hamilton (2002) used a step-up to account for ungulate biomass rather than stepped-down F-D estimate. This step-up process, however, has never been documented.

A conclusion of Mowat et al.'s report (2002a) was that the step-down process was so subjective that different individuals can obtain widely disparate results. In their case, the step-down regarding the effects of past harvests caused the most significant reduction in estimated population size. They used a simple demographic model to calculate this step-down, whereas the MWLAP uses a more subjective approach.

A1. Population estimation issues framed as questions

1. Is there a need for estimates of population size, and if so, at what geographic scale?

- The MWLAP has produced grizzly bear population estimates for each of the 60 GBPUs, which cover the occupied grizzly bear range in B.C. GBPUs range in size from 2700 to >46,000 km^2. Population estimates for GBPUs range from <50 to >850 bears, with estimated densities of 1 to 60 bears/1000 km^2. However, only one GBPU (Flathead) has an estimated density >37 bears/1000 km^2. The sum of the estimates for all 60 GBPUs is about 14,000 bears.

- Population estimates also are produced for smaller management units (MU), which comprise GBPUs. There are 183 of these MUs in the province, ranging in size from

70 to >18,000 km^2; however, 41 of these units have no bears and are thus not part of any GBPU.

- Hunting pressure is allocated either at the level of the MU or at subdivisions of the MU, referred to as Limited Entry Hunt (LEH) zones. In a few cases LEH zones encompass more than one MU, and may even overlap two GBPUs. Population estimates are not made specifically for each LEH zone.

- Many other big game species, including B.C. black bears, are hunted with little or no effort to estimate population size.

Conclusions: There are at least three distinct approaches to maintaining sustainable harvests. One is to estimate population size and sustainable harvest rates and based on this information, calculate a sustainable yield. A second is to make a best guess at a sustainable harvest, using historic records, and then adjust this harvest year to year in accordance with estimates of population trend. Population trends may be assessed through counts or other surveys of the living population, through analysis of harvest data, or through population modeling linked to field data. A third approach is to restrict the number of hunters to such a low level that it would be highly unlikely that they would ever exceed a sustainable harvest. As populations rise, the hunter success rate will climb, and as populations decline, so will the hunter success rate, but population estimation or trend monitoring would be unnecessary because the harvest would always be far below the maximum sustainable yield (MSY).

The choice of which of these approaches to use depends on: (1) how close to MSY the population will be harvested, (2) the feasibility of obtaining either population estimates or trend data, and (3) the reliability of these data. The level of harvest relates to the objectives of the management program. If the objective is to keep the population in check (e.g., to prevent over population or, in the case of bears, to prevent "nuisance" activity), then it needs to be harvested more intensively than if the objective is to allow for population growth. Feasibility relates largely to how much money can be invested on harvest management for that species; given enough money, nearly anything is feasible, but with limited funds, it is necessary to make tradeoffs among the different species for management resources. The reliability of biological estimates relates both to monetary investment and to the biology of the species.

If harvests are clearly conservative, there is certainly little need to spend large sums of money to produce population estimates or to obtain trend information. However, as harvests approach MSY, more caution is required, and since trend monitoring often has unacceptable errors and lag times, population estimation would be preferable in this case. Animals like grizzly bears, which occur at low densities with low reproductive rates, support a low rate of harvesting, so any size harvest is bound to be close to MSY. Hence, the population estimation approach would be desirable. The question in the case of B.C. grizzlies, though, is whether population estimates are reliable enough to ensure a

sustainable harvest. Population estimates that may err on the high side will be more harmful than beneficial (see #2 below).

Given that B.C. has chosen to base harvest management on population estimates, what geographic scale should these encompass? Harvests are allocated at the scale of the MU, or at smaller subdivisions (LEH zones). The smaller the area, however, the more potential error there is relative to the magnitude of the estimate. This disadvantage must be weighed against the potential for over-harvest if hunting effort is allocated for a large area but hunters congregate within a portion of the area. For example, if population sizes are estimated only to the level of the GBPU, and harvest pressure is also allocated at this level, some areas within the GBPU could be over-harvested. Although more significant errors may arise in producing population estimates at the scale of the MU, this seems necessary in B.C. Moreover, areas of MUs are similar to areas of grids used for DNA population estimates, so this is probably an appropriate scale for producing F-D estimates as well.

Population estimates at the scale of the GBPU are also valuable, enabling groups of MUs to be viewed within the context of a larger area. Ideally GBPUs should be delineated in terms of demographically distinct groups of bears (i.e., biologically discrete populations). Indeed, there may be habitat fractures that delineate boundaries of some real biological populations of grizzly bears in B.C., as evidenced by recent DNA data (Proctor et al. 2002). These biological boundaries should match GBPU boundaries. However, such data are not available for most parts of the province, and furthermore, it is likely that discrete biological populations do not exist in most of B.C. Hence, the currently defined units probably serve their intended function sufficiently well, although boundaries should be reconsidered as more evidence accumulates regarding real biological fracture zones.

2. Are population size estimates and subsequent harvest goals adequate for scientific bear management? Are the linkages between habitat and estimated bear density reasonable and/or conservative?

- Population sizes for harvest allocation are estimated using the F-D method. This method begins with an estimate of "habitat capability," or the potential carrying capacity in the absence of recent human impacts.

- Each unique combination of Ecosection and BEC variant/phase is assigned a habitat capability rating from a five-level scale: very high, high, moderate, low, or very low.

- Each of the five levels of habitat capability corresponds to a potential range of grizzly bear densities. The three upper levels in this scale each span a density range of 25 bears/1000 km^2; this increment diminishes for the lower two density steps.

- When the F-D method is applied, only the minimum values at each step of the scale are used.

- When the habitat capability density scale was developed, only the highest step was benchmarked against areas where the population density had been estimated using other means.

- Density estimates, based on DNA mark–recapture studies, now exist for various places in B.C. These mark–recapture estimates have been used to check or verify F-D estimates. Occasionally (twice), direct adjustments to F-D estimates were made based on results of these studies.

Conclusions: The assignment of habitat capability ratings is carefully considered through a process that is both objective and subjective. Potential errors include misclassification of unit types from aerial photographs, mistakes in transcribing unit types from aerial photographs to maps, and measurement errors in ground plots used to verify the type and condition of vegetation. These errors are less likely as the scale of the mapping increases, but presently it is not feasible to use large-scale (e.g., 1:20,000) maps in this process.

Some subjectivity is introduced into the process because a certain type of BEC unit could be more suitable for bears in one context (i.e., neighboring BEC units) than another. It is laudable that the MWLAP has attempted to account for such subtleties, which involves far more manual manipulation than a straightforward assignment of BEC units to density classes. A shortfall, however, is that this process is not documented and thus not necessarily repeatable by different personnel.

Another shortfall of the method is that it is based almost entirely on vegetative components of the habitat, whereas availability of meat can be (and often is) the overriding factor influencing grizzly bear density (Miller et al. 1997, Hilderbrand et al. 1999). Recent attempts have been made to adjust F-D estimates for availability of fish or ungulates, but this has not been applied in a systematic or quantifiable way. Moreover, this adjustment is made as a "step up," after consideration of vegetative factors, rather than being integrated into the process of estimating habitat capability. This does not suggest that the step-ups result in an incorrect density estimate, only that they further contribute to making the process non-standardized.

The most troublesome part of this process is the limited calibration of the habitat capability scale. Only the high end of the scale was benchmarked, which is the system specified in the British Columbia Wildlife Habitat Rating Standards manual (http://srmwww.gov.bc.ca/risc/pubs/teecolo/whrs/index.htm) . The grizzly bear benchmarking was based on a reasonably good density estimate in the Flathead and another somewhat less reliable estimate in the Khutzeymateen. Both of these areas had high densities of bears due to rich food resources (berries and salmon, respectively) and low human disturbance. However, whereas density in the Flathead was found to be increasing, from 64 to possibly 100 bears/1000 km^2 in less than two decades, an intermediate value (75 bears/1000 km^2) was chosen as the "minimum" for the highest density class. Similarly, it is likely that density also varied in the Khutzeymateen, due to varying salmon stocks, but data were not available to determine whether the density estimate for this area really represented an average value. Moreover, both of these areas

contained mosaics of habitat types, so although a density class could be assigned to each whole area, it is unclear how it was assigned to individual EC units within these areas. It is also unclear how the lower portion of the habitat capability scale was developed.

The MWLAP considers the selection of the minimum value within each density class a conservative process. However, it is impossible to tell if this is truly conservative because the scale is so poorly calibrated and lacks clear, biologically based, break points between classes. It is possible that some BEC units are classified to the wrong step of the scale, and it is also possible that the entire scale is inflated upward.

The only verification has been a recent comparison between estimates of bear densities generated from the F-D process and estimates from DNA mark–recapture (see #4 below). Notably, this comparison necessarily involves stepped-down F-D density estimates (i.e., reduced by human impacts), and so is not a true test of the habitat capability scale. The only way to check a scale of habitat capabilities is with areas free of human impacts. A mismatch between an F-D stepped-down estimate and a mark–recapture estimate might mean that either some part of the step-down process was in error, or the initial habitat capability rating was in error (presuming the mark–recapture estimate to be correct). Likewise, concurrence between an F-D stepped-down estimate and a mark–recapture estimate could indicate that both the habitat capability rating and step-down were reasonably accurate, or that opposing biases in each were offsetting.

3. Is the step-down process (for reducing estimated bear density based on habitat alteration and past harvests) realistic and/or conservative? Can it be simplified?

- The MWLAP uses a "step-down" process for reducing the *potential* population estimate based on habitat capability to a present estimate of actual population size.

- The step-down process considers the following human influences: (1) habitat loss; (2) habitat alteration (e.g., logging); (3) displacement of habitat use from human activities (e.g., from motorized traffic); (4) habitat fragmentation; and (5) human-caused mortality.

- Each of these five step-downs is comprised of several components, which are assigned a quantitative value on a spreadsheet. Some of these components are directly measurable, whereas others are subjectively rated by managers (with guidance from the Large Carnivore Research Biologist). For example, habitat loss is assumed to result in a 100% reduction in carrying capacity of the area affected, so if this area can be measured, this impact can be assessed fairly objectively. Conversely, the impact on grizzly bears of the other three aspects of habitat alteration must be subjectively rated, because their effects are less direct.

- After stepping down habitat capability for human alterations of the landscape (first four steps), the process yields an estimate of current carrying capacity, which the MWLAP calls "habitat effectiveness."

- Habitat effectiveness is then stepped down for human-caused mortalities over at least the previous 20 years to generate an estimate of current bear numbers. Although good records exist on numbers, locations, and sex-age composition of known human-caused mortalities, these data must be subjectively converted to "proportional impacts" on the population.

- Aside from human-caused mortalities, no other demographic variables are considered in the F-D process, and there is no way to incorporate independent assessments of population trend unless they can be directly linked to a part of the step-down process.

- The formal step-down process does not include availability of meat (fish and ungulates); however, this has been recognized as an important determinant of bear density, so this factor has been informally added as a "step up" in some cases.

- Although there are written guidelines, no exact protocol exists for implementing the subjective aspects of the step-down process. Some managers have complained that application of the process is overly complex and tedious. It involves 15 separate step-down inputs.

- F-D estimates are generated for all MUs and GBPUs. Population estimates used for harvest allocation do not include areas closed to grizzly bear hunting that are >100 km^2 .

Conclusions: The step-down process is a thorough and well-considered procedure for taking into account a variety of factors that can affect grizzly bear density. For the most part (apparently with the exception of the meat factor), data inputs and calculations are made using a standardized spreadsheet. However, a detailed protocol for the process is lacking, making it subject to potential inconsistencies in its application. Inconsistencies could arise from several steps in the process, especially those calling for subjective inputs. Although attempts have been made to maintain consistency among those applying the process by using a workshop-type format, the process has not been applied uniformly across the province. Moreover, there has been no quantitative assessment of the effects of the subjective inputs on the results, such as a sensitivity analysis (i.e., relationship between variations in inputs and corresponding output) or an analysis of variation among personnel involved in the process. Testing of the step-down process against actual field data is hampered both by the complexity of the process (requiring each individual step and combination of steps to be examined) as well as a shortage of field data

A particularly subjective step in the step-down process regards the inputs for effects of direct human-caused mortality. This step is based on reported bear kills, combined with estimates of unreported kills; subjectivity is necessarily introduced in estimating unreported kills. Furthermore, derivation of the value of the step-down corresponding to these kills involves a non-standardized procedure that inherently includes assumptions about population size and trend. One regional biologist uses his own simple demographic

model to aid in determining the input value of this step-down, but others have not adopted this procedure. It seems obvious that a more objective method, employing a mortality model, would be helpful in standardizing this step-down, but a model alone will not ensure reliable results. A fundamental aspect of the mortality step-down is that it relates to the *proportion* of the population killed by humans, whereas the data are in terms of the *number* killed (other important variables include sex and location). If one errs in estimating the size of the total population, then invariably that error will affect the calculation of the proportion killed. The danger is that overkill will not be detected if the size of the population is over-estimated on the spreadsheet. Indeed, it can only be hoped that a perpetually over-harvested, decreasing population would be detected on the ground by astute wildlife managers and other observers, because there is no intrinsic safeguard against this in the step-down process and also no ready fix to the problem.

This general criticism raises the important question as to whether the application of the step-down process is conservative. In other words, does it tend to underestimate population size (so harvest allocation is consequently conservative)? A conservative process would tend to exaggerate the magnitude of the various step-downs. Given the subjective nature of many of the inputs, we cannot tell whether in practice managers employ the process conservatively. In fact, it is possible that managers who perceive the habitat capability values to be conservative, because of the choice to use the minimum (rather than midpoint) density values at each step on the scale, compensate for this (maybe not purposefully) during the step-down process. It appears to us that neither the habitat capability values nor the step-down process is inherently conservative, although individuals may choose to apply it conservatively.

One recent modification of the process that seems particularly subjective is the application of step-ups for availability of meat (fish or ungulates). We certainly agree that abundance of meat results in increased density of grizzly bears, but the process for increasing the F-D estimate to account for this is neither documented nor calibrated, so it is impossible to ascertain whether it tends to be applied conservatively.

The best test of the conservative quality of the F-D process is a comparison of the results with independently derived population estimates. This has been done (see #4 below). Results indicate a reasonably good match between the F-D values (using minimum habitat capability ratings) and DNA mark–recapture estimates. If the process is conservative, we would expect the F-D values to err on the low side. In fact, in instances where the MWLAP uses mark–recapture estimates in place of F-D estimates, the protocol (to ensure a conservative process) requires use of the point estimate minus 1 SE (The Grizzly Bear Harvest Management Procedure, section 3.9, says 1 SD, which we presume equals $s/\sqrt{n}$, more commonly referred to as the standard error, SE). It follows that the MWLAP considers F-D estimates roughly equivalent to mark–recapture estimates minus 1 SE (i.e., on the lower end of the interval bracketing the degree of uncertainty). However, comparisons between F-D and DNA mark–recapture estimates indicate that this is not the case: F-D estimates best match DNA point estimates, not point estimates minus 1 SE. A caveat, though, which suggests the F-D estimates are more conservative than indicated by

this comparison is that DNA studies probably underestimate cubs; adding cubs to these estimates would tend to make DNA estimates higher than F-D estimates.

Possibly the most conservative aspect of the F-D process is the exclusion of large areas closed to grizzly bear hunting from population estimates for GBPUs. Certainly there are movements of bears in and out of such areas, so an unhunted area adjacent to a hunted area would tend to act as a source of bears. The potential magnitude of such ingress is not known, but it likely provides a conservative buffer to a neighboring hunted population.

A final important question is whether the step-down process can be simplified. We can envisage ways of combining some of the steps in the step-down process, which might make it seem simpler (fewer steps), but in practice it probably would not be. The benefit of having many inputs is that it forces managers to consider a complex array of variables one small step at a time. To attempt to combine these various factors in one's mind so as to reduce the number of spreadsheet inputs would probably be even more difficult and lead to even greater inconsistency. The strength of the present system is that it enables, indeed forces, documentation of a long series of decisions that theoretically at least, could be examined for trends, variability, and sensitivity. A weakness is that the system does not require written justification for the inputs, or even require the archiving of step-down worksheets. At the time of our review, step-down spreadsheets were not available for the entire province (apparently they are now).

4. How do present habitat-based estimates of population size compare with estimates derived from bear studies (e.g., DNA, mark-recapture/resight) for the same study areas in B.C., and areas of similar habitat outside the province? Are these comparisons adequate to evaluate the Fuhr-Demarchi methodology?

- Several B.C. research projects involving radio-collared bears have produced density estimates. However, most of these estimates were unreliable due to small sample sizes and violation of assumptions related to closure and incomplete accounting of unmarked bears.

- No attempt has been made to check F-D estimates in areas outside B.C. where other mark–recapture or mark–resight studies have been conducted.

- Since 1996, 11 DNA-based population estimates have been conducted in various places in B.C. One purpose for these studies was to help check, or calibrate, F-D estimates. Some other hair-snagging DNA studies did not produce reliable population estimates due to constraints of sampling methodology and/or small sample sizes.

- A regression by Boulanger and Hamilton (2002) indicated that DNA estimates reasonably predicted F-D estimates, although the Flathead, the area against which the F-D scale was developed, was an outlier (F-D estimate too high). A similar comparison by Mowat et al. (2002a) suggested that DNA estimates corresponded better with mid-point F-D estimates.

Conclusions: Despite a considerable effort to compare F-D estimates with other, independent estimates of grizzly bear density, several issues remain unresolved. Especially troubling are the differing results of the F-D vs. DNA comparisons made by Mowat et al (2002a) and Boulanger and Hamilton (2002), and the unexpectedly low DNA estimate obtained in the Flathead. The MWLAP has posed several explanations for these inconsistencies (A.N. Hamilton, personal communication), but they remain untested.

It would seem that a sufficient range of areas has been studied to adequately test, or recalibrate, the F-D scale. However, as it turns out, almost all F-D density estimates for DNA study grids fell within a fairly narrow range of bear density (13–30 bears/km^2), thus diminishing the utility of the comparison. Actual F-D density estimates for management units range from 1 to 68 bears/1000 km^2. Moreover, one DNA grid was excluded, one area was repeated three times (in different years), and step-downs varied enormously among study sites — from a 63% reduction related to habitat alteration (unhunted Granby-Kettle) to a 34% increase attributable to a large ungulate food component. These problems make it nearly impossible to independently check the F-D habitat capability scale and the various steps in the step-down process. It is conceivable that some of these steps tend to err high whereas others tend to err low, but the small number of sites, clustered within a small density range, precluded discerning these effects.

We conclude that whereas the comparisons done to date between F-D and DNA density estimates provide a good start toward evaluating the F-D process, many combinations of habitat capability and step-downs for human impacts have not been examined. For example, only one coastal area (Kingcome) was included, and in this case the F-D estimate was substantially lower than the DNA estimate. However, this result cannot be extended to other coastal areas. Density estimates for the Owikeno Lake area, which had been stepped-up for salmon and seasonal ingress of bears, over-estimated bear numbers when salmon returns collapsed (Austin and Hamilton 2002, Himmer and Boulanger 2002). The Flathead also seems to have been overestimated (at least compared to DNA estimates). Conversely, the Prophet would have been under-estimated by conventional F-D methodology had a modification for ungulates (prompted by the results of a DNA study) not been incorporated. These discrepancies among just the small number of cases that have been examined suggest that checking or recalibrating the F-D process will be enormously complex.

F-D estimates are much like Habitat Suitability Indices (HSI) in that they are derived from mathematical functions combining multiple variables, all with rather subjectively-determined values. There is no good way of testing the validity of any single value; nor is there a good way of testing the ways in which the variables are combined (e.g., additive versus multiplicative; unweighted or weighted to various degrees). The only check is the end number, which is the result of many steps. Hence, it is nearly impossible to identify the cause of over- or under-estimation, which makes it difficult to improve the procedure.

Other, more objective and more testable approaches for estimating relative bear density from habitat characteristics exist. One such method, based on Resource Selection

Functions (RSF), has attracted considerable recent attention (Boyce and McDonald 1999, Manly et al. 2002, Boyce and Waller 2003). RSF are mathematical models developed from patterns of use of different habitats in relation to their availability. An advantage of these models is that they enable the direct use of a variety of predictor variables (e.g., presence or absence of salmon and ungulates, road density, distance to human disturbances, etc.) when estimating selection probabilities.

The principle behind the RSF approach is that if one has a sample of units with known attributes (predictor variables) that are either used or not used by bears, then one can predict the probability of use for any units containing a mix of these same attributes. Furthermore, if the population size is known for the reference population (e.g., DNA study grid), then one can extrapolate habitat/attribute-specific densities to other areas containing the same mix of attributes (Boyce and McDonald 1999; Manly et al. 2002). Such estimates could be tested, and RSF models recalibrated on each new DNA study grid.

5. Are there empirical indicators of trends in grizzly bear populations that could be used to augment and compare with Fuhr-Demarchi estimates?

- Some attempts have been made to monitor trends in grizzly bear numbers using DNA identifications of hair samples and/or helicopter counts.

- Harvest statistics (sex and age structure of kill) have been collected for many years, but these data are generally poor indicators of population trend (see section B).

- F-D estimates are based on vegetation characteristics of the landscape and human-imposed mortality. If the vegetation characteristics remain unchanged and human-imposed mortality is deemed to be within sustainable limits, F-D estimates will remain unchanged.

Conclusions: The ultimate danger of managing a bear population without trend data is that populations may decline undetected. If population estimates are very conservative, then harvests should always remain within sustainable limits. However, if, there is a chance that some populations are over-estimated by the F-D process, then over-harvest may occur. The problem is that there is no way of knowing that an overkill has occurred because the same incorrect F-D estimates will be produced year after year, leading to increasing over-harvest — that is, the paper (computer) population may appear stable while the real population continues to decline, unnoticed.

Bear population size can change with increases or decreases in food production that may be related to weather, subtle changes in the forest, or human harvests of prey species such as ungulates and fish. Population size also can change with changes in harvest pressure. Allowable harvests, which are designed to be sustainable, are determined solely from F-D estimates; if these estimates are incorrect, bear numbers could increase or decrease accordingly. With no independent assessment of population trends, F-D estimates will remain unchanged as long as the harvest does not exceed the calculated allowable limit; meanwhile, the real population could be either increasing or decreasing.

A trend monitoring scheme would help avert this disconcerting scenario. However, presently there is no such simple scheme. Harvest data are rarely sensitive enough to indicate a population trend, and other methods, like helicopter surveys and DNA monitoring are narrowly focused and very expensive. Himmer and Boulanger (2002) showed that DNA identifications of snagged hair samples could be used to estimate population growth rates (λ), even in geographically open populations where density estimates tend to be biased by movements of bears in and out of the designated area. In such situations it would be preferable to monitor trend than to attempt to assess the validity of the F-D estimate because the DNA estimate would be unreliable.

With fixed resources, a tradeoff exists between allocating efforts toward trend monitoring in a fixed number of areas versus obtaining density estimates (to compare with F-D estimates) in a larger group of areas. Trend monitoring entails repeated surveys in the same areas, whereas density estimates can be produced in a single year, so different areas can be sampled each year. Arguments can be made for both, and we cannot, with presently available information, make recommendations as to the relative allocation toward each of these efforts. We suggest, however, that sites with the most variable resources (e.g., salmon runs) should be subject to trend monitoring (both bears and salmon). Additionally, demographic models could be developed that incorporate such trend information (λ) to assess the effects of future harvests of varying size.

6. What is the relative risk of population decline given the uncertainty in estimates of population size and vital rates?

- F-D estimates of bear numbers are associated with an unknown, but probably large, sampling error due to uncertainty in the habitat capability scale and the subjective step-down processes.

- The allowable human-caused mortality of grizzly bear populations in B.C. ranged from 3% to 6% per year. The values are designed to correspond with population productivity, and are derived from estimates of survival and reproduction (vital rates). Population-specific vital rates are assumed constant over time under the current strategy of harvest allocations in B.C. Empirical estimates of vital rates are not available for most GBPUs in B.C.

- Calculation of allowable grizzly bear harvests in B.C. does not take into account sampling error and uncertainty associated with population size and vital rates.

- The B.C. Wildlife Harvest Strategy (1996) recognizes that harvest must not impair the sustainability of any hunted populations, including grizzly bears.

Conclusions: The use of a deterministic approach to assess allowable harvest of grizzly bears does not capture the risk of population decline due to uncertainty in input variables (McLoughlin et al. 2002). A critical issue is whether uncertainty around estimates of population size and uncertainty in vital rates play a comparable role in risks of population

decline. In other words, how should limited resources be allocated toward either better surveys or studies aimed at precisely documenting vital rates?

The Panel commissioned a specific population viability analysis (PVA) addressing this question (McLoughlin 2003). The objective was to assess the contribution of error in population size and error in demographic parameters on the risk of population declines for grizzly bears. An "unacceptable" population decline within a management perspective was defined as a 20% reduction in population size over a period of 30 years.

McLoughlin (2003) showed that error in initial population size is vastly more influential in terms of risk of population decline than error in estimation of vital rates. Therefore, in allocating resources managers should give higher priority to more precise estimates of population size than precise estimates of vital rates.

B. Population management

The following material includes a description and critical review of grizzly bear population management in British Columbia and a response to questions formulated about the management process.

1. Hunter harvest

Grizzly bears are typically shy, secretive animals that are difficult to enumerate in many habitats they occupy. As a result, management biologists often attempt to use a variety of methods to monitor population status, including the mandatory reporting of all bears killed each year (Garshelis 1990, Miller 1990a). The MWLAP implemented a compulsory inspection in 1976 for harvested grizzly bears.

The Panel examined these mortality data to document apparent trends in the harvest and to identify any potential "red flags" that might suggest that a GBPU or MU was over-harvested. We observed declining trends in the harvest statistics, including the number of both male and female bears in the harvest and the percentage of grizzly bear mortalities attributed to hunters. No trends were observed in the number of 15+ year-old bears or in the percentage of female bears in the harvest. The declining trend in the number of male and female grizzly bears in the harvest, and in the percentage of mortalities resulting from hunting, is not necessarily suggestive of a decline in bear numbers in B.C. We believe both trends are most likely associated with hunting restrictions implemented in the last 10 years commensurate with an increase in human population, resulting in increased mortalities associated with human-bear conflicts. The lack of trend in the number of 15+ year-old bears in the harvest or percentage of females in the harvest may be an indication of reasonable harvest levels during the last 20 years or may result from geographic shifts in harvest pressure within the province.

The Panel's evaluation of grizzly bear harvest did not reveal any compelling evidence of over-harvest in the province as a whole or in any GBPUs. Nevertheless, the Panel cannot

conclude that over-harvest is not occurring. Small sample sizes precluded any meaningful analysis at the MU level.

2. Non-hunting and human-caused mortality

Non-hunting mortality is an important component of allowable harvest calculations and is estimated for each GBPU based on tabulations from compulsory inspection records. Grizzly bear translocations, as a result of control actions, are counted as "mortalities" in the GBPU where the control action occurs. However, they are not added to the population estimate in the release location. Likewise, translocated bears are not counted as mortalities in the release location if they subsequently die from human causes. If management objectives for a GBPU are below the population estimate for the GBPU, regional managers may deduct control kills and translocations from the population estimate rather than incorporating them into the maximum allowable total human-caused mortality. However, no population objectives have been approved by the MWLAP in order to reduce grizzly bear numbers in any GBPU, so this option has not been used in the process of calculating allowable harvest in the province.

There is some concern among the general public that conservative hunting seasons for grizzly bears may result in increased levels of human-bear conflicts. In fact, recent reductions in hunting permit levels and grizzly bear harvest have been accompanied by increased human-bear conflicts and control actions. However, no definitive data exist to document a correlation between harvest levels and human-bear conflicts; other alternatives, such as increased levels of human encroachment in grizzly bear habitat may explain these recent increases.

3. Unknown or unreported mortality

Another component considered in the calculation of allowable harvest is an estimate of unreported human-caused mortality. In GBPUs where human-bear conflicts are common, this rate is generally set at 2 % of the total population estimate. A minimum 1 % rate is used in all other GBPUs. However, the process for including an estimate of unreported mortalities does not provide a mechanism for assigning a proportion of these mortalities to the female quota in the allowable harvest for a GBPU. McLellan et al. (1999) reported that 42 % of unreported mortalities from a sample of radio-collared bears were females. If female grizzly bears comprise a large proportion of the unreported mortality in B.C., then some potential exists for exceeding the total maximum allowable human-caused mortality (30 %) for females in a GBPU.

4. Significance of point-location-of-kill data

The MWLAP collects exact information on the location of each kill by asking hunters to put a spot on a map, which is subsequently digitized and entered into a database. Although it was offered to us, this Panel did not insist on obtaining these data from the MWLAP because we believe such data are generally not useful as an indicator of over-harvest at a scale pertinent to our analysis. Precise locations of kills are potentially useful

to local managers interested in identifying clusters where harvests may be concentrated and locally excessive. They are also useful in documenting that harvests are not homogeneously distributed across the landscape, an assumption which is almost never valid, but typically made in efforts to analyze sex and age composition data. Harvests are commonly clustered in relation to habitat types and hunter access points.

Managers should periodically plot kill locations and evaluate whether adjustments to regulations need to be made. A highly clustered pattern of kill locations may not require a management action and may, in some circumstances, even be desirable from a population management standpoint. This would be the case if kill clusters are surrounded by a large, *de facto* refuge area. Under such a circumstance, especially if the cluster is small relative to the surrounding area of quasi-refuge, hunters would likely be concentrating harvests on the least significant segment of the population (i.e., subadult males). On the other hand, if the kill cluster is in a relatively rare but highly desirable habitat type frequented by a large segment of the population, then a management response may be called for to reduce the number of bears killed in the cluster. If locations of kill clusters change over a period of years, this may be indicative of bears being depleted in each small area, and hunters thus concentrating their efforts on the next most accessible area. Such a pattern may over time result in the depletion of the population over a wide area.

Accurate information on the location of kills is important for such analyses by local managers. However, we doubt that an independent analysis of these data would provide much insight into the adequacy of harvest management policies in B.C. as a whole. We concede that such analyses may uncover localized areas where managers should pay more attention to the possible need to institute localized changes in hunting regulations. However, harvest data categorized by individual MU should be sufficient to detect patterns of over-harvest at a scale appropriate for drawing general conclusions about the adequacy of harvest regimes.

5. Determination of allowable harvest

Allowable harvest is calculated as a proportion of the estimated number of animals in the allocation area. The process is carried out through the use of a spreadsheet and is straightforward. The calculation begins with the estimated number of grizzly bears in the allocation area, usually an MU or LEH zone if there is more than one zone in a unit, excluding areas >100 km^2 that are closed to hunting. The F-D method used for estimating bear numbers is described in more detail in section A. of this report. When the population estimate is based on direct inventories (e.g., DNA mark-recapture estimates), management guidelines indicate that the point estimate minus the standard error of the estimate is to be used. The maximum annual allowable human-caused mortality during an allocation period is estimated as a rate expressed as a proportion of the current population estimate. The rate is a sliding scale between 3 and 6% based on an estimate of habitat capability relative to other areas. The 6% maximum is based on work by Harris (1986b) and is assigned to LEH zones considered to contain the highest habitat capability in the province. It is assumed that the lower the productivity of the habitat, the less human-caused mortality the population is capable of sustaining (Eberhardt 1990, McLellan 1994). The

Grizzly Bear Harvest Management Procedure (B.C. Government 1999) subjectively assigns a 6% allowable rate to zones with very high and high habitat capability, 5% to zones with medium habitat capability, 4% to zones with low habitat capability, and 3% to units with very low habitat capability.

The maximum allowable rate is reduced by an estimate of annual unknown human-caused mortality, also expressed as a percentage of the population. This rate is subjectively set at 1% to 2%, depending on the assumed level of human-grizzly bear interactions. The resulting rate is considered the "maximum annual allowable known human-caused mortality" (i.e., allowable rate of mortality minus unreported mortality). This "net" allowable mortality rate is multiplied by the population estimate to produce the "maximum annual allowable number of known human-caused mortalities" for the allocation period.

Section 5.5 of B.C.'s grizzly bear harvest management procedure (B.C. Government 1999) indicates that excess mortality from the previous allocation period is carried forward, hence reducing the maximum allowable human-caused mortality for the current period. Excess mortality in an allocation period is any negative balance of mortalities after subtracting the total known human-caused mortality from the maximum allowable human-caused mortality for that period. However, the annual allowable number of human-caused bear mortalities for the current period is reduced only if a negative balance exists for the entire GBPU (which is calculated as the sum of positive and negative balances for each LEH within that GBPU). Alternatively, in a few instances regional wildlife managers simply modify the population estimate to account for over-harvest during the current or previous allocation period.

The resulting allowable mortality may also be reduced by an estimate of known non-hunting human-caused mortality (e.g., relocations, bears killed in defense of property, etc.) for the current allocation, at the discretion of the person completing the spreadsheet. If an estimate of known non-hunting human-caused mortality is not considered here, the harvest quotas will be reduced accordingly in the future. The maximum allowable number of human-caused mortalities for the future allocation period is the product of the "adjusted" annual allowable mortality and the number of years (usually 3) in the allocation period.

A maximum allowable harvest of bears for the current allocation period is calculated by subtracting the estimated non-hunting human-caused mortality from the maximum allowable number of human-caused mortalities. The maximum allowable harvest for bears is further reduced by the known hunting and non-hunting human-caused mortalities, resulting in a harvest balance for bears for the current allocation period. A sub-quota for female harvest is also established. The maximum allowable known female mortality rate is subjectively set at 30% of total allowable human-caused mortality for both sexes (Harris 1986b). The maximum allowable known human-caused mortality for female bears is also reduced by any excess mortality carried forward from the previous allocation period and the known hunting and non-hunting human-caused mortalities during the current period. The result is a harvest balance for female bears for the current allocation period.

6. Administration and establishment of regulations

Population management is accomplished through a combination of carefully controlled hunting seasons and area closures. All grizzly bear hunting in B.C. is currently controlled through LEH for residents and guide-outfitter quotas for non-residents. Non-residents must be accompanied by a licensed guide-outfitter when hunting big game. Each licensed guide-outfitter has a unique area with a quota assigned by the regional manager of Environmental Stewardship or the Director of the Fish & Wildlife Recreation and Allocation Branch. The allowable harvest is allocated to residents, nonresidents through guide-outfitter quotas, and to First Nations. Resident hunters are intended to have a higher priority than non-resident hunters in the allocation process.

The allocation of licenses to resident hunters assumes a hunter success equal to the average hunter success rate for the three most recent years with available data. A minimum hunter success rate of 10% is used for most LEHs when calculating quotas for resident hunters. Some regions that recently adopted fall LEH have used 20 or 25% as the minimum success rate until information on actual success rates becomes available. Before making the final recommendation, the wildlife manager may adjust the allowable harvest based on anecdotal information on population trend, concern about female mortalities, or other information felt to be important but not directly considered in the spreadsheet process. The annual bag limit for grizzly bears is one. Hunting grizzly bears over bait is illegal. It is also illegal to kill a bear less than two years old, or any bear in its company (e.g., siblings, mother).

Theoretically, harvests should be designed to achieve population objectives. Regional wildlife biologists have discretion to prepare and recommend objectives for grizzly bear populations for GBPUs. Objectives for specific population numbers may be higher, lower, or equal to the current population estimate. However, to our knowledge, population objectives have not been established for any GBPU in the province. In the absence of approved objectives, grizzly bear populations must be managed to sustain current numbers. If the manager wishes to reduce bear numbers, this change of objective must be justified in writing and is subject to public consultation. Reductions would be considered appropriate only where chronic grizzly bear/human conflicts occur that cannot be addressed by other means such as management of attractants and public education. All objectives must provide for a grizzly population that is viable over the long term. The Director of the Fish and Wildlife Recreation and Allocation Branch approves population objectives based on recommendations from the Regional Manager of Environmental Stewardship. All harvested grizzly bears must be brought to a provincial government office or approved contractors for compulsory inspection, including a determination of sex, the extraction of a tooth for aging, and the date and location of the kill. In some cases hair samples are collected for DNA analysis.

7. Criteria for closing populations to harvest

Grizzly bear hunting is closed in all national parks and some provincial parks. Additionally, any GBPUs that are isolated from other GBPUs and have a population estimate of less than 100 grizzly bears are not harvested due to their "inherent vulnerability." The Ministry also does not allow harvest from populations considered threatened, defined as those at less than 50% of their habitat capability. Population size is typically determined through the F-D method.

8. Policy for dealing with bear/human conflicts

As in other regions that support grizzly bears, the majority of conflicts between bears and humans in B.C. result from poor handling of potential bear attractants such as garbage and food waste. The province has a policy to reduce the amount of garbage available to bears. The Ministry has also devoted a good deal of its education effort to help prevent situations that create problem bears.

The Ministry has adopted a policy of using agency control or relocation to resolve the inevitable conflicts between humans and bears. It is our understanding that populations can be managed to reduce bear numbers in areas where conflicts with humans are a high probability. Nevertheless, conflicts can occur in almost any occupied habitat shared with humans. Relocation of bears likely to survive without further conflicts may be used to resolve conflicts. However, relocation is considered expensive and many bears may not be suitable candidates (e.g., habituated bears, injured bears). When bears are considered poor relocation candidates, they are removed through agency control. Bears removed from populations through relocation out of the GBPU in question or agency control are treated as known human-caused mortalities within the process for determining allowable harvest.

9. Public education to reduce bear incidents

The establishment of the Bear Smart Community Program by the Ministry in June 2002 enhanced ongoing information efforts intended to reduce bear incidents. This program includes establishing a bear hazard assessment, a conflict management plan, revision of planning and decision-making documents, implementation of a continuing education program, managing solid waste, and prohibiting provision of food to bears. The program is voluntary, with communities requesting to participate.

A province-wide Grizzly Bear Conservation Strategy includes an educational component intended to inform the public about bear ecology, safety, waste management, and regulations. This program is provided to the general public through existing programs. In addition, this information is provided to grade schools upon request. An insert into the fishing and hunting regulations synopses is provided to alert sportsmen about encounters with grizzly bears. Recommendations about using pepper spray and how to respond when confronted by bears are also included.

These public education efforts are voluntary, meaning that to participate the general public must request them. The Bear Smart Community Program should include a proactive component that is based upon an assessment of communities with the most potential for bear problems. Additional efforts could involve identifying locations where chronic grizzly bear non-hunting mortality occurs and evaluating causes and some approaches for reducing such mortality. The program should include a monitoring effort to assess strategies for involving the public in grizzly bear management and progress in reducing grizzly bear mortality in the province.

B1. Population management issues framed as questions

1. Are the currently designated grizzly bear population units reasonable and are they used appropriately in harvest management?

- Grizzly bear population units (GBPUs) are generally defined as areas comprising reasonably distinct grizzly bear population segments or subpopulations. The boundaries of GBPUs were originally designed to follow natural or man-made features in the landscape. However, in some northern and coastal areas, the boundaries for GBPUs follow topographical features dividing watersheds that may not actually function to impede grizzly bear movements between drainages. In 2000, the boundaries for some GBPUs were altered to correspond to MU boundaries for administrative purposes in an attempt to better regulate human-caused mortalities.

- The GBPUs are groupings of LEH zones. Known human-caused mortality within LEH zones is summed to the population unit for the purpose of determining annual overkill. Only the net overkill for the GBPU is carried forward to the next year and/or the next allocation period.

- Allowable human-caused mortality levels are determined on the basis of LEH zones as a means of allocating grizzly bear harvests more homogenously within GBPUs and thus over a relatively large geographic area within the province.

- B.C.'s Grizzly Bear Harvest Procedure Manual provides a set of guidelines for managing grizzly bear harvest on the basis of GBPUs.

Conclusions: The concept of GBPUs, based on geographically or ecologically significant boundaries and subdivided by MU and/or LEH zones, appears to be a reasonable approach for managing human-caused mortalities for grizzly bears in the province. The primary advantage of this approach is related to the ability of managers to distribute hunting pressure effectively over a large area. The size of GBPUs also allows managers to pool harvest data from smaller areas to achieve reasonable sample sizes for harvest analysis. The primary disadvantage is that excessive harvest of female grizzly bears within smaller MUs or LEHs in a GBPU may be masked when harvest data are pooled with data from adjacent MUs and LEHs within the same GBPU (Table 1). We recognize that no geographic system will work to completely control the location of harvests within any geographic area and localized over-harvests of adult females may occur with any system.

However, localized over-harvest is unlikely to be of widespread conservation significance because, if it occurred in many places within a GBPU, an over-harvest indicator should be triggered. There is no more appropriate way to allocate harvests than with a system of well-designed GBPUs, MUs and LEH zones.

Table 1. Percent females in the harvest for the Robson GBPU and Management Unit 7-5 within the Robson GBPU, 1981-2000. The high harvest of females within MU 7-5 during 1981-95 was not evident at the GBPU level.

	1981-85	1986-90	1991-95	1996-00
Robson GBPU	40	35	35	16
MU 7-5	50	41	42	25

2. Are allocation procedures (numbers and geographic distribution) appropriate for maintaining locally sustainable harvests? Are annual allowable harvests in GBPUs sustainable? Do differences in the boundaries of harvest units and guide/outfitter areas result in local areas of over-harvest?

- Allowable harvest is calculated as a proportion of the estimated number of animals in the allocation area, excluding estimates for animals residing in closed portions of the zone. The allocation area is the MU or LEH zone if there is more than one LEH zone in a MU. Allowable harvest in each allocation area is essentially the maximum allowable human-caused mortality, minus an estimate of unknown human-caused mortality, minus an estimate of known non-hunting mortality, calculated for both total bears and female bears.

- Any balance of allowable mortality is allocated as allowable harvest to LEH zones, with an assumption of a minimum of 10% hunter success. Hunter success may be higher, based on past hunter success information resulting in a smaller license quota.

- The sustainability of the harvest depends on the accuracy of the original population estimate, the accuracy of the estimated harvest, and assumptions about allowable harvest rate.

- GBPUs that are isolated from other GBPUs and contain an estimated population of <100 grizzly bears, are not harvested due to their "inherent vulnerability" to over-harvest. The Ministry also does not allow harvest from populations considered threatened, which by definition means that their estimated numbers are < 50% of the habitat capability.

- GBPUs typically correspond to the boundary of one or more MUs and their subdivisions, LEH zones. However, there are some MU and LEH zones that occur in more than one GBPU.

Conclusions: The issue of sustainability of the harvest is a function of population demographics, total harvest and the percentage of the harvest that is female. The most important component of population demography for grizzly bears in B.C. is mortality, particularly human-caused mortality. We addressed sustainability in two ways, through model-based risk analysis (McLoughlin 2003) and through a critical review of the harvest allocation process. The following is a summary of our review of the harvest allocation process.

Population estimates are derived for each harvested GBPU. GBPUs are composed of adjacent MUs that collectively make up a reasonably distinct population. The management guidelines indicate that if a MU is split between two GBPUs, a LEH zone should be created for each of the two portions. The current GBPU and LEH zone boundaries in some areas are not consistent with this direction. It is our understanding that in some cases where GBPUs cross regional boundaries, the portion of the GBPU in each region is managed independently. The management of these shared population units should be coordinated so that consistent management is possible. We also understand that some LEH zones occupy portions of at least two GBPUs. While we did not conduct a through analysis of the distribution of past harvest, we know from experience in limited entry hunting for other species that this condition can lead to local over-harvest. When two population units share a zone, it is possible for the entire harvest for the LEH zone to come from one GBPU, which results in an over-harvest for that unit. We suggest that each LEH zone be completely contained within one GBPU.

The selection of an allowable rate of human-caused mortality is a critical assumption in this process. The current allowable harvest rate varies with the inherent quality of the habitat (i.e., the average habitat capability) of the MU. This process for calculating this value is not entirely clear. Higher rates of human-caused mortality are allowed in areas with a higher habitat capability, because productivity of bears is likely to be higher. A maximum rate of human-caused mortality of 6% was based on literature regarding maximum sustainable mortality rates for grizzly bears (Bunnell and Tait 1980, 1981; Harris 1986b; Miller 1990a). If the assumptions inherent in this rate are correct then theoretically total human-caused mortality at this level should be sustainable in prime bear habitat, given unchanging conditions.

We found no written justification for rates of allowable harvest in areas with lower habitat capability. The process does not account for the total number of bears occupying a unit or zone. Harris (1986b) cautioned against applying allowable harvest rates without considering the total number of bears. Shaffer (1987) and Suchy et al. (1985) illustrated the potential effect on population viability of demographic stochasticity present in small populations.

The MWLAP (B.C. Government 1995, p. 48) recommends a general guideline of 4% as the maximum provincial harvest level, including kills from all sources. The current practice is to use 6% as the maximum harvest level, under the assumption that reducing the harvest level by 2% for unknown human-caused mortality will achieve the 4% goal.

The harvest procedure does not consider the proportion of unreported human-caused mortality that is comprised of females. McLellan et al. (1999) suggest that it is possible for unknown human-caused mortalities to be skewed toward females. Hence, a more conservative approach would be to assume sex differential mortality rates for unknown mortality. We understand that current estimates for unreported human-caused mortality are set at 1% for many MUs, the lowest level allowed under the harvest procedure in the absence of a written rationale. A more conservative approach, in the absence of empirical data on poaching, crippling loss, unreported harvest by First Nations people, and unreported accidents would be to use 2% unknown human-caused mortality.

The population estimate used in estimating allowable harvest is typically derived from the application of the F-D method, excluding areas >100 km^2 that are closed to hunting. Neither the spreadsheet for estimating population size nor the spreadsheet used for calculating the allowable grizzly bear harvest contains a direct entry for exclusion of such areas. While this may not be a problem, we believe that adding a column for reducing the starting population estimate by the number of bears excluded due to hunting closures would reduce the potential for missing this step.

3. Are harvest allocation procedures conservative or too conservative?

- The maximum annual allowable human-caused mortality for a given GBPU is determined using a sliding scale of 3%-6%, which is linked to habitat capability estimates calculated using the F-D method. Within this 3%-6% sliding scale, adjustments to the maximum annual allowable human-caused mortality rate can be made based on population objectives for the GBPU.

- For harvest purposes, the low end of the F-D density capability is used to establish allowable harvests; in areas where population inventories have been conducted, harvest levels are based on the population estimate minus one standard deviation. Population estimates include all ages of grizzly bears.

- The Grizzly Bear Harvest Procedure Manual (Section 5.6) sets the maximum known human-caused mortality level for female grizzly bears at 30% of the maximum allowable human-caused mortality for both sexes combined.

- Population objectives are not required for each GBPU. However, a GBPU cannot be managed to reduce the grizzly bear population size without establishing a population objective for that GBPU that has been approved by the Director of the Fish and Wildlife Recreation and Allocation Branch.

- A comprehensive system of grizzly bear management areas (GBMA) was proposed in B.C.'s Grizzly Bear Conservation Strategy document (B.C. Government 1995b) to ensure the long-term viability of grizzly bears. These areas would contain high quality bear habitat and would be closed to hunting for grizzly bears, although other natural resource extraction activities would be allowed. These GBMAs would be designed to buffer the effects of possible over-harvest of grizzly bear populations in adjacent GBPUs and also serve as linkages, benchmarks, and sources for population augmentation.

- The unknown mortality rate is estimated at 2% in areas with high human-grizzly bear interactions and no less than 1% in areas with low human-grizzly bear interactions.

- Harvest allocations are set for multiple-year intervals (usually three to five years), with yearly adjustments that reflect the current status of the harvest in relation to harvest objectives for the allocation period.

Conclusions: Several researchers have attempted to model maximum allowable harvest rates for grizzly bears. The MWLAP used estimates based on a modeling effort by Harris (1986b) that suggested total harvest rates below 6.35%, and 3.5% for female grizzly bears did not lead to a population decline. Miller (1990) reported that under optimal conditions the estimated maximum sustained hunting mortality was 5.7% of the total population for grizzly bears in Alaska. The Harris model included compensatory increases in cub survival associated with removal of adult males while the Miller model did not.

Beddington and May (1977) concluded that fluctuating environmental conditions resulted in variable vital rates, which lowered sustainable harvest levels. Recent population viability analyses on grizzly bears (Boyce 2001, McLoughlin et al. 2002, McLoughlin 2003) also showed that sampling error in population size and vital rates add to the risk of population decline, especially when the harvest rate is close to the maximum sustainable rate. McLoughlin (2003) modeled a hypothetical grizzly bear population in a productive environment and found increased risks of population decline when human-caused mortality exceeded 5%; this suggests that a human-imposed mortality rate of 6% would not be conservative. McLoughlin (2003) used model input data that were more conservative, in terms of potential rate of population increase, than empirical estimates obtained for the productive population on the Flathead (Hovey and McLellan 1996, McLellan et al. 1999).

The MWLAP uses the minimum density estimates from the F-D method to establish maximum annual allowable human-caused mortality for each GBPU. This approach might appear to provide a buffer against the uncertainties associated with the F-D method, thereby reducing the likelihood of over-harvest in a GBPU. However, allowable human-caused mortality cannot be considered conservative if the uncertainties associated with population estimates derived from the F-D method are wider than the F-D density categories. Over-harvest is more likely to result from mistaken estimates of population size than from errors in vital rates (McLoughlin 2003). Additional factors that may

contribute to making current harvest allocation procedure less conservative than intended include: 1) undocumented rates of human-caused mortality in GBPUs with varying road densities or resource extraction activities; 2) lack of a mechanism for adjusting maximum allowable harvest rates to reflect annual variations in environmental conditions; 3) inability to consistently restrict female mortality below total allowable at the MU level; and, 4) inadequacy of protected areas and linkage zones to buffer over-harvest.

The magnitude of unreported mortality for grizzly bear populations is still an open question. McLellan et al. (1999, personal communication) reported three unreported human-caused mortalities (out of 18 known or suspected human-caused mortalities in radiocollared animals) in about 200 bear-years of radio-tracking in the Flathead area; this represents an unreported human-caused mortality rate of 1.5% per year which falls within the 1-2% range that the MWLAP uses in their calculations for allowable harvests. However, for areas like the Flathead, with few bear-human interactions, the MWLAP would likely use the 1% value, which might be an underestimate, given McLellan's findings.

4. Are the criteria used for closing areas to harvest adequate to ensure long-term sustainability of grizzly bear populations?

- Threatened populations are designated at the level of GBPUs.
- Populations estimated to be <50% of the habitat capability are considered threatened and are closed to hunting. Eleven GBPUs are so designated, with estimated populations that range from 7-45% of the habitat capability
- GBPUs with <100 bears that are disjunct from other GBPUs also may be closed to hunting but may not necessarily be designated as threatened. A few GBPUs have estimated populations <100, but none are considered isolated enough to be closed for this reason alone.
- GBPUs may be closed to hunting if harvest levels must be reduced to zero for two or more years to meet the maximum allowable human-caused mortality objective.
- Some MUs have been closed at the discretion of the manager because of low bear density or a low reproductive rate.

Conclusions: The use of GBPU boundaries to designate threatened populations seems appropriate. Although these areas probably do not represent populations in the true biological sense, they represent areas for which demographic analyses are meaningful. The primary question is whether the criteria used to distinguish threatened from huntable populations is sufficiently conservative.

Fundamental principles of population biology indicate that the number of animals in the living population must be >50% of the habitat carrying capacity (K) to sustain a hunt near the maximum sustainable yield (MSY). For animals like grizzly bears, the population growth curve is thought to be skewed so that MSY occurs at substantially more than 50% K, possibly as high as 80% K, due to non-linear density effects (Taylor et al. 1994). If

MSY occurred at 80% K, but the population was at 60% K, then a harvest at the level of MSY would cause a population decline.

Current guidelines for managing B.C. grizzly bears consider populations at >50% of habitat capability huntable; this level is not the same as 50% of K. Habitat capability is the carrying capacity in the absence of human influences on the landscape. Present carrying capacity is lower. K is estimable from the step-down process (the value derived after considering human influences on the habitat, but before reductions for historic human-caused mortality). If the habitat step-downs are large, then 50% of habitat capability would be much greater than 50% of K; however, if these step-downs are not large, then 50% of habitat capability might be close to 50%K, which likely would be below the level at which MSY harvesting is possible.

In B.C., however, the goal is not to remove a fixed *yield* but rather a fixed percentage of the population. This is a significant distinction. As long as the harvest *rate* is conservative, the population will be harvested below the maximum sustained yield, so there is no particular concern about the population size in relation to K. The 50% of habitat capability criterion used to designate threatened populations seems appropriate from the standpoint of defining and protecting areas that have been highly disturbed or over-harvested.

The second criterion, related to a specific minimum population size, is also difficult to evaluate. The status of grizzly populations involves much more than population abundance. Other factors that should be evaluated include habitat quality and trend, distribution of bears in the GBPU and adjacent GBPUs, genetic integrity, reproductive potential, habitat fragmentation and potential linkage zones (Banci et al 1994).

The risk of extirpation is particularly high for small populations subject to extreme environmental variation, for populations at the fringe of their distribution, and for fragmented populations. Some studies have suggested that a population of at least 125 bears is necessary to maintain long-term viability (Suchy et al. 1985). However, estimates of minimum viable populations (MVP) can rarely account for the true complexity of factors affecting bear populations, both in the present and in the future (Boyce et al. 2001). With protection, very small bear populations can (Wiegand et al. 1998) and have (Swenson et al. 1995, Zedrosser et al. 2001) recovered.

Whereas there are some GBPUs with very small numbers of bears (<100) that continue to be harvested, none are considered biologically disjunct. Moreover, other criteria for closing a harvest — a kill far in excess of the allowable mortality, low bear numbers or a low reproductive rate — provide additional safeguards towards ensuring population viability.

5. Should sex-specific density dependent effects be incorporated into the harvest management strategy? If so, how?

- The maximum annual allowable total human-caused mortality for grizzly bears in B.C. is set at a maximum of 6% of estimated population size.

- This percentage is based on simulation models whose accuracy may be dependent on assumptions about density dependent compensatory mechanisms.

- If male-biased hunting increases the survival of young through compensatory mechanisms, and if this assumption is included in the model, then the calculated sustainable rate of mortality will be higher because male removal will increase cub survival.

- If male-biased hunting decreases survival of young through depensatory mechanisms, and if this assumption is included in the model, then the resulting calculated sustainable rate of mortality will be lower because male removal will decrease cub or offspring survival.

- B.C. harvest guidelines do not include density dependent effects as a consequence of harvesting biased toward male bears.

Conclusions: Scientists have claimed to find both compensatory and depensatory effects as a consequence of male removal in grizzly bear populations. McCullough (1981, 1986) and Stringham (1980, 1983) suggested that changes in male abundance might have had compensatory effects on grizzly bears in Yellowstone National Park. The mechanism behind this relationship is that adult males kill cubs, so fewer males in a population yields less male predation on cubs. Miller (1990), McLellan (1994) and Craighead et al. (1995) questioned the existence of compensatory relationships in grizzly bears. Garshelis (1994) questioned these conclusions for black bears, and Elowe and Dodge (1989) and Sargeant and Ruff (2001) found equivocal results. The existence of compensatory relationships between male removal and cub survival would make bear populations more resilient to hunting.

Wielgus and Bunnell (2000) and Swenson et al. (1997, 2001) recently suggested depensatory relationships between hunting and cub survival. The work of Wielgus and Bunnell was based on observations of sexual segregation in a lightly hunted Canadian grizzly bear population (Wielgus and Bunnell 1994a). Wielgus and Bunnell (2000) suggested that male removal by hunting creates a vacuum that is filled by immigrant males more likely to prey on cubs and that females avoid this predation by not using the best foraging habitats and consequently produce smaller litters. Swenson et al. (2001) observed clear differences in cub survival rates in two different areas of Sweden and suggested these differences resulted from disruption of social structure caused by more frequent removal of males through hunting in the area with lower cub survival. The high mortality of newborn cubs was observed two years following the death of a resident male but not one or three years following this death (Swenson et al. 2001). Bellemain et al.

(unpublished) found that increased cub mortality in this Scandinavian hunted area resulted from the killing of cubs by resident males, not by immigrant males. The depensatory mechanism reported by Wielgus and Bunnell (2000) was based on too few observations of litters to be convincing. The Scandinavian studies had real differences in cub survival between their two areas, but the differences between these areas may have explanations more parsimonious than sexually selected infanticide triggered by male removals.

Results contrary to the Scandinavian studies were found in Alaska where higher rates of cub mortality occurred in non-hunted national parks than in nearby hunted areas (Miller and Sellers 2003). Two Alaskan studies found there was no change in cub survival rates in areas subjected to increasing rates of hunting and a resulting decline in the proportion of males in the population (Miller and Sellers 2003, Reynolds 1997).

If there were a depensatory effect on cub survival related to the removal of males by hunting, it would be more conservative to include such a relationship in models designed to estimate sustainable hunting rates. However, we think that presently available data on this matter are equivocal, and therefore that hunting-related changes in density or social structure should not be incorporated into B.C. harvest management.

6. What is the significance of precise kill location data to the management of grizzly bear hunting?

- The MWLAP has collected harvest data, including kill locations, for grizzly bears through compulsory inspections beginning in 1976.

- These data take the form of precise and digitized point information that allows persons who obtain it to go directly to the immediate vicinity where kills are reported.

- It is believed that hunters and guide outfitters would be reluctant to provide accurate kill location data to the MWLAP if kill location data were routinely released to the public.

- Failure to release the data to the public leads to accusations that the MWLAP is concealing information that would indicate over-harvest of grizzly bears.

Conclusions: Precise kill location data can be useful in identifying localized areas of intensive harvest and can help interpret information on the sex and age composition of harvests. In cases where harvest is patchy on the landscape, the patches may appear over-harvested, but the population in a wider geographic area will actually be more secure than indicated by harvest composition data. Information on the precise locations of harvests may also be useful in determining shifts in the patches where hunter kills are concentrated that may result from changes in road access, hunter technology, or habitat conditions. Precise kill location data can also be used to evaluate the impacts of habitat alteration on bear abundance, distribution, and habitat use, and to identify localized areas where over-harvest may be occurring. However, all of these issues are confounded, because a non-

uniform distribution of bears may result in a "patchy" harvest but a rather uniform *rate* of harvest mortality.

Bear researchers commonly use radio-telemetry to assess the impacts of habitat alterations, road densities, and changes in human populations on bear numbers, distribution, and habitat use patterns. This approach is generally restricted to small geographic scales, largely because of logistic and financial constraints. Rossell and Livaitis (1994) used kill location data to examine the response of black bears to land use changes and were able to identify threshold densities that may be critical for managing bear populations. They suggested that kill location data might be useful, when combined with data on hunter effort and food distribution (mast abundance), in assessing the impacts of land use changes on bear populations.

Although kill locations may be useful data, they are data that must be obtained directly from hunters. Hunters may be reluctant to provide this information accurately if they believe it will result in attracting more hunters to their hunting areas, or if it will be used by those opposed to hunting to highlight potential areas of over-harvest. To the degree that hunters have this motive for misrepresenting the locations of their kills, then kill location data will be seriously compromised, and the data will become useless or, worse, misleading. It may be preferable to ask hunters to report their kill locations to small geographic areas (portions of MUs) rather than precise locations, so as not to risk losing accurate kill location data altogether. Alternatively, hunters could report precise locations, but these data would be released to the public at a lower level of resolution.

7. Are non-hunted refugia necessary to sustain populations? If so, are the size and distribution of non-hunted refugia in B.C. adequate?

- The Grizzly Bear Conservation Strategy (B.C. Government 1995b) indicates that establishing grizzly bear management areas (GBMAs), which would be closed to grizzly bear hunting, would be important for maintaining the long-term viability of grizzly bears in the province.

- The Grizzly Bear Scientific Advisory Committee, working with the MWLAP identified three types of GBMAs to facilitate grizzly bear management in the province: 1) small linkage GBMAs designed to enhance grizzly bear movement across human-caused fractures in the environment; 2) medium-sized GBMAs that would serve as protected areas within larger exploited habitats; and, 3) at least one large, benchmark GBMA within each terrestrial ecoprovince in B.C. that would not be hunted and would serve as a representative population for that ecoprovince.

- B.C. national and provincial parks, containing over 4.5 million hectares, represent a significant quantity of protected lands within the province. However, grizzly bear hunting is still permitted in some provincial parks.

Conclusions: The state of North Carolina experimented with establishing black bear sanctuaries. An analysis of one of the larger sanctuaries suggested that although bear

densities and survival were higher than on the adjacent national forest lands, the sanctuary was not large enough to provide for long-term black bear population stability (Powell et al. 1992). The size of a sanctuary appeared to be critical for ensuring the continued viability of a bear population. The location of the sanctuary within occupied habitat and its connectivity to adjacent protected areas is also important (Yerena 1998).

Grizzly bears exhibit many characteristics that make them vulnerable to changes across the landscape (Pasitschniak-Arts and Messier 2000, Sunquist and Sunquist 2001). They occur at low densities, have low reproductive rates, occupy large home ranges, and disperse over long distances (Pasitschniak-Arts 1993). Beier (1995) demonstrated that the size of the protected areas and the existence of migration corridors were important correlates in determining the probability of a population persisting through time. Several studies indicated that island populations of carnivores were more likely to go extinct in small habitat patches than in larger habitat patches (Brown 1971, Bolger et al. 1991, Newmark 1995, Woodroffe and Ginsberg 1998).

The concept of establishing large, protected GBMAs in B.C. has considerable value as a strategy for maintaining the long-term viability of grizzly bear populations, especially when accompanied by linkage zones connecting them to other occupied habitat in the province. Two large protected areas that function like GBMAs were established in the province: the Khutzeymateen in 1984 and the Kitimat River area in the 1990s. However, attempts to establish additional GBMAs and appropriate linkage zones have not been successful due to opposition from wildlife managers and user groups. Increased efforts to educate the public about the value of GBMAs may be necessary before this concept can be fully implemented in the province.

8. Do harvest data (i.e., sex and age composition, numbers) in selected areas of B.C. show any indication of population decline (i.e., over-harvest)?

- The MWLAP has collected harvest data for grizzly bears since 1976 and before. These data include the sex, as reported by hunters, and age, as determined from analysis of cementum annuli of teeth submitted by hunters. Submission of a tooth is a mandatory part of registering a hunter-killed bear.

- Hunters are prohibited from killing grizzly bears <2 years of age and adult females accompanied by young. Hunting season dates are selected to reduce female mortality in some instances. This introduces a "regulation-based" bias into the harvest data.

- B.C.'s grizzly bear harvest strategy is based on a "tracking" method rather than a "constant" effort method. The tracking method enables the MWLAP to adjust hunter numbers in relation to perceived increases or declines in estimated bear numbers. By contrast, a constant effort method would use a fixed number of hunters each year whose hunting success fluctuates with changes in grizzly bear numbers.

- Harvest allocations are set for multiple-year intervals (usually three to five years), with yearly adjustments that reflect the current status of the harvest in relation to harvest objectives for the allocation period.

Conclusions: Efforts to correlate harvest data with the status of or trends in standing bear populations have largely proved unsuccessful for a variety of reasons. However, population modeling in combination with analyses of actual bear harvest data has contributed to our understanding of the vulnerability of bear populations to hunting (McLoughlin 2003) and the sensitivity of sex and age harvest data to changes in population size (Bunnell and Tait 1980, Kolenosky 1986, Harris and Metzgar 1987a,b, Miller 1990). Some general principles are listed below along with a discussion of their pertinence with respect to harvest data in B.C.

a) Male bears are more vulnerable to harvest than females.

Male grizzly bears have consistently made up nearly two-thirds of the B.C. harvest since 1980 in all GBPUs. Subadult males in the process of dispersing are particularly vulnerable to harvest except in circumstances where hunters are strongly motivated to take large (trophy) bears. Harvests of subadult males have less demographic consequence than the harvest of any other sex-age segment of the population.

The proportion of males in the harvest varies considerably from year to year in some MUs within GBPUs. However, when data are viewed by GBPU, males dominate the harvest, even in the older age classes (see below).

b) Adult female bears are least vulnerable to hunting in jurisdictions that prohibit the killing of female bears accompanied by young.

Hunters in B.C. are prohibited from killing adult female grizzly bears accompanied by young and grizzly bears <2 years of age. Because adult females typically have offspring with them for 2.5 out of 3 years, this regulation protects the breeding female segment of the population. In addition, hunting season dates are set to minimize harvest of females. This contributes to a predominance of males in the kill of adult bears despite there being fewer adult males in the living population. This pattern is reversed only when males become so scarce that there are more legally vulnerable females than males (Fraser et al. 1982).

c) In heavily hunted bear populations, the sex ratio in the kill may approach parity in the absence of significant immigration from adjacent habitat.

The sex ratio in the harvest of grizzly bears in B.C. approaches parity in some years in some MUs. This may suggest local over-harvest in the female segment of the population, or may simply be an artifact of temporal variation in vulnerability associated with environmental conditions in the MU (e.g. Noyce and Garshelis 1997).

d) The proportion of males in the harvest will decline in each successive age class up to some age at which females dominate the harvest.

The explanation for this trend, observed commonly in bear harvest data, is that although males continue to be more vulnerable to harvest at all ages, disproportionate harvests of young males (compared to females) leaves much fewer older males (compared to females) to be harvested. In fact, the age at which females become more numerous in the harvest than males may be used as an indicator of harvest pressure (Paloheimo and Fraser 1981).

Analysis of B.C. harvest data shows no pattern in the proportion of males in the harvest when the data are pooled into five-year blocks of time. However, when data are pooled into two ten-year blocks of time, a decline in the proportion of males in the harvest by age class was evident. No consistent differences were observed for selected GBPUs from coastal B.C., the northern interior, or the southern interior of the province.

A general analysis of actual harvest data by GBPU from 1980-2000 revealed no clear indication of over-harvesting of grizzly bears in the province. On the other hand, the absence of any indication of over-harvest is inadequate evidence that over-harvest is not occurring. The possibility exists that pooling MU level data may mask the over-harvesting of grizzly bears in localized areas. It is also possible that the unknown proportion of females in unreported human-caused mortality (set at 1-2% of the population estimate for a GBPU) may result in a female harvest that exceeds the total allowable harvest of females in a GBPU. The Panel made no attempt to compare the actual harvest of bears by GBPU to the maximum allowable human-caused mortality targets set for each allocation period by the MWLAP.

C. Habitat condition and assessment

It is not possible to fully address the issues pertinent to the persistence of bear populations in B.C. without consideration of bear habitat. Harvest management and population estimation issues could be adequately addressed but populations would still decline if the habitat base on which bears depend is deteriorating. The fundamental issues of habitat loss, habitat alienation, adverse habitat changes, and increase in human access are high management priorities for the conservation of grizzly bears in B.C. Moreover, these issues have consequences for all wildlife, not just grizzly bears.

MWLAP is responsible for bear management in the province; the Ministry of Sustainable Resource Management and the Ministry of Forests are responsible for management of bear habitat on public lands, except for provincial parks. The MWLAP role in habitat management on public lands is strictly consultative. The conservation strategy makes it clear that any initiatives to “impose new land use processes or new demands on the land base” to protect bear habitat must be accomplished through existing land use initiatives. On public lands, the Ministry of Sustainable Resource Management has the final say on

land use decisions. While this is not unlike the situation in the U.S. on public lands at the federal level, where habitat management is the responsibility of the land management agency (e.g., Bureau of Land Management, Forest Service), the province appears to lack the overriding federal legislation requiring consideration of wildlife habitat needs on public lands. It is thus imperative that there be a close relationship between the wildlife managers and habitat managers. Each agency has a different mandate, organization, and legal issues with which it must contend. There are coordination problems at all levels, from the individual examining proposed land use permits, up through regional offices, to the ministerial offices where policies are developed.

Grizzly bears are distributed across the landscape at low densities. For grizzly bears, then, planning and habitat conservation and monitoring must occur at large landscape scales (Schoen 1987). The B.C. government has a comprehensive GIS mapping capability that can be used to address habitat changes across large landscapes. Appropriate use of this GIS capability is necessary to assure that grizzly bear habitat is evaluated at the proper landscape scale.

Across North America, access management is a major issue for grizzly bears and many other species of wildlife. Increased forest access can cause an increase in human-grizzly bear encounters and reductions in habitat effectiveness in the vicinity of active roads and trails. As well, grizzly bears that come into contact with humans along the urban-wild land interface are at greater risk of being killed through legal, illegal, or incidental take. In the southern regions where bear populations are considerably diminished, it is especially important to manage access effectively to minimize bear mortality. Access management should be directed at reducing grizzly bear mortality and minimizing displacement of bears from habitats subjected to human activities.

Comprehensive provincial programs that address human-bear interactions are the major means of reducing kills of grizzly bears and risks to humans. These programs need to be vigorously pursued. They can reduce mortality of bears in areas where forest management activities are ongoing, as well as in areas used for recreation. In many areas in North America, humans have demonstrated their ability to live in proximity to grizzly bears without significant problems. Such “harmony” is facilitated by programs that keep residences and other developments clean of potential food sources and patterns of human activity that reduce the potential for contacts with bears. Examples such as Kodiak, Alaska, and the country of Slovenia demonstrate that humans can coexist with bears.

C1. Habitat issues framed as questions

The Panel intended to address habitat issues more fully than is reflected in this report. However, the information we requested on the magnitude of habitat changes that have occurred or are occurring was not readily available and time constraints precluded analysis. Consequently, consideration of habitat issues is based on the literature, and is not as specific to the situation in B.C. as we intended.

1. How significant is habitat loss relative to harvest in the long-term persistence of grizzly bears?

- The biogeoclimatic zones of B.C. (Pojar et al. 1987) are extensive and all include habitats that grizzly bears may use.

- Current trends of increased numbers of bears killed in defense of life or property, especially along the southern portions of the province where bears have been considerably reduced, illustrate the need to manage access and provide better protection through public information programs.

- Grizzly bears in B.C. are currently distributed in three groups, the Southern Selkirks group, the North Cascades group, and the remaining grizzlies that are interconnected with populations across western Canada (Ross 2001). The two isolated populations are small and considered to be at risk. Grizzly bear mortality associated with grazing, mining, logging, access, recreational activities, and land alienation pose threats to maintenance and enhancement of bear populations (B.C. Government 1995a).

- Bear habitat use is highly variable and must be considered at the landscape level (Schoen 1987). Variation in habitat use by grizzly bears is evidenced by studies in southeastern Alaska (Titus et al. 1999) and central British Columbia coastal rainforests (MacHutchon et al. 1993). Avalanche chutes, old-growth forest, and alpine habitats are used extensively by bears in Alaska when salmon do not run. When salmon are present, riparian zones received the highest use. In contrast, few bears in central B.C. use alpine habitat and valley bottom habitats are exploited in all seasons. Riparian zones become important in late summer and autumn when salmon runs occur. In Alaska, clear cuts are avoided, probably because sufficient high-quality habitat away from human influence is available. Conversely, in central B.C. coastal forests, clear cuts may receive extensive use (A. N. Hamilton, personal communication). Declines in grizzly bear populations in the Owikeno River drainage over the 1998-2001 period coincided with reduced salmon runs (Himmer and Boulanger 2002) and increased logging activity and associated access.

- In the absence of significant human interference, bears seek out high quality food resources (Schoen 1987) and habitat selection will be driven by the presence of those resources. If logged areas are producing high quality berry crops, and other forage sources are either less palatable or less available, then logged areas should be used for foraging habitat given low human disturbance and proximity to suitable cover (Zager et al. 1983). This appears to be the case in the Parsnip River unit in east-central B.C., where extensive logging has created beneficial habitats for black bears with resulting substantial increases in population (D. Heard, personal communication, July 2002). Conversely, grizzly bears did not make much use of logged areas in southeastern B.C. and adjacent Montana because there was little bear food, whereas recent burns that had significant berry crops received extensive use (Zager et al. 1983, Almack 1986, McLellan and Hovey 2001a). An investigation of

species composition in burned and logged sites in the East Kootenay (Stuart-Smith 2002) found higher shrub cover in logged sites than on burns. In this case, the burns were very hot and were regenerating to dense stands of conifer, while the logged areas were left to regenerate naturally allowing more shrubs to establish, including soapberry, an important bear food. Prescribed burning following timber harvest will increase herbs and shrubs that are important for grizzly bears in the interior forests (Irwin and Peek 1979, Scrivener and MacKinnon 1989, Wittinger et al. 1977). Logging practices that include the use of prescribed fire may produce sufficient biodiversity in the subsequent understories to promote their use by bears. However, human activities in the cutting units may deter bears from using them.

- Factors that affect grizzly bear use of logged areas include the amount and variety of suitable foods and the degree of human activity that is present. Craighead and Mitchell (1982) defined four major energy sources and their general season of use. Grasses and forbs were primarily spring and summer foods, berries were summer food, and pine nuts were autumn foods. Grasses are the most stable energy source and bears will use them at all times when other energy sources are less available. Bears use animal foods at all seasons but primarily in spring when young ungulates are born and adults are weakened from winter conditions. Ungulates may be important in the diet again in autumn prior to denning. Gut piles and associated discarded parts of carcasses associated with hunting can be important food sources for grizzly bears in areas where ungulates are hunted.

Conclusions: We recognize that it is impossible to divorce the management of grizzly bear hunting from the management of grizzly bear habitat. In the face of significant habitat loss, reducing hunting quotas would accomplish little, except perhaps to slow the rate of decline due to habitat loss and degradation.. The importance of habitat to grizzly bear management is recognized in the B.C. harvest management scheme that closes MUs to hunting if the overall habitat capability declines by over 50% due to human-caused modifications. At present, 82 MUs (45%) have been closed to grizzly bear hunting while 101 MUs remain open. Closures to hunting, however, are unlikely to stem declines within individual MUs unless the ultimate causes of the decline are addressed. Hunting conducted under properly managed game management principles rarely poses a threat to bear populations; chronic habitat changes and increased human access, however, can have serious deleterious effects. One such effect is increased mortality as a consequence of increased road development and access.

It is clear that some of the habitat still occupied by grizzly bears in B.C. is badly degraded, but we were unable to determine the extent of habitat problems with the information we had available. The fact that grizzly bears still exist in 89% of historically occupied habitat in the province, however, is promising (by contrast, they exist in only 2% of their historic range in the U.S.). Although it is difficult to restore habitat to improve its capacity to sustain grizzly bears, ultimately this is easier than restoring grizzly bears to areas where bears were extirpated by habitat deterioration.

There is potential for maintaining adequate habitat in B.C. to sustain grizzly bear populations that are both healthy and viable over the long term. However, it is not clear that current trends in habitat are consistent with maintaining this capability. Multiple land use activities can be managed to maintain healthy populations of grizzly bears if these are properly coordinated. It is appropriate to be especially concerned about forest management activities because these pose problems for grizzly bears by increasing access into grizzly bear habitat and by creating situations where humans and bears come into conflict.

2. Are trends in bear mortality correlated with environmental factors such as changes in land use? Is this appropriately incorporated into the step-down process?

- The population estimation procedure used in B.C. includes an estimation of the density of bears that a given habitat could support under ideal conditions. This estimate is then "stepped down" for human influences. The first step-down accommodates factors that have reduced or potentially reduced the number of bears supported in an area as a consequence of habitat loss and alteration (termed "habitat suitability"). This result may be further "stepped down" to reflect habitat displacement and fragmentation that reduces the number of bears an area can support (termed "habitat effectiveness"). Finally, this number may be further reduced by a value intended to reflect historic human-caused mortality.

- A model proposed by Knight and Cole (1995) considers responses of wildlife to recreational activities and provides a basis for evaluating relationships. Human activity may cause changes in harvest, modify habitat, and alter behavior patterns of wildlife. Immediate responses are changes in behavior or mortality. Longer term effects on individuals include altered behavior, lower body condition, decreased productivity and death. Long term population responses include changes in abundance, distribution, and demographics. At the ecosystem level, species composition and interactions between species may be modified.

- Joslin and Youmans (1999) review the recent history of management of grizzly bears. While initial concerns were directed at mortality, subsequent concerns extended to the effects of human activities that displaced bears from important habitats as well as the associated increased mortality risk. Forest roads are considered one of the biggest effects on bear habitat use in B.C. (B.C. Government 1995a). Effects of access on grizzly bears are provided by the Interagency Grizzly Bear Committee (1987), Stein (2000), Anonymous (2001), Ross (2001), and Wielgus et al. (2002).

- The history of brown bear mortality on northeastern Chichagof Island in southeastern Alaska illustrates the effects of human access and activity on bears (Schoen 1987). Between 1961 and 1979, the annual harvest averaged 5.5 bears. After 1980, when road building and logging became common on the island, the mean harvest more than doubled to 11.8 bears per year, and during the 1985-88

period the mean harvest averaged 17.5 bears per year. The hunting season was closed and six additional kills in defense of life or property occurred. In the absence of hunting, control actions around human habitations were still killing bears.

- The southern interior ecoprovince, where grizzly populations are most threatened, has high levels of agriculture, grazing, access, recreation and land alienation (Banci 1994, B.C. Government 1995a). In the US-Canadian border area, an analysis of cause of grizzly bear deaths was conducted by McLellan et al. (1999). Between 1975 and 1997, people killed 77-85% of 73 radio-marked grizzly bears known or suspected to have died in this area. Of these, 22% were legal sport kills, almost all in B.C., where sport kills constituted about half of the known mortalities to radio-collared bears. Other major causes of mortality were control killing (22%), poaching (10%), self-defense (8%), misidentification (26%), and malicious killing (10%).

- Grizzly bears are adaptable creatures and the degree to which they respond behaviorally to human influences may vary. Extrapolation of results and recommendations from one area to another may be imperfect (Morrison 2001). Nevertheless, all investigations indicate that active road systems cause grizzly bears to use adjacent areas less than if the road system was absent. Notwithstanding the variation in how this differs between areas, the collective work on this topic lends strength to the fundamental conclusion that access generally displaces grizzly bears.

- Wielgus et al. (2002) review several investigations that show the variability in grizzly bears' response to the presence of roads. Displacement of female bears towards roads was noted in Yellowstone National Park (Mattson et al. 1987), and the Flathead River, B.C. (McLellan and Shackleton 1988, 1989). Wielgus et al (2002) found that adult males used closed roads while adult females selected against closed roads. The distances over which bears select against road systems has ranged from 100 m to <900 m, depending on vegetative cover. Neither sex of grizzly bears selected against roads that had access restricted to forestry operations, and that were closed to the public (Wielgus 2002).

- Mechanisms by which bears learn to reduce activity near humans are associated with the disturbance that occurs during encounters. Considering the long history of interactions between grizzlies and humans, it is logical to assume that bears associate humans with “danger.” In most cases, interactions result in circumstances that cause the bear to leave an area. During summer in Yellowstone National Park, Mattson et al. (1987) calculated that reductions in adult female habitat use near human facilities and roads resulted in a loss of habitat sufficient to support 15% of the estimated female population of 30 animals.

Conclusions: The issues identified in the step down process as adjustments to habitat capacity due to habitat changes are appropriate. As noted elsewhere in this report, the actual parameter values and assumptions made in each step have not been made explicit or accessible. Even when these parameters are necessarily subjective, the process used in making step-downs for these factors should be standardized and documented.

It is important to recognize that changes in land use that lead to increased mortality can be mitigated to a significant degree by training and education programs. We view programs such as B.C.'s Bear Smart Community Program as essential to minimizing mortality associated with land use changes. The survival of grizzly bears throughout much of their original range in B.C. is an indication that the province still has the potential to address the habitat needs of grizzly bears adequately and to perpetuate healthy, viable populations throughout much of the province.

3. Where are the major areas of habitat fragmentation in the province, and what are the effects on bear populations?

- The southern interior ecoprovince is the area that shows the greatest habitat fragmentation. The two isolated grizzly bear populations that are classified as threatened are within this province. Habitat fragmentation is in large measure responsible for this situation.

- Recent work by Proctor et al. (2002) demonstrates that highways are very effective at restricting bear movements and fragmenting habitat. Proctor used DNA evidence to study movements of grizzly bears across Highway 3 in southeastern B.C. and found a high degree of isolation between populations on the north and south sides of the highway. Similar genetic isolation was not found across an ecologically similar valley in the North Fork of the Flathead where a highway was not present. Proctor et al. (2002) suggested that, in addition to avoidance of the highway itself, increased human kills of bears may have contributed to the fragmentation along the highway corridor.

Conclusions: The southern interior ecoprovince, where grizzly populations are most threatened, has high levels of agriculture, grazing, access, recreation and land alienation (Banci 1994, B.C. Government 1995a). Populations that are fragmented and isolated from neighboring populations are potentially subject to inbreeding. Since these fragmented populations are typically small, perhaps the most serious short term concern is that they will be exterminated as a consequence of small population demographic and environmental stochasticity. The pattern of extermination of populations in the U.S. clearly shows that when populations become fragmented and isolated, they shrink numerically and are subject to extirpation (Mattson and Merrill 2002).

4. Is the administrative structure for habitat management in B.C. adequate to ensure long-term persistence of grizzly bears?

- In B.C., MWLAP is responsible for wildlife population management, while the Ministry of Forests is responsible for land management, and the Ministry of Sustainable Resource Management coordinates land use planning. Coordination between the population and the habitat managers is necessary to manage wildlife, including the grizzly bear, correctly.

- The Forest Practices Code of B.C. Forest Act of 1998, as amended in 2000, authorizes the Ministry of Forests to regulate forest roads and habitats. Regulations for forest roads include provisions for revegetation of inactive borrow pits, waste areas, road cuts, fill slopes and other disturbed areas. Provisions for revegetating areas include a two-year period after completion, modification, or deactivation of a road. Provisions for deactivating roads include stabilization to prevent erosion and restoration to allow fish passage. Deactivation must not adversely affect forest resources and must be accommodated without additional expenditure. Road construction or modification in wildlife habitat areas must be done in accordance with measures intended to reduce effects on wildlife.

- Mattson and Merrill (2002) concluded that the management practices taken to reduce mortality and protect habitat in the Yellowstone National Park region have contributed to an increase in grizzly bear populations. Changes in access management, improved sanitation around human habitations, and information and education programs have all contributed to population increases. In the United States, the Endangered Species Act provides the impetus for these actions (Mattson and Merrill 2002). Land management agencies have developed programs and plans to enhance habitat management and are responsible for carrying them out.

- An example of a land use plan that considers grizzly bear habitat is the Kootenay-Boundary Land Use Implementation Strategy (1999). General measures call for conserving critical feeding and breeding habitats, ensuring bear access to these habitats, managing access, using timber harvest and silviculture methods that sustain bear food production, avoiding residential and recreational conflicts, eliminating landfills and other sanitation sources, using landscape-level forest ecosystem networks and providing for dispersal corridors between populations. Critical areas are defined as post wildfire shrubfields, avalanche chutes, alpine meadows, riparian habitats, wet seeps and others as may be identified. Recommendations for forest management suggest using methods that enhance food sources for bears. These include variation in size and arrangement of cuts, screening cut areas from roads by leaving strips of trees, and avoiding areas adjoining meadows or other foraging areas for bears. Partial cutting systems that benefit some herbs and shrubs used by bears are also recommended. These recommendations follow the published work from the ongoing Flathead grizzly bear research program.

- It is apparent that land use plans and the Forest Practices Code of B.C. consider grizzly bears and recommend practices that will benefit them. These plans and practices are of recent origin and are only now being implemented, to varying degrees. Managing access is highly controversial. Forest managers require access to tend stands and protect against fire. Recreationists use forest roads for travel with ATVs, snowmobiles, and other motorized vehicles and as access to trap lines, scenery, fishing and hunting. Legal measures to limit access have rarely been implemented in B.C. (J.B. Nyberg, personal communication 12 July 2002).

- Use of prescribed fire for site preparation following logging has declined in recent years, primarily because of costs.

Conclusions. Knowledge is available to coordinate forest management activities with grizzly bear and other wildlife habitat needs, and a legal basis for doing so is in place. The final analysis comes down to how the knowledge and the policies are carried out.

At present, access is not uniformly managed to accommodate bear populations. There is little assurance that bear habitat, and therefore wildlife habitat in general, will always be given all due consideration in management activities. Conservation areas that can be managed specifically for their wildlife values may be needed to effectively maintain distribution of viable populations of grizzly bears.

IV. MANAGEMENT IMPLICATIONS

A. Estimation of grizzly bear numbers

Wildlife agencies can and do manage harvests of grizzly bears without having precise population estimates. Such harvesting can be sustainable if harvest pressure is low, but some monitoring of population trend would be desirable to safeguard against over-harvest. However, trend monitoring is exceedingly difficult for most bear populations, in fact generally more difficult than population estimation. Hence, a more practical management approach is to estimate population size and restrict the harvest to a small proportion of the population, based on the expected productivity (recruitment rate). This is the procedure followed in B.C.

The overarching difficulty with the B.C. approach is in estimating population size for areas encompassing the entire province. Further, the harvest must be managed within smaller areas within the province (i.e., LEHs), so reliable population estimates are needed for these many areas, not just the province as a whole. Conceivably mark–recapture estimates (e.g., based on radio telemetry or DNA from hair samples) could be obtained for each individually managed area, but this is impractical given the expense of obtaining such estimates. A more practical, albeit less accurate, approach is to base population estimates on the quantity and quality of existing habitat. It is well accepted that bear density varies with habitat, so it should be possible to exploit this relationship to estimate density from habitat information. We believe that the MWLAP has made a good start in that direction through their F-D methodology.

We have identified several shortcomings of the F-D methodology, but these should not be construed as a general condemnation of the habitat-based approach for population estimation nor of the MWLAP's attempt to employ this approach in bear harvest management. We believe that the MWLAP has made an appreciable effort to consider the innumerable habitat factors that may influence grizzly bear density, especially in the F-D step-down process, and to check the results of their habitat-based population estimation with mark–recapture studies. Moreover, biologists in B.C. pioneered an innovative mark–

recapture technique (based on hair snagging), and then applied it in several areas to check results from the F-D process. Our principal criticism is that the F-D process has not been modified (calibrated) in accordance with the results of these mark–recapture estimates. This calibration will necessitate more mark–recapture studies in a variety of habitats, spanning the spectrum of bear densities.

A major obstacle in calibrating the F-D procedure, however, is its inherently subjective nature, leading to inconsistent applications across the province. There is a need to provide standardized guidelines for managers involved in the F-D process to help minimize this subjectivity. As an example, these guidelines might indicate the magnitude of the step-down for various types of roads.

A particularly subjective, yet important, step in the F-D process regards the step-down for historic human harvest. Although records exist on numbers of bears killed over the years, there is no standardized methodology for ascertaining how these mortalities may have affected current population size. Clearly, a more objective demographic modeling step needs to be incorporated into the process.

Whereas we support the use of a habitat-based approach to estimate bear numbers in B.C., we are concerned that there may be no way to sufficiently reduce the extent of subjectivity in the current approach. Resource selection functions (RSF) (Boyce and McDonald 1999, Manly et. al. 2002) provide a more rigorous approach for estimating bear density within MUs based on habitat attributes and other disturbance factors commonly available in GIS. The RSF approach has an advantage over the F-D method in that it enables the direct use of data on both positive and negative habitat attributes and actual bear use.

We believe that the most logical process for investigating RSF is in conjunction with the recalibration efforts described above. In particular, opportunities exist for analyzing habitat use data from the long-term study of bears in the Flathead and from DNA mark-recapture studies. With minor changes in the protocol for the DNA studies, the data could be used for estimating both population size and RSF.

One important modification of this application of RSF for B.C. is the need to incorporate historic harvest data. Two areas with virtually identical habitat attributes could have vastly different bear densities due to different levels of past harvests. It would be advisable initially to calibrate RSF with DNA-estimated bear density in areas subjected to low levels of harvest but varying degrees of other human impacts.

Regardless of which habitat-based system is used, we believe that all facets of bear management, including calculation of allowable harvest, should employ the most accurate population estimates, not scaled-down “conservative” estimates. Currently, the MWLAP attempts to use population estimates scaled downward by 1 SE to incorporate the uncertainty in these estimates, thus providing a safeguard against over-harvest due to overestimation of population size. This system can be confusing in that population estimates used in management are not the same estimates that would be used, for example, in a scientific investigation. Moreover, it is unclear whether estimates scaled down by 1

SE provide a sufficient degree of conservatism in harvest management. A more defensible and straightforward approach would be to incorporate all of the uncertainties in the process in determining a harvest rate. That is, instead of attempting to be conservative by scaling down population estimates, it would be preferable to include conservatism by scaling down the allowable harvest rate. The harvest rate could then be manipulated, if necessary, to be more conservative, while the estimate of population size would remain as a true reflection of the best available information.

B. Risk management in grizzly bear harvests

Because of grizzly bears' low reproductive rate and low density, extraordinary caution must be exercised in harvesting them. Nevertheless, the Panel concludes that the harvest of grizzly bears in B.C. can be managed on a sustainable basis, with minimal risk of population declines. One important improvement in the current system would be to incorporate the effect of uncertainty in population parameters when calculating quota allocations. The current scale of allowable harvest (3% to 6% per year) has been derived from population models that did not include sampling error as a distinct source of uncertainty in parameter values. Recent population models on bears (e.g., McLoughlin et al. 2002, McLoughlin 2003) incorporate all the sources of uncertainty: demographic stochasticity, environmental stochasticity, and sampling errors in demographic parameters. The general approach is based on risk management analyses (Taylor et al. 2001), a special type of population viability analysis (Boyce et al. 2001) for harvested systems.

Sampling error in population size and vital rates leads to uncertainty in the sustainability of quota allocations. In essence, the acknowledgement that the input data are imprecise actually forces managers to be more conservative in their harvest policies. McLoughlin (2003) showed that a moderate reduction in harvest rate, below the rate suggested when sampling error is ignored, decreases the risk of unexpected population declines to negligible levels.

Sampling error in initial population size is particularly important in terms of risk of population declines following implementation of a quota system (McLoughlin 2003). This finding represents a strong justification for giving a higher priority to securing precise estimates of population size than to securing precise estimates of reproduction and survival parameters. Precise estimates of survival rates are notoriously difficult to achieve (McLellan et al. 1999).

Some controversy exists over both the usefulness and availability of data concerning the exact locations of grizzly bear kills for assessing areas of over-harvest. The issue has been raised as to whether the MWLAP should release this information to persons requesting to evaluate it. The MWLAP has resisted releasing these data on the grounds that this would result in hunters and outfitters providing misleading information about where kills were made, and would also represent a violation of the implicit agreements under which the data were obtained. The refusal to release these data has been portrayed by those requesting them as an effort by the MWLAP to obfuscate evidence of overharvests. We believe it is plausible that misrepresentation of kill location data will increase if hunters

and outfitters know this information will be released, but we have no basis for judging the extent of this. Reliable information on kill locations, at least to the level of general geographic region has significant utility for managers; however, we believe that data on precise geographic location is of little value in indicating over-harvests at the MU or LEH level. Such data are primarily useful to managers for identifying local management concerns: for example, in highlighting the need for restricting access to areas where bears may be especially vulnerable or identifying shortcomings of administrative boundaries.

A sound conservation strategy for a species like the grizzly bear is by nature multi-faceted, consisting of a suite of protective measures. B.C. has instituted several of these. First, these measures strive to ensure that females do not comprise more than 30% of the total allowable human-caused mortality; this represents a very effective protective measure. Second, they fully protect females accompanied by cubs as well as these dependent cubs; this ensures continued population productivity. Third, the presence of a network of protected areas without bear hunting offers a safeguard against errors in quota allocations in neighbouring areas. Fourth, the presence of explicit closure criteria for grizzly bear hunting in cases of high levels of human disturbance or small isolated populations represents an important measure for conserving declining populations. Fifth, consideration of unreported mortality sources in the process of quota allocations is a conservative measure to avoid over-harvest. As an additional safeguard, the Panel suggests that the scale of allowable human-caused mortality be adjusted downward to account for uncertainty in the population parameters.

Overall, the Panel concludes that current protective measures, combined with some additional measures listed in the recommendations section of this report offer a robust conservation strategy for grizzly bears. Our confidence in this conservation strategy is enhanced by the recognition that the B.C. government has access to a group of engaged and qualified professionals that are committed to the long-term conservation of grizzly bears. Accordingly, we do not see any justification for imposition of a ban on imports of bears (e.g., by the European Union) that are legally harvested in B.C.

C. Administrative process for managing grizzly bears

Grizzly bear hunting in British Columbia has become a controversial issue. In part, this is because a complicated process is followed to develop harvest quotas, and components of the process are both subjective and obscure to outside parties interested in the issue. In the Panel's own efforts to evaluate this system we were frustrated by the difficulty of obtaining detailed information, especially for the implementation of the F-D step-down procedure. The input parameters were not available in a centralized database or in reports, so it was difficult, and sometimes impossible, to obtain them. The regional biologists in different regions appear to make different assumptions about the importance of various parameters but this was difficult to document.

The Panel believes that the regional biologists should better document the process and assumptions they make in deriving the population estimate used to set the quota. We suggest that they prepare a periodic report in which the values used in deriving the

population estimate and step-downs or step-ups from this estimate are both justified in writing and clearly available to all who are interested. We further suggest that an appropriate schedule for this report would be the same as the allocation period used for setting the quotas (every three years). We acknowledge that providing this information will afford an opportunity for critics of grizzly bear hunting in B.C. to challenge many of the assumptions made and parameters used. Regardless, we believe that more openness will lead to better acceptance of the process employed to set hunting quotas.

The allocation of harvest quotas based on habitat type and human-influenced changes in habitat capability can be no better than the information (input) used to make the individual decisions in each step of the process. If the information is wrong, then the conclusions drawn from that decision will also be wrong. If an area is logged, burned, or crisscrossed with roads, then these actions will and should influence the quota set for the next allocation period. If the data on these impacts are not regularly updated in time for them to be used in making new harvest allocation decisions, then the likelihood is increased that errors in the setting of quotas will result. Impacts that happen quickly can abruptly change the capability of the habitat to sustain bears and use of old data will not account for these changes. If changes such as increased access or abrupt declines in salmon runs occur, then over-harvests are more likely to occur. Habitat information should be updated immediately preceding the review of quotas for the next allocation period.

B.C. faces significant challenges in managing grizzly bears because of the way responsibilities are separately allocated to the MWLAP and the Ministry of Forests. The ability of the MWLAP to accomplish its mission with respect to grizzly bears and other wildlife species requires the active cooperation of the Ministry of Forests and Ministry of Sustainable Resource Management. This is because decisions on whether and how habitat modifications occur are not under MWLAP control. The mission of the MWLAP will not and can not be accomplished unless these other ministries are active participants in managing the habitat in ways that address the requirements of grizzly bears. If the agency managing the habitat looks at its mission as one of maximizing the production of wood products without regard to the habitats wildlife require on the same landscapes, these landscapes will cease to be areas where wildlife can survive in viable numbers. The format for this collaboration is beyond the scope of this Panel; however, the Panel would be remiss in its obligation under our terms of reference not to identify it as an issue in need of solutions to avoid conflicting missions by different ministries. Based on past history on both sides of the border, such a conflict in missions, if not addressed explicitly, is unlikely to be resolved in ways that benefit grizzly bears.

The MWLAP has a laudable province-wide population objective for grizzly bears. Actions that promote or detract from this goal, however, are made at a more local level. There can be little likelihood that a province-wide goal will be achieved if the bulk of decisions made at a local level are inimical to achieving the goal. Agencies or persons proposing actions that are locally unhelpful in attaining the overall provincial goal can assume that progress toward the goal will be made “elsewhere.” We believe that formal planning at a local level must specifically recognize the needs of grizzly bears and other wildlife species or, in some cases, clearly acknowledge these as conflicting with the

desired outcome. To avoid building a narrow basis of support for wildlife conservation activities, this planning process should find ways to accommodate as wide a variety of potential uses of wildlife resources as possible. In the case of grizzly bears, for example, the planning process should acknowledge and accommodate the development of bear-viewing opportunities as a source of revenue for British Columbians as well as a way of building a constituency for bears. In many places, both consumptive and non-consumptive uses of bears may be compatible. In other places they may be incompatible and, where this occurs, choices will have to be made between these uses. We believe that it is desirable for the provincial government to provide regional offices with guidelines on how to conduct this planning, especially with regard to issues such as the interaction between hunting and bear-viewing activities.

D. Habitat issues related to grizzly bears

The problems of harvest management and population estimation must be addressed in the context of habitat. The fundamental issues of habitat alienation, adverse habitat changes, and the resulting increase in human access, are high management priorities for the conservation of grizzly bears in B.C. Whereas this report focuses on the grizzly bear, these issues have consequences for all wildlife.

For species like the grizzly bear that are distributed across the landscape at low density, planning at landscape levels is important. The B.C. government has a comprehensive capability in GIS mapping that can be used to address habitat changes across large landscapes. This capability will help to ensure that grizzly bear habitat is given consideration at the scale that is most suitable.

Management of access is a major issue across North America. Efforts to manage access in B.C. will benefit many species of wildlife as well as grizzly bears. Increased forest access can cause an increase in human-grizzly bear encounters and a reduction in habitat effectiveness in the vicinity of active roads and trails. Furthermore, grizzly bears that come into contact with humans along the urban-wild land interface are at greater risk of being killed. In the southern regions where bear populations are considerably diminished, it is especially important to minimize bear mortality by managing access effectively.

V. RECOMMENDATIONS

The Panel feels that there is room for improvement in the grizzly bear management system as currently implemented in B.C. The Panel members are unanimous in supporting the following recommendations; they are grouped in sections but presented in no particular order.

A. Estimation of grizzly bear numbers

1. The Panel recommends that the MWLAP recalibrate the scale of densities associated with the various habitat categories (i.e., habitat capability rating) by using additional benchmark density estimates, especially for habitat categories three to five. Benchmark density estimates must be based on rigorous sampling designs such as mark-recapture models for open populations. An effort should be made to secure "replicates" for each of the habitat categories, resulting in a single reference density per habitat category. Further, the calibration should be based on the (point) estimate of density, not the estimate minus 1 SE.

2. The Panel recommends that the MWLAP explore the possibility of using resource selection functions (RSF) to assess bear density by MUs based on habitat attributes and other disturbance factors. It would be advisable to develop RSFs through studies in areas with a range of average habitat capabilities. RSFs can be developed and applied with far less subjectivity than the F-D method of assessing bear density.

3. The Panel recommends fully documenting and standardizing the basis for the rating of the final step-down in the F-D process, concerning "human-caused mortality." Ideally, the rating should be based on a demographic model to assess the effect of past harvests and the sex/age ratio of such harvests.

4. The Panel recommends that the MWLAP take steps to ensure consistencies in the application of the F-D step-down process relative to habitat changes. The goal should be to develop standardized, well-documented protocols that will be applied in a systematic way for all MUs. Considering this, protocols should be applied province-wide, and the central office should play a pivotal role in coordinating and assuring continuity and consistency in implementing policies.

B. Risk management in grizzly bear harvests

1. The Panel recommends that the MWLAP assign higher priority to securing precise population size estimates, than to securing precise vital rate estimates. Sampling error in population estimates are particularly important in terms of risks of population decline due to over-harvest, especially under a LEH system.

2. The Panel recommends that the MWLAP acknowledge the effect of sampling error on estimates of population size and vital rates when establishing maximum

allowable human-caused mortality rates. Instead of attempting to incorporate uncertainty into population estimates (e.g., by reducing estimates by the equivalent of 1 SE), we recommend including effects of this uncertainty in the scale of maximum allowable human-caused mortality. Until better information becomes available, we recommend that the upper end of the current scale be reduced by 1% (i.e., from 6% to 5%) to ensure that it captures the full extent of uncertainty.

3. The Panel recommends that the scale used to determine the level of allowable human-caused mortality be matched to the current habitat conditions of a MU (and hence the actual productivity of resident grizzly bears), not the potential habitat capability without human disturbances (as is currently the case).

C. Administrative process for managing grizzly bears

1. The Panel recommends that regional biologists prepare a report describing the procedure used for estimating population sizes and quota allocation in MUs for each allocation period, including justification of parameters (e.g., F-D step-down). The report should include all information used in estimating population sizes and harvest allocations, as well as documentation of model assumptions, model outputs, and other data that were considered (e.g., trend information, demographic data, etc.).

2. The Panel recommends that management boundaries be revised as necessary so that each LEH zone is contained wholly within a MU and each MU contained wholly within a GBPU. There should be a direct correspondence between the unit base used for calculating an allowable quota and the area where the quota is used. Hunting statistics should be compiled at the LEH level, but they can be summarized at the GBPU level.

3. The Panel recommends that GIS layers for land use and land condition attributes be updated prior to each allocation period to ensure that the latest habitat information is used in estimating populations and allowable harvest rates.

4. The Panel recommends better joint planning between the Ministry of Forests, Ministry of Sustainable Resource Management, and the MWLAP. For example, the MWLAP should ensure that land use planning initiatives by the Ministry of Forests reflect the needs of wildlife in general, and the needs of grizzly bears in particular, within a context of ecosystem management.

5. The Panel recommends the establishment of management objectives for bear populations (i.e., GBPUs) using a formalized planning process. Management objectives should recognize that both hunting and non-consumptive uses are acceptable. Province-wide guidelines should be developed to guide this planning process, especially with regard to the interaction between hunting and bear-viewing activities.

D. Habitat issues related to grizzly bears

1. The Panel recommends that the MWLAP aggressively address human access into B.C.'s wild lands, not only to reduce grizzly bear mortality more effectively, but also to manage other species of wildlife that are sensitive to human activity such as elk and caribou. A program established cooperatively by the Ministry of Forests and MWLAP to manage access by motorized vehicles is needed. Restrictions of motorized vehicles in time and space should be a part of this program. When timber harvest is contemplated in largely roadless areas, programs to restrict access are needed.

2. The Panel recommends that the MWLAP pursue opportunities to encourage use of prescribed burning of some portions of logged areas to enhance habitat for grizzly bears. Intensive forest management activities that expedite conifer regeneration and minimize the amount of time that associated shrubs and herbs are present following logging reduce the habitat potential for grizzly bears; this should be considered in the development of forestry programs. This recommendation is particularly applicable to interior forests.

3. The Panel recommends that the MWLAP implement the provision of the Grizzly Bear Conservation Strategy relative to the establishment of a Grizzly Bear Management Area within each bioclimatic region of the province. This should include provisions for maintaining connectivity between grizzly bear populations to facilitate movements.

E. Research needs regarding grizzly bears

1. The Panel recommends that the MWLAP pursue efforts to develop an efficient method for monitoring population trend with limited resources. Such trend data would be most important for populations at elevated risk of decline due to over-harvest, severe habitat loss, or isolation.

2. The Panel recommends that the MWLAP initiate a study to quantify the representation of cubs-of-the-year in population estimates based on DNA from barbed wire hair-snags.

3. The Panel recommends that the MWLAP attempt to assess the magnitude and sex ratio of unreported human-caused bear mortalities.

4. The Panel recommends that the MWLAP undertake further risk assessment analyses in order to guide grizzly bear management policies, taking into account uncertainty in population parameters. In particular, there is a need to evaluate the actual relationship between grizzly bear productivity (which is directly related to the maximum allowable human-caused mortality) and the average habitat quality in a MU.

VI. LITERATURE CITED

Almack, J.A. 1986. Grizzly bear habitat use, food habits, and movements in the Selkirk Mountains, Northern Idaho. Pages 150-157 *in* G.P. Contreras and K.E. Evans, compilers. Proceedings: grizzly bear habitat symposium. USDA Forest Service General Technical Report INT-207.

Anonymous. 2001. Proceedings of Managing roads for Wildlife. Sponsored by Yellowstone to Yukon Conservation Initiative, Wildlands Center for Preventing Roads, and Canadian Parks and Wilderness Society. Crowsnest Pass, Alberta. 105 pp.

Apps, C.D., B.N. McLellan, J.G. Woods, and M.F. Proctor. 2000. Estimating grizzly bear distribution and abundance relative to habitat and human influence. Unpublished manuscript. Aspen Wildlife Research, Calgary.

Austin, M.A. and A.N. Hamilton. 2002. A review of grizzly bear harvest management in British Columbia. Prepared for the information of the British Columbia Grizzly Bear Scientific Panel. Biodiversity Branch, Ministry of Water Land and Air Protection, Victoria, British Columbia. 28 pp.

Ballard, W.B., and D. Larsen. 1987. Implications of predator-prey relationships to moose management. Swedish Wildlife Research Supplement 1, Part 2: 581-602.

Banci, V. 1991. The status of the grizzly bear in Canada in 1990. Unpublished Status Report, COSEWIC. 171 pp.

Banci, V., D.A. DeMarchi, and W.R. Archibald. 1994. Evaluation of the population status of grizzly bears in Canada. International Conference on Bear Research and Management 9: 129-142.

B.C. Government. 1995a. Conservation of grizzly bears in British Columbia: background report. Ministry of Environment, Lands and Parks.Victoria. 70 pp.

B.C. Government. 1995b. A future for the grizzly: British Columbia grizzly bear conservation strategy. Ministry of Environment, Lands and Parks.Victoria. 15 pp.

B.C. Government. 1996. Wildlife Harvest Strategy, improving British Columbia's Wildlife Harvest Regulations. British Columbia Ministry of Environment, Lands and Parks. Wildlife Program. 72 pp.

B.C. Government. 1999. Procedure manual: grizzly bear harvest management. British Columbia Ministry of Environment, Lands and Parks. Wildlife Program. 8 pp.

Beddington, J.R. and R.M. May. 1977. Harvesting natural populations in a randomly fluctuating environment. Science 197: 463-465

Beier, P. 1995. Dispersal of juvenile cougars in fragmented habitat. Journal of Wildlife Management 59: 228-237.

Berg, R.L., L.L. McDonald, and M.D. Strickland. 1983. Distribution of mountain lions in Wyoming as determined by mail questionnaires. Wildlife Society Bulletin 11: 265-268.

Berger, J., P. B. Stacey, M. L. Johnson, and L. Bellis. 2001. A mammalian predator-prey imbalance: grizzly bear and wolf extinction affects avian neotropical migrants. Ecological Applications 11: 947-960.

Blower, D. 1977. Statistics from April 1977 grizzly bear distribution and relative abundance map. In Preliminary grizzly bear management plan for British Columbia, Fish and MWLAP, Ministry of Environment.

Bolger, D.T., A.C. Alberts, and M.E. Soule´. 1991. Occurrence patterns of bird species in habitat fragments: sampling, extinction and nested species subsets. American Naturalist 137: 155-166.

Boulanger, J., and A.N. Hamilton. 2002. A comparison of DNA mark-recapture and Fuhr-Demarchi/step-down population and density estimates for grizzly bears in British Columbia. Integrated Ecological. Research, Nelson, B.C.

Boulanger, J., and B. McLellan. 2001. Closure violation in DNA-based mark-recapture estimation of grizzly bear populations. Canadian Journal of Zoology 79: 642-651.

Boulanger, J., G.C. White, B.N. McLellan, J. Woods, M. Proctor, and S. Himmer. 2003. A meta-analysis of grizzly bear DNA mark-recapture projects in British Columbia, Canada. Ursus 13, in press.

Boyce, M.S. 1992. Population viability analysis. Annual Review of Ecology and Systematics 23: 481-506.

Boyce, M.S., B.M. Blanchard, R.R. Knight, and C. Servheen. 2001. Population viability for grizzly bears: a critical review. International Association on Bear Research and Management. Monograph Series No. 4. 39 pp.

Boyce, M.S. and L.L. McDonald. 1999. Relating populations to habitats using resource selection functions. Trends in Ecology and Evolution. 14: 268-272.

Boyce, M.S., and J.S. Waller. 2003. Predicting grizzly bear recovery for the Bitterroot ecosystem. Wildlife Society Bulletin, submitted.

Brown, J. H. 1971. Mammals on mountaintops: nonequilibrium insular biogeography. American Naturalist 105: 467-478.

Bunnell, F.L. and D.E.N. Tait. 1980. Bears in models and reality - implications to management. International Conference on Bear Research and Management 4: 15-23.

Bunnell, F.L. and D.E.N. Tait. 1981. Population dynamics of bears-implications. Pages 75-98 *In* D.W. Fowler and T.D. Smith. editors. Dynamics of large mammal populations. John Wiley and Sons, NY.

Caughley, G. 1994. Directions in conservation biology. Journal of Animal Ecology 63: 215-244.

Clark, J.D., D. Huber, and C. Servheen. 2003. Bear reintroduction: lessons and challenges. Ursus 13: in press.

Cowan, I. McT. 1972. The status and conservation of bears (Ursidae) of the world – 1972. International Conference on Bear Research and Management 2: 343-367

Craighead, J.J., and J.A. Mitchell. 1982. Grizzly bear (*Ursus arctos*). pp 515- 556 *in* J.A. Chapman and G.D. Feldhamer, editors. Wild mammals of North America. Johns Hopkins University Press. Baltimore, Maryland.

Craighead, J.J., J.S. Sumner, and J.A. Mitchell. 1995. The grizzly bears of Yellowstone: their ecology in the Yellowstone Ecosystem, 1959-1992. Island Press, Washington DC.

Crête, M., D. Vandal, and L.P. Rivest. 1991. Double counts in aerial surveys to estimate polar bear numbers during the ice-free period. Arctic 44: 275-278.

Dean, F.C. 1976. Aspects of grizzly bear population ecology in Mount McKinley National Park. International Conference on Bear Research and Management 3: 111-119.

de Leeuw, A.D 1997. Conflicts and interests in British Columbia bear management. Terrace, B.C

de Leeuw, A.D. 1998. Limiting hunter entry in British Columbia bear management. Terrace, B.C.

de Leeuw, A.D. 1999. Grizzly overkill in British Columbia bear management. Terrace, B.C.

de Leeuw, A.D. 2001. Just kill in British Columbia bear management. Terrace, B.C.

Demarchi, D.A., R.D. Marsh, A.P Harcombe, and E.C. Lea. 1990. The Environment, Ecoregions of British Columbia. pp 55-144 *in* R.W. Campbell, N.K. Dawe, I. McT. Cowan, J.M. Cooper, G.W. Kaiser and M.C.E. McNall. Birds of British Columbia, volume One: Nonpasserines. Introduction, Loons through Waterfowl. Royal British Columbia Museum, Environment Canada and Canadian Wildlife Service. 514 pp.

Eberhardt, L.L. 1990a. Using radio telemetry for mark-recapture studies with edge effects. Journal of Applied Ecology 2: 259-271.

Eberhardt, L.L. 1990b. Survival rates required to sustain bear populations. Journal of Wildlife Management 54: 587-590.

Elowe, K.D. and W.E. Dodge. 1989. Factors affecting black bear reproductive success and cub survival. Journal of Wildlife Management 53: 962-968.

Fischer, H., and M. Roy. 1998. New approaches to citizen participation in endangered species management: recovery in the Bitterroot Ecosystem. Ursus 10: 603-606.

Frankel, O.H., and M.E. Soulé. 1981. Conservation and evolution. Cambridge University Press, Cambridge. 327 pp.

Fraser, D., J.F. Gardner, J.F. Kolenosky, and S. Strathearn. 1982. Estimation of harvest rate of black bears from age and sex data. Wildlife Society Bulletin 10: 53-57.

Fuhr, B.L., and D. A. Demarchi. 1990. A methodology for grizzly bear habitat assessment in British Columbia. Wildlife Bulletin B-67. Ministry of Environment, MWLAP. 28 pp.

Garshelis, D.L. 1990. Monitoring effects of harvest on black bear populations in North America: A review and evaluation of techniques. Eastern Workshop. Black Bear Research and Management 10: 120-144.

Garshelis, D.L. 1992. Mark-recapture density estimation for animals with large home ranges. Pages 1098-1111 *in* D.R. McCullough and R.H. Barrett, editors. Wildlife 2001: populations. Elsevier Applied Science, London.

Garshelis, D.L. 1993. Monitoring black bear populations: pitfalls and recommendations. Western Black Bear Workshop 4:123-144.

Garshelis, D. L. 1994. Density dependent population regulation of black bears. Pages 3-14 in M. Taylor, editor. Density-dependent population regulation in black, brown, and polar bears. International Conference on Bear Research and Management Monograph Series No. 3.

Garshelis, D.L., P.L. Coy, and B.D. Kontio. 1993. Applications of remote animal-activated cameras in bear research. Proceedings of the International Union of Game Biologists Congress 21(1):315-322.

Garshelis, D.L., and L.G. Visser. 1997. Enumerating megapopulations of wild bears with an ingested biomarker. Journal of Wildlife Management 61: 466-480.

Gniadek, S.J., and K.C. Kendall. 1998. A summary of bear management in Glacier National Park, Montana, 1960-1994. Ursus 10: 155-159.

Guide Outfitters Association of British Columbia. 2001. Support for scientific management of grizzly bears in British Columbia: a Guide Outfitter perspective. Report submitted to the B.C. Grizzly Bear Scientific Panel, Richmond, B.C. 27 pp.

Hamilton, A.N. and M. A. Austin. 2001. Grizzly bear harvest management in British Columbia: background report. Prepared for the information of the British Columbia Grizzly Bear Scientific Panel. Biodiversity Branch, Ministry of Water Land and Air Protection, Victoria, British Columbia. 72pp.

Harris, R.B. 1986a. Grizzly bear population monitoring: current options and considerations. Montana Forest and Conservation Experiment Station University of Montana, Missoula Misc. Publ. 45. 80 pp.

Harris, R.B. 1986b. Modeling sustainable harvest rates for grizzly bears. Appendix K. Pages 268-279 *in* A.E. Dood, R.D. Brannon, and R.D. Mace, Editors. Final programmatic environmental impact statement: The grizzly bear in northwestern Montana. Montana Department of Fish, Wildlife and Parks, Helena, Montana. 287 pp.

Harris, R.B., and L.H. Metzgar. 1987a. Estimating harvest rates of bears from sex ratio changes. Journal of Wildlife Management 51: 802-811.

Harris, R.B., and L.H. Metzgar. 1987b. Harvest age structures as indicators of decline in small populations of grizzly bears. International Conference on Bear Research and Management 7: 109-116.

Hatler, D.F. 2000. "Overkill" in assessment of grizzly bear management in British Columbia. Review of: Grizzly overkill in British Columbia bear management. Report to the co-chairs of the Grizzly Bear Scientific Advisory Committee.

Herrero, S. 1985. Bear attacks: their causes and avoidance. Winchester Press, Piscataway, New Jersey. 287 pp.

Hilderbrand, G.V., T.A. Hanley, C.T. Robbins, and C.C. Schwartz. 1999a. Role of brown bears (*Ursus arctos*) in the flow of marine nitrogen into a terrestrial ecosystem. Oecologia 121: 546-550.

Hilderbrand, G.V., C.C. Schwartz, C.T. Robbins, M.E. Jacoby, T.A. Hanley, S.M. Arthur, and C. Servheen. 1999b. The importance of meat, particularly salmon, to body size, population productivity, and conservation of North American brown bears. Canadian Journal of Zoology 77: 132-138.

Himmer, S., and J. Boulanger. 2002. Trends in grizzly bears utilizing salmon streams in the Owikeno System: 1998-2001. Arctos Wildlife Services, Hagensborg, B.C.

Horejsi, B.L 1999. The endangered Granby-Gladstone Grizzly bear population: a conservation biology analysis for recovery. Western Wildlife Environments Consulting Ltd, Calgary.

Horejsi, B.L. 2000a. The Purcell Mountains grizzly bear: cumulative effects and the proposed Jumbo Glacier Development. Western Wildlife Environments Consulting, Ltd. Calgary.

Horejsi, B.L. 2000b. A future for the grizzly: science and risk assessment or "Let's pray the cow can jump over the blue moon"? Western Wildlife Environments Consulting, Ltd., Calgary

Horejsi, B.L., B.K. Gilbert, and F.L. Craighead. 1998. British Columbia's grizzly bear conservation strategy: an independent review of science and policy. Western Wildlife Environments Consulting, Ltd., Calgary. 64 pp.

Hovey, F.W., and B. N. McLellan.1996. Estimating population growth of grizzly bears from the Flathead River drainage using computer simulations of reproduction and survival rates. Canadian Journal of Zoology 74: 1409-1416.

Interagency Grizzly Bear Committee. 1987. Grizzly Bear Compendium. U.S. Fish & Wildlife Service. Washington, D.C.

Joslin, G. and H. Youmans, coord.. 1999. Effects of recreation on Rocky Mountain wildlife: a review from Montana. Montana Chapter, The Wildlife Society, 307 pp.

Kasworm, W., T. Their, and C. Servheen. 1998. Grizzly bear recovery efforts in the Cabinet/Yaak ecosystem. Ursus 10: 147-153.

Kendall, W.L. 1999. Robustness of closed capture-recapture methods to violations of the closure assumption. Ecology 80: 2517-2525.

Knight, R.R., B.M. Blanchard, and L.L. Eberhardt. 1995. Appraising status of the Yellowstone grizzly bear population by counting females with cubs-of-the-year. Wildlife Society Bulletin 23:245-248.

Knight, R.L. and D.M. Cole. 1995. Wildlife responses to recreationists. pp 169-181 *in* R.L. Knight and J.K. Gutzwiller, editors. Wildlife and recreationists: coexistence through management and research. Island Press, Washington, D.C.

Knudsen, K.L., and F.W. Allendorf. 1985. Preliminary survey of genetic variation in grizzly bears. University of Montana. 17 pages.

Kolenosky, G.B. 1986. The effects of hunting on an Ontario black bear population. International Conference on Bear Research and Management 6: 45-55.

Kootenay-Boundary Land Use Implementation Strategy, Chapter B. 1999. Grizzly bear management guidelines. Revelstoke, B.C.

Mace, R.D., S.C. Minta, T.L. Manley, and K.E. Aune. 1994. Estimating grizzly bear population size using camera sightings. Wildlife Society Bulletin 22:74-83.

Mace, R.D., J.S. Waller, T.L. Manley, L.J. Lyon, and H. Zuring. 1996. Relationships among grizzly bears, roads, and habitat in the Swan Mountains, Montana. Journal of Applied Ecology 33: 1395-1404.

Mace, R.D., and J.S. Waller. 1998. Demography and population trend of grizzly bears in the Swan Mountains, Montana. Conservation Biology 12: 1005-1016

Mace, R.D., J. S. Waller, T. L. Manley, K. Ake, and W.T. Wittinger. 1999. Landscape valuation of grizzly bear habitat in western Montana. Conservation Biology 13: 367-377.

MacHutchon, A.G., S. Himmer, C.A. Bryden. 1993. Khutzeymateen Valley Grizzly Bear Study. Ministry of Forests Wildlife Research Report R-25.105 pp.

Macnab, J. 1985. Carrying capacity and related slippery shibboleths. Wildlife Society Bulletin 13: 403-410.

Manly, F.J., L.L. McDonald, D.L. Thomas, T.L. McDonald, and W.P. Erickson. 2002. Resource selection by animals, statistical design and analysis for field studies. 2nd Edition. Kluwer Academic Publishers. 221 pp.

Martinka, C.J. 1974. Population characteristics of grizzly bears in Glacier National Park, Montana. Journal of Mammalogy 55: 21-29.

Martorello, D.A., T.H. Eason, and M.R. Pelton. 2001. A sighting technique using cameras to estimate population size of black bears. Wildlife Society Bulletin 29:560-567.

Mattson, D.J., R.R. Knight, and B.M. Blanchard.1987. The effects of developments and primary roads on grizzly bear habitat use in Yellowstone National Park, Wyoming. International Conference on Bear Research and Management 7: 259-273.

Mattson, D.J. and T. Merrill. 2002. Extirpations of grizzly bears in the contiguous United States, 1850-2000. Conservation Biology 16: 1123-1136.

McCullough, D.R. 1981. Population dynamics of the Yellowstone grizzly bear. pp 173-196 *in* C.W. Fowler and T.D. Smith, editors. Dynamics of large mammal populations. John Wiley and Sons, New York, New York.

McCullough, D.R. 1986. The Craighead's data on Yellowstone grizzly bear populations. l: relevance to current research and management. International Conference on Bear Research and Management 6:21-32.

McLellan, B.N. 1989a. Dynamics of a grizzly bear population during a period of industrial resource development. I. Density and age-sex composition. Canadian Journal of Zoology 67: 1856-1860.

McLellan, B.N. 1989b. Dynamics of a grizzly bear population during a period of industrial resource development. II. Mortality rates and causes of death. Canadian Journal of Zoology 67: 1861-1864.

McLellan, B.N. 1989c. Dynamics of a grizzly bear population during a period of industrial resource development. III. Natality and rate of increase. Canadian Journal of Zoology 67: 1865-1868.

McLellan, B. N. 1990. Relationships between human industrial activity and grizzly bears. International Conference on Bear Research and Management 8: 57-64.

McLellan, B. N. 1994. Density dependent population regulation of brown bears. Pages 15-24 *in* M. Taylor, editor. Density-dependent population regulation in black, brown, and polar bears. International Conference on Bear Research and Management, Monograph Series No. 3.

McLellan, B.N 1998. Maintaining viability of brown bears along the southern fringe of their distribution. Ursus 10: 607-611.

McLellan, B.N and F.W. Hovey. 2001a. Habitats selected by grizzly bears in a multiple use landscape. Journal of Wildlife Management 65: 92-99.

McLellan, B.N and F.W. Hovey. 2001b. Natal dispersal of grizzly bears. Canadian Journal of Zoology 79: 838-844.

McLellan, B.N., F.W. Hovey, R.D. Mace, J.G. Woods, D.W. Carney, M.L. Gibeau, W.L. Wakkinen, and W.F. Kasworm. 1999. Rates and causes of grizzly bear mortality in the interior mountains of British Columbia, Alberta, Montana, Washington and Idaho. Journal of Wildlife Management 63: 911-920.

McLellan, B.N. and D.M. Shackleton. 1988. Immediate reactions of grizzly bears to human activities. Wildlife Society Bulletin 17: 269-274.

McLellan, B.N. and D.M. Shackleton. 1989. Grizzly bears and resource-extraction industries: habitat displacement in response to seismic exploration, timber harvesting and road maintenance. Journal of Applied Ecology 26:371-380.

McLoughlin, P.D. 2003. Managing risks of decline for hunted populations of grizzly bears given uncertainty in population parameters. Report submitted to the British Columbia Independent Scientific Panel on Grizzly Bears, University of Alberta, Department of Biological Sciences, Edmonton. 63 pp.

McLoughlin, P.D., M.K. Taylor, H.D. Cluff, R. J. Gau, R. Mulders, R.L. Case, and F. Messier. 2002. Population viability of barren-ground grizzly bears in Nunavut and the Northwest Territories. Arctic 55: in press.

Miller, S.D. 1990a. Population management of bears in North America. International Conference on Bear Research and Management 8: 357-373.

Miller, S.D. 1990b. Detection of differences in brown bear density and population composition caused by hunting. International Conference on Bear Research and Management 8: 393-404.

Miller, S. D. 1990c. Impact of increased bear hunting on survivorship of young bears. Wildlife Society Bulletin 18: 462-467.

Miller, S.D. 1993. Brown bears in Alaska: a statewide management overview. Alaska Department of Fish and Game, Wildlife Technical Bulletin No. 11. 40 pp.

Miller, S.D. and W.B. Ballard. 1992. Analysis of an effort to increase moose calf survivorship by increased hunting of brown bears in southcentral Alaska. Wildlife Society Bulletin 20: 445-454.

Miller, S.M., S.D. Miller, and D.W. McCollum. 1998. Attitudes toward and relative value of Alaskan brown and black bears to resident voters, resident hunters, and nonresident hunters. Ursus 10: 357-376.

Miller, S. and R. Sellers. 2003. Effects of hunting on brown bear cub survival and litter size in Alaska. Ursus 14: in press.

Miller, S.D., G.C. White, R.A. Sellers, H.V. Reynolds, J.W. Schoen, K. Titus, V.G. Barnes, Jr., R. B. Smith, R.R. Nelson, W.B. Ballard, and C.C. Schwartz. 1997. Brown and black bear density estimation in Alaska using radiotelemetry and replicated mark-resight techniques Wildlife Monographs No. 133. 55 pp.

Morrison, M.L. 2001. Proposed research emphasis to overcome the limits of wildlife-habitat relationship studies. Journal of Wildlife Management 65: 613-623.

Mowat, G., and C. Strobeck. 2000. Estimating population size of grizzly bears using hair capture, DNA profiling, and mark-recapture analysis. Journal of Wildlife Management 64: 183-193.

Mowat, G., M. Wolowicz, D.R. Seip, and D. C. Heard. 2002. Grizzly bear density and movement in the Bowron River Valley of British Columbia. Aurora Wildlife Research, Crescent Valley, B.C.

Mundy, K.R.D., and D.R. Flook. 1973. Background for managing grizzly bears in the National Parks of Canada. Canadian Wildlife Service, Report Series No. 22.

Newmark, W.D. 1995. Extinction of mammal populations in western North American national parks. Conservation. Biology 9: 512-526.

Noyce, K.V. and D.L. Garshelis. 1997. Influence of natural food abundance on black bear harvests in Minnesota. Journal of Wildlife Management 61:1067-1074.

Paetkau, D., L.P. Waits, P.L. Clarkson, L. Craighead, E. Vyse, R. Ward, and C. Strobeck. 1998. Variation in genetic diversity across the range of North American brown bears. Conservation Biology 12: 4418-429.

Pasitschniak-Arts, M. 1993. Ursus arctos. Mammalian Species No. 439. 10 pp.

Pasitschniak-Arts, M. and F. Messier. 2000. Brown (grizzly) and polar bears. pp 409-428 *in* S. Demarais and P.R. Krausman, editors. Ecology and management of large mammals in North America. Prentice-Hall Inc., New Jersey.

Pearson, A.M. 1975. The northern interior grizzly bear. Canadian Wildlife Service, Report Series N. 34.

Paloheimo, J.E., and D. Fraser. 1981. Estimation of harvest rate and vulnerability from age and sex data. Journal of Wildlife Management 45: 948-958.

Pojar, J., K. Klinka, and D.V. Meidinger. 1987. Biogeoclimatic ecosystem classification in British Columbia. Forest Ecology and Management 22: 119-154.

Powell, R.A., J.W. Zimmerman, and D.E. Seaman. 1992. An analysis and evaluation of a black bear sanctuary in western North Carolina. Federal Aid Wildlife Restoration. Final Report for study B2, Project W-57. 66 pp.

Proctor, M. F., B.N. McLellan, and C. Strobeck. 2002. Population fragmentation of grizzly bears in southeastern British Columbia, Canada. Manuscript. University of Calgary. 20 pp.

Raine, R.M., and R.N. Riddell. 1991. Grizzly bear research in Yoho and Kootenay National Parks 1988-1990. Final Report. Canadian Parks Service, File No. 9-019-01-01.

Reynolds, H.V. 1997. Effects of harvest on grizzly bear population dynamics in the northcentral Alaska Range. Alaska Dept. of Fish and Game, Federal Aid in Wildlife Restoration, Research Final Report on Study 4.25. 61 pp.

Rockwell, D. 1991. Giving voice to bear: North American Indian myths, rituals, and images of the bear. Roberts Rinehart Publishers, Niwot, Colorado. 224 pp.

Rossell, C.R., Jr. and J.A. Litvaitis. 1994. Application of harvest data to examine responses of black bears to land-use changes. International Conference Bear Research and Management 9: 275-281.

Ross, P.I. 2001. Update: COSEWIC status report on grizzly bear. Arc Wildlife Services Ltd. Calgary AB. 99 pp + figures.

Russell, R.H., J.W. Nolan, N.G. Woody, and G.H. Anderson. 1979. A study of the grizzly bear in Jasper National Park, 1975-1978. Canadian Wildlife Service, Edmonton, Alberta.

Sargeant, G.A., and R.L. Ruff. 2001. Demographic response of American black bears at Cold Lake, Alberta to the removal of adult males. Ursus. 12: 59-68.

Schoen, J.W. 1990. Bear habitat management: a review and future perspective. International Conference on Bear Research and Management 8: 143-154.

Schoenwald-Cox, C.M., S.M. Chambers, B. MacBryde, and L. Thomas. 1983. Genetics and conservation, a reference for managing wild animal and plant populations. Benjamin/Cummings, London. 722 pp.

Schwartz, C.C., S.D. Miller, and M.A. Haroldson. 2003. Grizzly/brown bears. In press *in* G. Feldhammer, B. Thompson, and J. Chapman, editors. Wild mammals of North America. Johns Hopkins University Press. New York.

Schwartz, C. C., J.E. Swenson, and S.D. Miller. 2002. Large carnivores, moose and humans: A changing paradigm of predator management in the 21st Century. Alces 38: (in press).

Scrivener, B.A. and J.A. MacKinnon. 1989. Learning from the past, looking to the future. Proceedings of the Northern Silviculture Committee's 1988 winter workshop, Feb 2 & 3, 1988, Prince George, B.C. Ministry of Forests.

Servheen, C. 1998. Conservation of small bear populations through strategic planning. Ursus 10: 67-73.

Shaffer, M.L. 1986. Assessment of application of species viability theories. Draft report prepared for the Office Technology Assessment, U.S. Congress.

Shaffer, M.L. 1987. Minimum viable populations: Coping with uncertainty. pp 69-86 *in* M. Soulé, editor. Viable populations for conservation. Cambridge Univ. Press, N.Y.

Soulé, M.E. and B. A. Wilcox. 1980. Conservation biology: an ecological-evolutionary perspective. Sinauer Assoc., Sunderland, Mass. 395 pp.

Spalding, D., B.Gates, W. McKay, and K. Mundy. 1972. Management plan for British Columbia's grizzly bears. Carnivore committee. British Columbia Fish and MWLAP, Victoria. 20 pp.

Stein , J. T. 2000. Roads less traveled? The effects of roads on wolves and brown bears worldwide. Chapter 4 in Stein, J.T. From extermination to reintroduction: a snapshot of North American large carnivore conservation at the millennium. Unpublished MS Thesis, Yale School of Forestry and Environmental Studies, New Haven, Conn.

Stringham, S.F. 1980. Possible impacts of hunting on the grizzly/brown bear, a threatened species. International Conference on Bear Research and Management 4: 337-349.

Stringham, S.F. 1983. Roles of adult males in grizzly bear population biology. International Conference on Bear Research and Management 5:140-1512.

Stuart-Smith, A.K. 2002. The influence of disturbance type and residual tree density on the distribution and abundance of songbirds in the Canadian Rocky Mountains. PhD Dissertation, Oregon State University, Corvallis.

Suchy, W.J., L.L. McDonald, M.D. Strickland, and S.H. Anderson. 1985. New estimates of minimum viable population size for grizzly bears of the Yellowstone ecosystem. Wildlife Society Bulletin 13: 223-228.

Sunquist, M.E. and F. Sunquist. 2001. Changing landscapes: consequences for carnivores. Pp. 399-418 **i***n* Carnivore Conservation. *Edited by* J.L. Gittleman, S.M. Funk, D. Macdonald, and R.K. Wayne. Cambridge Univ. Press, London.

Swenson, J., F. Sandegren, S. Brunberg, and P. Segerstrom. 2001. Factors associated with loss of brown bear cubs in Sweden. Ursus 12: 69-80.

Swenson, J., F. Sandegren, A. Soderberg, A. Bjarvall, R. Franzen, and P. Wabakken. 1997. Infanticide caused by hunting of male bears. Nature 386: 450-451.

Swenson, J., P. Wabakken, F. Sandegren, A. Bjärvall, R. Franzén, and A. Soderberg. 1995. The near extinction and recovery of brown bears in Scandinavia in relation to the bear management policies of Norway and Sweden. Wildlife Biology 1: 11-25.

Taylor, M. (ed.). 1994. Density-dependent population regulation in black, brown, and polar bears. International Conference on Bear Research and Management Monograph Series No. 3. 43 pp.

Taylor, M.K., D. DeMaster, F.L. Bunnell, and R. Schweinsburg. 1987. Modeling the sustainable harvest of female polar bears. Journal of Wildlife Management 51: 811-820.

Taylor, M.K., M. Kuk, M. Obbard, H.D. Cluff, and B. Pond. 2001. RISKMAN: risk analysis for harvested populations of age structured, birth pulse species. Software manual. 24 pp.

Taylor, M.K., J. Laake, H.D. Cluff, M. Ramsay, and F. Messier. 2003. Managing the risk of harvest for the Viscount Melville Sound polar bear population. Ursus 13: in press.

Titus, K., R.W. Flynn, G.W. Pendleton and LR. Beier. 1999. Population and habitat ecology of brown bears on Admiralty and Chichagof Islands. Alaska Department of Fish and Game Research, Final Report.

US Fish and Wildlife Service. 1993. Grizzly bear recovery plan. Missoula, MT. 181 pp.

Waits, L.P. 2002. Promise and pitfalls of noninvasive DNA sampling for studying abundance of rare and/or elusive wildlife species. Paper presented at the 9th Annual Conference of The Wildlife Society, Bismark, North Dakota.

Wiegand, T., J. Naves, T. Stephan, and A. Fernandez. 1998. Assessing the risk of extinction for the brown bear (*Ursus arctos*) in the Cordillero Cantabrica, Spain. Ecological Monographs 68:539-570.

Wielgus, R.B. 2002. Minimum viable population and reserve sizes for naturally regulated grizzly bears in British Columbia. Biological Conservation

Wielgus, R.B., and F.L. Bunnell. 1994a. Sexual segregation and female grizzly bear avoidance of males. Journal of Wildlife Management 58:405-413.

Wielgus, R.B., and F.L. Bunnell. 1994b. Dynamics of a small, hunted brown bear *Ursus arctos* population in southwestern Alberta, Canada. Biological Conservation 67: 161-166.

Wielgus, R.B., and F.L. Bunnell. 2000. Possible negative effects of adult male mortality on female grizzly bear reproduction. Biological Conservation 93: 145-154.

Wielgus, R.B., F.L. Bunnell, W.L. Wakkinen, and P.E. Zager. 1994. Population dynamics of Selkirk Mountain grizzly bears. Journal of Wildlife Management 58: 266-272.

Wielgus, R.B., P.R. Vernier, and T. Schivatcheva. 2002. Grizzly bear use of open, closed, and restricted forestry roads. Canadian Journal of Forest Research. In press.

Wittinger, W.T., WL. Pengelly, L.L. Irwin, and J.M. Peek 1977. A 20-year record of shrub succession in logged areas in the cedar-hemlock zone of northern Idaho. Northwest Science 51: 161-171.

Woodroffe, R., 2001. Strategies for carnivore conservation: lessons from contemporary extinctions. Pages 61-92 *In* Carnivore Conservation. *Edited by* J.L. Gittleman, S.M. Funk, D.W. McDonald and R.K. Wayne. Cambridge University Press. 675 pp.

Woodroffe, R. and J. R. Ginsberg. 1998. Edge effects and the extinction of populations inside protected areas. Science 280: 2126-2128.

Woods, J.G., D. Paetkau, D. Lewis, B.N. McLellan, M. Proctor, and C. Strobeck. 1999. Genetic tagging of free-ranging black and brown bears. Wildlife Society Bulletin 27: 616-627.

Yerena, E. 1998. Protected areas for the Andean bear in South America. Ursus 10: 101-106.

Zager, P, C. Jonkel, and J. Habeck. 1983. Logging and wildfire influence on grizzly bear habitat in northwestern Montana. International Conference on Bear Research and Management 5: 124-132.

Zedrosser, A., B. Dahle, J.E. Swenson, and N. Gerstl. 2001. Status and management of the brown bear in Europe. Ursus 12: 9–20.

VII. OTHER LITERATURE REVIEWED BY PANEL

Alaback, P.B. 1984. Secondary succession following in the Sitka spruce-western hemlock forests of southeast Alaska: implications for wildlife management. USDA Forest Service General Technical Report PNW- 173. 26 pp

Banner, A., J. Pojar, R. Trowbridge, and A. Hamilton. 1986. Grizzly bear habitat in the Kimsquit River Valley, coastal British Columbia: classification, description and mapping. Pages 36-49 *in* G.P. Contreras and K.E. Evans, compilers: Proceedings: grizzly bear habitat symposium. USDA Forest Service General Technical Report INT-207.

Bellemain, E., J. Swenson, and P. Taberlet. Unpublished manuscript. Infanticide is adaptive for resident male bears.

British Columbia Ministry Environment, Lands and Parks. Environmental trends in British Columbia. review draft.

Canfield, J. and A.L. Harting. 1987. Home range and movements. pp33-34 *in* Grizzly Bear Compendium. Interagency Grizzly Bear Committee.

Craighead, J.J., J.S. Sumner, and G.B. Scaggs. 1982. A definitive system for analysis of grizzly bear habitat and other wilderness resources. Wildlife Wildlands Institute Monograph 1. University of Montana, Missoula. 279 pp.

Derocher, A.E. and M. Taylor. 1994. Density dependent population regulation of polar bears. pp. 25-30 *in* M. Taylor, editor. Density-dependent population regulation in black, brown, and polar bears. International Conference on Bear Research and Management. Monograph Series No. 3.

Grizzly Bear Scientific Advisory Committee. 1996. Letter concerning Jumbo Ski Development in Purcell Mountains to B.C. Minister of Environment, Lands and Parks.

Grizzly Bear Scientific Advisory Committee. 1997. Review of draft discussion paper on grizzly bear management units and conservations areas. On File, MLAP, Victoria

Grizzly Bear Scientific Advisory Committee. 1998. Letter to Minister Cathy McGregor, Ministry of Environment, Lands and Parks, Victoria.

Grizzly Bear Scientific Advisory Committee. 1998. Draft of grizzly habitat guidelines for identified wildlife strategy under Forest Practices Code and June 1998 letter to B.C. Minister of Environment.

Hamilton, A.N. and W. R. Archibald. 1986. Grizzly bear habitat in the Kimsquit River Valley, coastal British Columbia: evaluation. Pp 50-57 in G.P. Contreras and K.E. Evans, compilers: Proceedings: grizzly bear habitat symposium. USDA Forest Service General Technical Report INT-207.

Harestad, A and T. Hamilton. 2000. Comments on the de Leeuw report, McCrory's grizzly bear population estimate, and the Horejsi et al. report. Draft letter to Jim Walker, Assistant Deputy Minister, Ministry of Land Air and Parks, Victoria.

Harting, A.L.. 1987. Food habits summary. p 111 in Grizzly Bear Compendium. Interagency Grizzly Bear Committee.

Jones, G. 1998. Comments on Conflicts and interests in British Columbia bear management by A.D. de Leeuw. Report to the Executive of the MWLAP, Victoria.

Jeo, R.M., M.A. Sanjayan, and D. Sizemore.2002. A conservation area design for the central coast region of British Columbia, Canada. Round River Conservation studies, Salt Lake City, Utah.

Kemp, G.A. 1976. The dynamics and regulation of black bear (Ursus americanus) populations in northern Alberta. International Conference on Bear Research and Management 2:26-31.

Kolenosky, G.B. 1990. Reproductive biology of black bears in east-central Ontario. International Conference on Bear Research and Management 8: 385-392

Lande, R., B.E. Sæther, and S. Engen. 1997. Threshold harvesting for sustainability of fluctuating resources. Ecology 78: 1341-1350.

MacHutchon, A.G. 2001. British Columbia bear bibliography. Ministry of Land Air and Parks, Victoria. 21 pp.

Mattson, D. 1999. Coefficients of productivity for Yellowstone's grizzly bear habitat. Forest & Rangeland Ecosystem Science Center, University of Idaho, Moscow.

Mattson, D. 2001. Calculation of estimated annual death rate of brown bears in coastal British Columbia based on landscape features. Unpubl, ms., US Geological Survey, Northern Arizona University, Flagstaff, AZ.

Mattson, D.J., S. Herrero, R. G. Wright, and C.M. Pease. 1996. Science and management of Rocky Mountain grizzly bears. Conservation Biology 10: 1013-1025.

McCrory, W. P, S.M. Herrero, G.W. Jones, and E.D. Mallam. 1994. The role of the B.C. Provincial park system in grizzly bear preservation. International Conference on Bear Research and Management 8:11-16.

McCrory, W. P, and S.M. Herrero. Preservation and management of the grizzly bear in B.C. provincial parks the urgent challenge. McCrory Wildlife Services, New Denver, B.C.

McCrory, W. P. 2000. Letter concerning comments on critique of Cayoosh/Melvin Creek Resort proposal. McCrory Wildlife Services Ltd., New Denver.

McLellan, B.N 2000. Memo to Doug Dryden, Director MWLAP re: Grizzly overkill in British Columbia bear management by A.D. de Leeuw.

McLellan, B.N 1999. Review of 1999 report by Dr. Mitch Taylor report to Safari Club International: "Social, biological, economic and political factors affecting grizzly bear hunting in British Columbia". Letter to Dr. Stuart Marks, Director of Research and Community Development, safari Club International, Herndon, VA

McLellan, B.N 2001. Letter to Brian Horejsi, Barrie Gilbert and Lance Craighead re misunderstand or misquote of McLellan's research findings on grizzly bear densities in the Flathead watershed of southeastern British Columbia. Ministry of Forests, Revelstoke.

Miller, S.D. and J. Schoen. 1999. Brown bear conservation action plan for Alaska. Pages 40-46 *in* C. Servheen, S. Herrero and B Peyton, compilers. Bears: status survey and conservation action plan. International Union for Conservation of Nature, Gland, Switzerland.

Mowat, G., D. Fear, and K.G. Poole. 2002. Grizzly bear habitat in the South Selkirk Mountains of British Columbia. Aurora Wildlife Research, Crescent Valley, B.C.

Mowat, G., K. Poole, D.R. Seip, D.C. Heard, R. Smith, and D.W. Paetkau. 2001. Grizzly and black bears densities in interior British Columbia. Aurora Wildlife Research, Ltd. Crescent Valley, B.C.

Mowat, G., K. Stalker, G. Stenhouse, C. Strobeck. 2000. Foothills model forest grizzly bear research project-DNA inventory 1999. Final Report, Timberland Consultants, Nelson, B.C.

Mowat, G. and R. Rancharita. 1999. A review of grizzly bear habitat use and habitat management options for the Kootenay Region of British Columbia. Timberland Consultants, Ltd. Nelson.

Nyberg, J.B., and D.W. Janz. 1990 Deer and elk habitats in coastal forests of southern British Columbia. B.C. Ministry of Forests, Special Report Series 5. 331 pp.

Oswald, E.T., and B.N. Brown. 1993. Vegetation development on skid trails and burned sites in southeastern British Columbia. The Forestry Chronicle 69: 75-880.

Petition to B.C. government dated 1999 by 68 biologists concerning a moratorium on road-building and hunting.

Pimm, S.A. 1996. A pragmatic approach to grizzly bear conservation. Conservation Biology 10: 1026-1035.

Reinhart, D.P., and D. J. Mattson. 1992. Bear use of cutthroat trout spawning streams in Yellowstone National Park. International Conference on Bear Research and Management 8: 343-350.

Ruth, R.H., and A.S. Harris. 1979. Management of western hemlock-Sitka spruce forests for timber production. USDA Forest Service General Technical Report PNW-88. 197 pp.

Schoen, J.W., M.D. Kirchhoff, and J.H. Hughes. 1988. Wildlife and old-growth forests in southeastern Alaska. Natural Areas Journal 8: 138-145.

Shaffer, M.L. 1978. Determining minimum viable population size: A case study of the grizzly bear (Ursus arctos L.) PhD. Dissertation, Duke University, Durham, NC 190 pp.

Taylor, M. 1999 (estimated). Social, biological, economic and political factors affecting grizzly bear hunting in British Columbia. Report to Safari Club International. Herndon, VA. 31 pp.

VIII. CONTACTS MADE BY PANEL

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Tony Hamilton, MWLAP, Victoria, B.C.
Douglas Heard, Ministry of Forests, Prince George, B.C.
Brian Horejsi, Western Wildlife Environments Consulting, Ltd., Calgary, AB
Bob Jamieson, BioQuest International Consulting Ltd, Fort St. John, B.C.
David Mattson, U.S. Biological Service, Flagstaff, AZ
Bruce McLellan, B.C. Ministry of Forests, Revelstoke, B.C.
Wayne McCrory, McCrory Wildlife Services, New Denver, B.C.
Troy Merrill, Moscow, ID
Garth Mowat, Timberland Consultants, Ltd, Nelson B.C.
Martin Powell, Environmental Investigation Agency, London, UK
Mike Proctor, University of Calgary, Calgary, AB
John Schoen, National Audubon Society, Anchorage, AK
Kari Stewart Smith, Tembec Industries, Cranbrook, B.C.
Mitch Taylor, Government of Nunavut, Iqaluit, NU
Kim Titus, Alaska Fish & Game, Anchorage, AK

Appendix I: Terms of reference for grizzly bear scientific panel peer review of population estimates and harvest

Procedures: Terms of Reference

Purpose:
The purpose of the panel is, in the context of grizzly bear conservation science, to conduct a review to ensure that hunting, as it is currently managed, does not threaten the long term conservation of grizzly bears in British Columbia and, if necessary, to make recommendations for improvements to the existing harvest management regime.

Reporting to:
Minister of Water, Land and Air Protection

Structure and composition:
The panel will consist of a minimum of five respected bear scientists, appointed for a period of up to two years.

Mandate:
The panel will conduct an independent review of, and provide recommendations on:
(1) The methods currently used to estimate grizzly bear populations in British Columbia.
(2) Provincial management strategies and harvest procedures regarding grizzly bear hunting; and
(3) Related issues deemed by the panel to be significant to grizzly bear conservation.

Support to the panel:
The panel may hire a full-time biologist or related scientific position to assist it with analysis, drafting of reports and co-ordination. Salary and expenses for this position will be covered by government as will logistical support, including travel expenses and honoraria, for the panel.

Timelines:
The duration of the review will be contingent on the availability of data and the degree of revision in management strategies and practices recommended by the panel.

The panel will provide an interim report by January 31, 2002, and a final report on or before December 31, 2002.

Consultation and liaison:
The panel may request whatever advice and assistance it requires from wildlife biologists and scientists within government.

The panel may solicit advice and submissions from other scientists and the public as it feels necessary. The manner and timing of this solicitation will be decided by the panel. To maintain the scientific independence and focus of the panel, requests to the panel from the public or the media will be routed through the office of the Assistant Deputy Minister, Wildlife, Habitat and Enforcement Division.

Appendix II: Executive summary of final report submitted by P. D. McLoughlin: Managing risks of decline for hunted populations of grizzly bears given uncertainty in population parameters. (March 5, 2003)

Executive Summary

A better understanding of how sampling error influences results of population viability analysis (PVA) will serve to focus research aimed at improving the applicability of PVA for management purposes. In Section 1.0 of this report, I evaluate the relative contributions of sampling error in initial population size and sampling errors in vital rates to the outcome of PVA for grizzly bears (*Ursus arctos*) in western North America. I used a 2-way, random-effects analysis of variance to estimate the components of variance in PVA outcomes explained by errors (standard errors applied between 0–30% of parameter estimates) in vital rates and initial population size. Error in population size accounted for the largest source of variation in the model ($F_{35,5} = 10.8$, $P = 0.00001$), explaining 60.5% of the variance. In contrast, error in vital rates contributed very little to simulation outcomes ($F_{35,5} = 0.61$, $P = 0.70$), accounting for only 2.4% of model variation. The results demonstrate that error in initial population size can be an important determinant of simulation outcomes, and that removing sampling error from process variation in models of PVA in order to make them more realistic is perhaps not as critical as is currently thought. Errors in estimates of initial population size, if ignored in models of PVA, have the potential to leave managers with estimates of population persistence that are of little value for making management decisions.

In Section 2.0, I quantify management risks associated with how close harvest approximates a population's finite rate of increase. I describe the existence of a threshold of human-caused mortality for grizzly bears (*Ursus arctos*) in North America, which, if exceeded, accelerates declines in the persistence probabilities of populations. Using population viability analysis (PVA), I identified thresholds of annual kill for 3 simulated grizzly bear populations with a common population size from breakpoints in slopes of regression curves relating annual kill to persistence probabilities of populations. The position of the threshold is shown to shift with changes in vital rates (natural survival, reproduction) and life history that varied according to net primary productivity (PP) of habitat. For populations inhabiting relatively good habitat (PP > 1000 g/m^2/y), the breakpoint model suggesting a threshold at 4.9% annual kill was the most parsimonious compared to all other breakpoint models. As habitat productivity and natural growth rates decreased, the threshold level shifted to the left in regressions of persistence *versus* annual kill. The threshold of kill for the simulated population inhabiting moderate habitat (PP = 700–1000 g/m^2/y) was best described at 2.8% of initial population size. A linear decline in population persistence as annual kill increased was the most parsimonious solution for the population inhabiting poor habitat (PP < 700 g/m^2/y), suggesting that any threshold of human-caused mortality was already surpassed even at extremely low levels of annual kill. Prior to any management strategy to set levels of harvest for actual populations, population size, productivity and state of habitat, life history, and estimates of population

growth in the absence of human-caused mortality should be considered to predict the response of a population to non-natural mortality.

Section 3.0 of this study examines risks of population decline for 10 grizzly bear populations in British Columbia based upon documented population size and standard error, offtake, and vital rates assumed for populations inhabiting good, moderate, and poor areas of habitat quality. Although regulated harvest rates (2.8–3.8% of *N* per year) appear reasonable considering population viability thresholds presented in Section 2.0, they are likely unsustainable in conjunction with uncertainty in population size plus the additional 2.2%/year estimated unknown, non-hunter mortality observed for most study areas. The general pattern was for a 50% chance that grizzly bear populations will decline at rates exceeding 20% over 30 years. If the province plans to maintain a 2.8–3.8% annual harvest without first decreasing the amount of uncertainty in population estimates, it is imperative that non-hunting mortality be reduced substantially to develop more acceptable outcomes of PVA. If enforcement of hunting regulations cannot be improved and non-hunter mortalities reduced (e.g., road and rail deaths, kills in defense of life or property), then it is only through a reduction in quota that grizzly bear populations can be modeled sustainably using PVA. The size of reduction in quota necessary to maintain persistence of populations has yet to be modeled.