# BEAR HABITAT MANAGEMENT: A REVIEW AND FUTURE PERSPECTIVE[1]

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*Abstract*: Throughout the world, bears are declining in numbers and range as habitat is reduced and bear-human interactions increase. Although ursids are widely distributed and inhabit a variety of habitats, they possess a number of biological characteristics that make them particularly vulnerable to conflict with humans. The habitat concept is discussed relative to the unique characteristics of bears. Because bears are wide-ranging species of landscapes, habitat relationships must be evaluated on a broader context than habitat types per se. Human activities and land uses must be factored into bear habitat relationships. Forest clearing and road building, in particular, are common problems for the conservation and management of many bear populations. An understanding of the processes of habitat fragmentation and population extinction is necessary for maintaining viable bear populations in the face of increasing habitat destruction and isolation. Several management tools and research needs for bear habitat management are discussed.

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The concept of habitat – fundamental to the study of ecology and management of wildlife populations – is centuries old.

*The law locks up both man and woman*
*Who steals the goose from off the common,*
*But lets the greater felon loose*
*Who steals the common from the Goose.*

Medieval English Quatrain

Broadly defined, habitat is the place an organism lives or where you can find it (Odum 1971, Moen 1973, Ricklefs 1973). The actual relationship of individuals, populations, and species to their habitat, however, is much more complex and variable, spatially and temporally, than can be portrayed by a written definition. An understanding of the intricate relationships between an organism and its environment requires a knowledge of the organism's ecological niche (Grinnell 1917, Elton 1927, Hutchinson 1965).

Within the last decade, the quantity and sophistication of bear habitat research have increased tremendously. This growing research emphasis parallels increasing changes in, or destruction of, bear habitat throughout the world. Managing habitat capable of supporting viable and productive bear populations in the face of increasing pressures on a finite resource base will not be easy. It will involve a strong management commitment including a considerable investment in time and money. Effective population management of bears will require a detailed understanding of habitat relationships.

The purpose of this paper is to review the habitat concept and its specific application to the theme of this conference: a "Future for Bears." Few of the relationships presented here are original. Rather, I have extracted ideas and concepts I consider important for stimulating discussion and perhaps some new perspectives on the conservation and management of bears and their habitat.

[1] Invited paper

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## BACKGROUND

### Historical Perspective of Bear Management

Despite that humans have had a long association and interest in bears throughout the world (Shepard and Sanders 1985), few scientific investigations were initiated until the 1960's, and most habitat studies have been published only in the last decade and a half. For example, a computer search (for the word "habitat" in titles and/or key words) of a black bear (*Ursus americanus*) bibliography (Tracy et al. 1982) revealed only 38 citations specific to North American black bears during the period 1910 through 1969 (Table 1). From 1970 through 1979 there was a 5-fold increase over the previous 6 decades. Thirty-two of those papers (16%) dealt specifically with habitat relationships.

Until very recently, scientific interest in bears has lagged behind many other large mammals. A computer search of the Journal of Wildlife Management from 1969 through 1988 identified all papers published on bears and deer and habitat topics related to those species (Table 2). From 1969 through 1975, 179 deer papers and 12 bear

**Table 1. Black bear literature from 1910 through 1979 listed in the Tracy et al. (1982) black bear bibliography.**

| Period | Number of black bear citations: General information | Number of black bear citations: Habitat study[a] |
|---|---|---|
| 1910-69 | 38 | 1 |
| 1970-79 | 194 | 32 |

[a] Determined by a computer search of titles and key words.

**Table 2. Deer[a] and bear[b] literature published in The Journal of Wildlife Management, 1969-88.**

| Period | Deer papers[a] (% habitat related) | Bear papers[b] (% habitat related) |
|---|---|---|
| 1969-75 | 179 (4%) | 12 (0%) |
| 1976-88 | 359 (20%) | 58 (14%) |

[a] Includes mule, black-tailed, and white-tailed deer.
[b] Includes black, brown, and polar bear.

papers were published; few of these covered habitat issues. In later years, a larger proportion of the Journal's papers on both deer (359 papers) and bears (58 papers) were habitat related.

Clearly, there has been a paucity of published literature on bears and particularly bear habitat relationships until relatively recently. This was largely a result, in the United States at least, of legislative requirements (e.g., Endangered Species Act, National Environmental Policy Act, National Forest Management Act), university research, and new techniques such as radio telemetry. But even today the quantity of published literature on bear habitat relationships still lags behind comparable literature on ungulates. The reasons for this are easily understood and have significant ramifications for the conservation and management of bears.

In contrast to ungulates, which have long been considered valuable by human standards, bears have been perceived as dangerous or undesirable, and little effort was expended on management or habitat studies. By the turn of the century throughout most of the United States and Canada, for example, ungulates were provided protection and managed through the enforcement of game regulations whereas bears were bountied in many areas. It was decades later before most wildlife management agencies in North America provided bears protection similar to that of ungulates (Jonkel 1978, Miller 1990). Though bears are now managed as important big game species in North America, in other parts of the world, some species like the spectacled bear (*Tremarctos ornatus*) and the Asiatic black bear (*Ursus thibetanus*) are still persecuted by rural hunters and farmers (Servheen 1990).

## Biology and Status

A review of the general biology and status of bears as a group lends perspective on the problems associated with managing and conserving bears for the future.

All bears are large-bodied species capable of inflicting serious injury or death to humans. Bears are intelligent and individualistic animals with a great capacity for learning during an extended maternal care period and over a relatively long life (>25 yr). This capacity for learning and their generally omnivorous diet have allowed each species to exploit a variety of food resources across a wide range of habitat types (though the polar bear [*U. maritimus*], sloth bear [*U. ursinus*], and giant panda [*Ailuropoda melanoleuca*] are most specialized in their food habits). For example, the 8 living species of ursids may be found from the arctic ice pack and tundra, through boreal and temperate forests, to tropical forests (Nowak and Paradiso 1983).

As a result of their relatively inefficient carnivore digestive systems, most bears exploit high quality, food resources. These usually occur seasonally on the most productive lands, such as riparian bottom lands, coastal tidelands, productive grazing lands, anadromous fish streams, and often bring bears into conflict with humans using the same high quality land base. In addition, because most bears in temperate regions den over winter, they must focus their feeding activities on the highest quality sites during a limited period of the year. Their wide-ranging movements, opportunistic nature, and capacity for learning also increase their probability of interacting with humans through feeding on livestock, crops, human foods, or garbage. Once bears learn to exploit such food resources, they may become habituated to humans, thus increasing the opportunity for human-bear conflict (Herrero 1985).

The reproductive rates of bears are nutritionally regulated and density independent and are some of the lowest among terrestrial mammals (Bunnell and Tait 1981). As a result, significant population declines may be long and difficult to reverse. Natural mortality rates appear to be density dependent and influenced by adult males, particularly at higher population densities (Bunnell and Tait 1981). Within the last several centuries, the killing of bears by humans has become a major source of adult mortality. As wild lands are developed throughout the world by expanding human populations, the geographical range of bears continues to decline.

The status of bears of the world has been reviewed by

Servheen (1990). Of the 8 living species, all (if recognized populations within a species are considered) are listed as endangered, threatened, or potentially facing a precarious future. The Asiatic black bear, spectacled bear, sun bear (*Ursus malayanus*), and giant panda are listed on Appendix I and brown bear (*U. arctos*) and polar bear are listed on Appendix II of the Convention on International Trade in Endangered Species (CITES). The sloth bear's status is considered indeterminate by the IUCN (i.e., not enough information known to determine whether it is endangered, just vulnerable, or rare). The State of Florida has classified the Florida black bear as threatened, and the U.S. Fish and Wildlife Service has put both the Florida and Louisiana black bears on their candidate list for Category II.

Clearly, bears as a group face an uncertain future in a rapidly changing world. Consider, for example, the brown bear (*Ursus arctos*) that recently occupied a wide range of habitats and had one of the greatest natural distributions of terrestrial mammals (Nowak and Paradiso 1983). Once widely distributed across Europe, Asia, and into northwestern Africa, the brown bear has largely been extirpated in the southern and western regions of its former range. Surviving populations in Europe are now small and largely restricted to remote, isolated islands of forest habitat (Servheen 1990).

In North America, the historic range of the brown bear encompassed most of the western United States (Fig. 1).

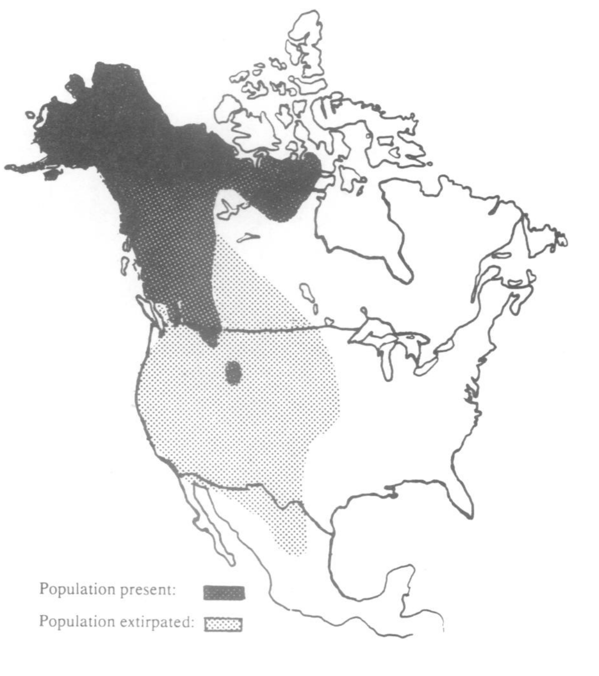


**Fig. 1. Present and historic distribution of the brown bear in North America. (Redrawn from Jonkel 1978 and Craighead and Mitchell 1982)**

Though in the early 19th century there may have been as many as 100,000 brown/grizzly bears in the United States south of Canada (Nowak and Paradiso 1983), their decline was so substantial that they were classified as threatened in 1975 under the Endangered Species Act. Today, the brown bear population in the conterminous United States is estimated to be fewer than 1,000 (Servheen 1990) and receives high management priority on an interagency level (Strickland 1990).

Even the geographic range of the North American black bear (worldwide, the species in the least jeopardy) has declined in the last century (Fig. 2). Originally widespread throughout the forested regions of the conti-

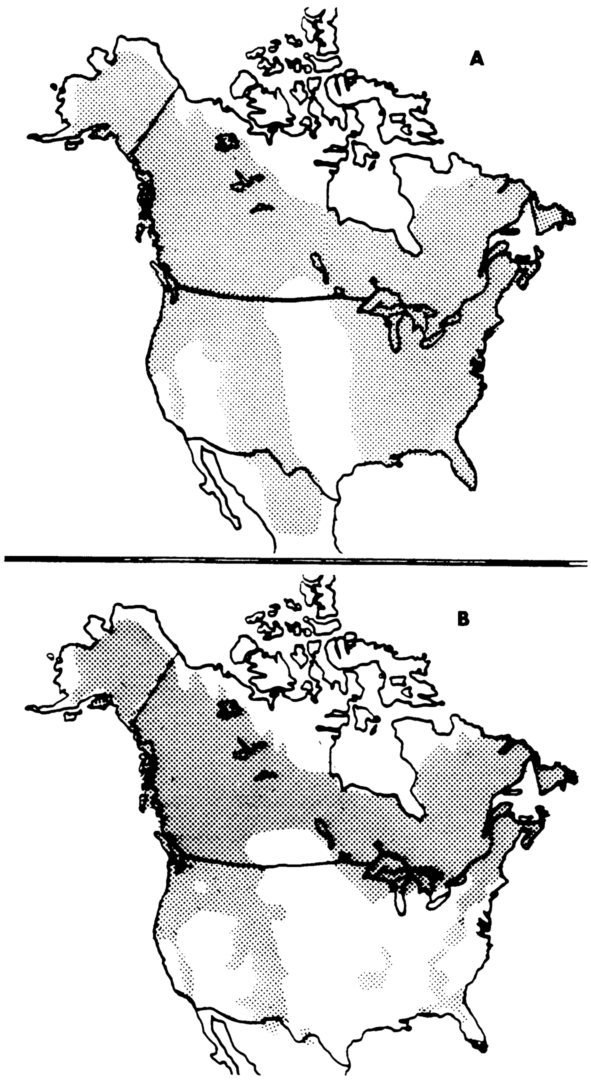


**Fig. 2. Historic (A) and present (B) distribution (stipled area) of black bears in North America. (Redrawn from Hall and Kelson 1959 and Pelton 1982)**

nent, black bear populations today are much more scattered and isolated, particularly in the midwestern, eastern, and southeastern United States where lands have been most intensively developed and high density human populations exist (Pelton 1982).

Many species of bears have relatively broad habitat requirements. A recurrent theme of many papers covering a variety of bear species and geographical regions is that mortality increases, and populations decline as forest clearing and roads penetrate bear habitat. However, bears can generally accommodate substantial human activity and some habitat alteration if humans can tolerate their presence without killing them (G. Alt pers. commun., Mattson 1990, McLellan 1990). Because human tolerance for bears is generally low, inaccessible, forested habitat appears to be a prerequisite for their continued existence near or adjacent to human populations south of 60 degrees North latitude.

## HABITAT RELATIONSHIPS

Bears derive all their life needs, such as food, water, cover, and space, from their habitat. Because of their size, omnivorous feeding habits, and large scale movements, bears use a wide range of habitats varying in importance seasonally and geographically. Part of our task in managing bear habitat is to identify what habitats are important to bears and determine the optimal or sometimes minimal habitat mix necessary for maintaining populations at desired or viable population levels.

Effective habitat management requires a working definition of habitat beyond the place an animal lives. Harris (1984) defined primary habitat as the suite of areas and conditions necessary for all life requirements of a species. Secondary habitat, in contrast, may be used substantially by a species but not meet all its life's requirements. Later, Harris and Kangas (1988) proposed that primary habitat extends beyond requirements of the individual to include a sufficient area capable of supporting a viable population of the species under consideration. As explained later, these concepts are particularly relevant to habitat management for bears. Consider, for example, the concern over population viability of the Yellowstone grizzly (Craighead 1980, Shaffer 1983, Knight and Eberhardt 1985, Samson et al. 1985).

Under natural conditions (without human influence), the distribution and productivity of bear populations is nutritionally regulated by the availability of high quality food resources (Bunnell and Tait 1981, Rogers 1987). Spatial and temporal variation in latitude, climate, topography, and site quality largely determine the availability of food and other resources which, in turn, influence the distribution and abundance of bear populations. An understanding of these habitat relationships is a fundamental component in the management of lands designated to include a future for bears.

Today, however, few lands on earth are without the influence of human activity. Because humans interact with bears as predators and/or competitors (in an ecological sense), we must consider habitat in a broader context that includes humans and human land-use activities. Though numerous papers have described bear habitat in terms of landforms and plant community types (Contreras and Evans 1986), relatively few papers (Weaver et al. 1986, Mattson et al. 1987, Rogers and Allen 1987) have integrated human activities or cumulative effects into habitat analyses. If we are to manage bears successfully over the long-term, we must shift our approach toward understanding their ecological niche rather than simply describing their use of discrete habitat types.

In fact, a narrow concept of habitat may be inapplicable for bears, which are wide-ranging creatures of landscapes rather than habitat types per se (Knight 1980, Harris and Kangas 1988). For example, annual home range sizes for adult female brown bears in North America range from 24 $km^2$ in southeastern Alaska (Schoen et al. 1986) to 294 $km^2$ in southcentral Alaska (Miller 1987) to 382 $km^2$ in Arctic Alaska (Reynolds 1976). In the Yellowstone Ecosystem, mean annual home range of adult females was 384 $km^2$, but lifetime ranges averaged 874 $km^2$ (Knight et al 1984). Male home ranges are several-fold larger than female ranges. Polar bears also make extensive movements across the arctic ice pack which, in turn, is carried hundreds of kilometers by ocean currents (Jonkel 1978, Amstrup and DeMaster 1988). Even the home range size of the smaller ranging American black bear varies from several to over 100 $km^2$ (Pelton 1982, Rogers and Allen 1987).

Clearly, the normal movements of bears are so extensive that bear habitat must be evaluated and managed on a landscape scale often exceeding thousands of square kilometers. For example, in the largest National Park in the conterminous United States, "...there are no true refuges for the Yellowstone grizzly bears" (Knight et al. 1988). Even in large areas, managers should be as concerned about the composition and status of the surrounding habitat as they are about the area they wish to conserve (Janzen 1986).

Though bears concentrate their use of the landscape in the most productive foraging habitats, seasonal variability in food abundance and quality often result in extensive movements from one portion of their range to another. In addition, annual variability in food abundance (including occasional failures in food production) may result in extensive movements outside their normal home ranges increasing the potential for interaction with humans (Beeman and Pelton 1980, Rogers 1987, Knight et al. 1988). Although there may be a reasonable mix of productive foraging sites within a bear's normal range of movements, it may be forced to traverse many habitat types in search of those few productive sites. And herein lies one of the most serious problems facing bear managers throughout the world — habitat fragmentation.

The study of habitat fragmentation is a relatively new field founded in large part on MacArthur and Wilson's (1967) classic work *The Theory of Island Biogeography* and specifically applied to forest habitat management in Harris' (1984) book *The Fragmented Forest.* Problems with bears today are generally a result of habitat loss or because insufficient habitat is available to provide adequate separation of bears and people. Recognition of habitat fragmentation and an understanding of island biogeography theory and its influence on population viability offer bear managers new insights and tools for approaching the increasingly difficult task of managing populations in the face of increasing habitat destruction and isolation.

The reduction of forested habitat in Warwickshire, England from 400 A.D. to 1960 (Fig. 3) is a classic example of habitat fragmentation. If we assume this trend occurred more generally throughout England as a whole, it is not unreasonable to infer this scale of habitat destruction and fragmentation may have had an influence on the extirpation of the brown bear, which Curry-Lindahl (1972) estimates occurred around the 10th century. Throughout Europe, the brown bear now occurs primarily in remote scattered "islands" of habitat and its future there is far from assurred (Mysterud and Falck 1989*a*, Servheen 1990).

Though the extinction of species closely parallels habitat modification and destruction (Ehrlich 1988), population viability can also be threatened without total elimination of habitat. Habitat fragmentation leads to the creation of smaller, more isolated populations that are more vulnerable to extinction (Diamond 1986, Wilcove et al. 1986, Wilcove 1987). For example, some habitat fragments may be smaller than the size of individual home ranges, and all of the necessary elements for meeting a species habitat requirements may not be represented, even in the larger fragments (Wilcove 1987).

Another consequence of fragmentation is the creation of edge effects. Once considered only beneficial to wildlife populations (Leopold 1933, Reynolds 1966,

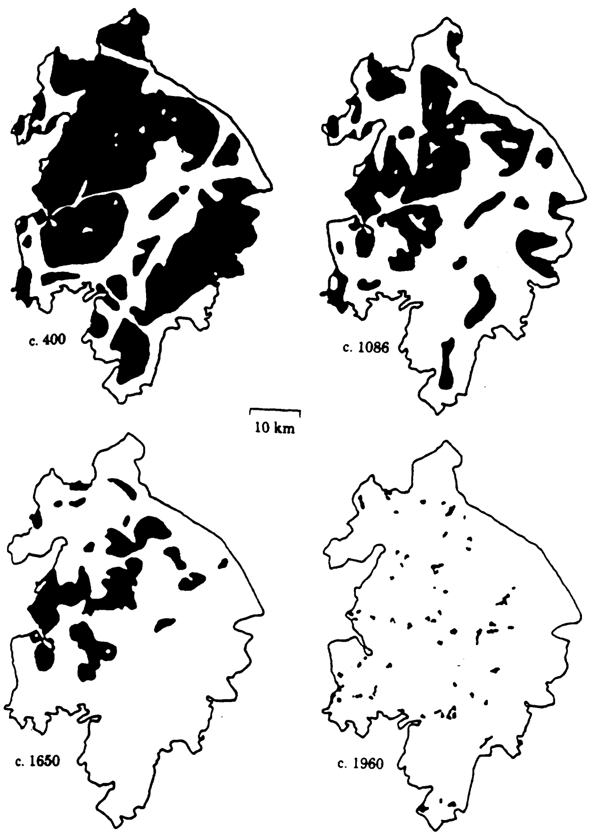


Fig. 3. Fragmentation of forests (black area) in Warwickshire, England, from 400 A.D. to 1960. (Redrawn from Wilcove et al. 1986)

Odum 1971), wildlife managers and ecologists are now recognizing some of the negative effects (Soule 1986, Wilcove 1987, Reese and Ratti 1988). Human communities, farmland, logging, and any resource development activities surrounding or bisecting undeveloped bear habitat can be considered edge effects. All these developments increase the opportunity for bear-human interactions and pose serious threats to many bear populations. Examples include human settlements around Yellowstone Park and farms in the Upper Great Lakes that act as "population sinks" for brown and black bears, respectively (Rogers and Allen 1987, Knight et al. 1988). Population sinks are sites where bears are removed from the ecosystem after coming in contact with humans.

Roads also increase the opportunity for human-induced mortality of bears through legal hunting, defense of life and property kills, and illegal killing (Knight 1980, Peek et al. 1987, Rogers and Allen 1987, McLellan and Shackleton 1988, Schoen et al. 1988, Brody and Pelton 1989). In addition, vehicle collisions with bears are a major source of mortality for some populations like the threatened Florida black bear (Harris and Kangas 1988).

Even in the absence of human-induced factors, small populations are particularly susceptible to extinction because they are vulnerable to environmental variability and natural catastrophes, demographic stochasticity, and genetic deterioration (Wilcox 1986, Wilcove 1987). Only recently have we begun to recognize such factors in our management of threatened bear populations like the Yellowstone grizzly (Shaffer 1981, 1983; Knight and Eberhardt 1985; Samson et al. 1985; Allendorff and Servheen 1986) and the Norwegian brown bear (Mysterud and Falck 1989*a*).

Management concerns about the effects of habitat fragmentation on bear populations are not restricted to threatened or small and isolated populations. In southeastern Alaska, for example, habitat fragmentation is occurring at an accelerated rate as a result of industrial-scale logging. Not only is valuable old-growth habitat being replaced by early successional forest of lower value to bears (Schoen et al. 1989), but hundreds of kilometers of new roads are being pushed into bear habitat previously inaccessible to most humans.

Historically, boats were used for brown bear hunting in southeastern Alaska, and most of the bear harvest occurred along the shoreline. Thus, the interior of the islands were refugia separating many bears from humans. Within the last few years, however, that historical pattern has changed significantly. For example, over 200 km of logging roads have recently been built on the 1,000 $km^2$ northeastern peninsula of Chichagof Island, and over 600 km are scheduled to be built over the life of the timber sale (Fig. 4).

The total kill of brown bears on northeastern Chichagof Island has increased substantially in recent years. From 1961 through 1979, the mean annual harvest of brown bears on northeastern Chichagof Island was 5.5 bears (Alaska Dep. Fish and Game unpublished harvest data). Since 1980, when most road building and logging occurred, the mean annual harvest (11.8) has more than doubled. In addition, from 1985 through 1988, the total harvest was 13, 15, 23, and 19 bears, respectively. The hunting season for brown bears on northeastern Chichagof Island was closed by emergency order of the Alaska Department of Fish and Game on 30 September 1988. During that year, 6 of the kills were in defense of life or property; many were associated with garbage dumps around local communities or logging camps. Even in the absence of legal hunting, many bears will likely be killed in control actions around rural communities and camps (particularly around garbage dumps), by deer hunters in defense of life, and by an unknown amount of poaching.

Considering the amount of road construction and habitat change scheduled for this area, the long-term viability of this small (approximately 125 bears), relatively isolated population is in question. Certainly, management and enforcement efforts will need to be increased substantially to ensure the population's future. But how can we accurately assess the probability of population persistence in the face of such rapid and significant changes in the landscape? This is one of the most important and difficult questions faced by bear managers throughout the world.

According to Harris and Kangas (1988), "In states experiencing rapid human population growth or in areas of rapid forest clearance, the contextual setting of habitats is changing so rapidly that the presence of small faunal populations is a good predictor of neither adequate habitat, nor the likely future occurrence of the species." Many, or perhaps most, habitat assessment studies are but "snapshots" of a species' habitat relationships at a particular time, often near the time of habitat alteration. Because of long-term environmental variability, demographic stochasticity, and the longevity of bears, it may take many years before the effects of habitat loss or fragmentation are evident in a population, and by that time reversal of the situation may not be possible.

One relatively new and promising approach for assessing the effects of habitat change on wildlife populations is cumulative effects analysis. Cumulative effects analysis (CEA) is "...an assessment of how the combination of natural processes and events and man's activities cause resources and environmental conditions in an area to change over time" (Salwasser and Samson 1985). Thus, instead of evaluating individual management actions in isolation, the CEA approach offers managers a tool for evaluating cumulative habitat alterations over time. It is unlikely, however, that any single development will threaten an entire population. Although additional developments will incrementally increase impacts to a population by a relatively small percent, it is the *direction*, not magnitude, of change relative to a *threshold* that is the critical parameter affecting the entire population (D. Mattson pers. commun.). Further, certain effects amplify the impacts; they are not just cumulative (C. Jonkel pers. commun.).

Let us consider a hypothetical model of the relationship between a bear population and some cumulative index of habitat deterioration. As habitat is reduced, fragmented, or otherwise lowered in value, the bear population will decline at perhaps a constant or increasing rate until it reaches a threshold point at which the rate of decline becomes precipitous (Fig. 5). Once the thresh-

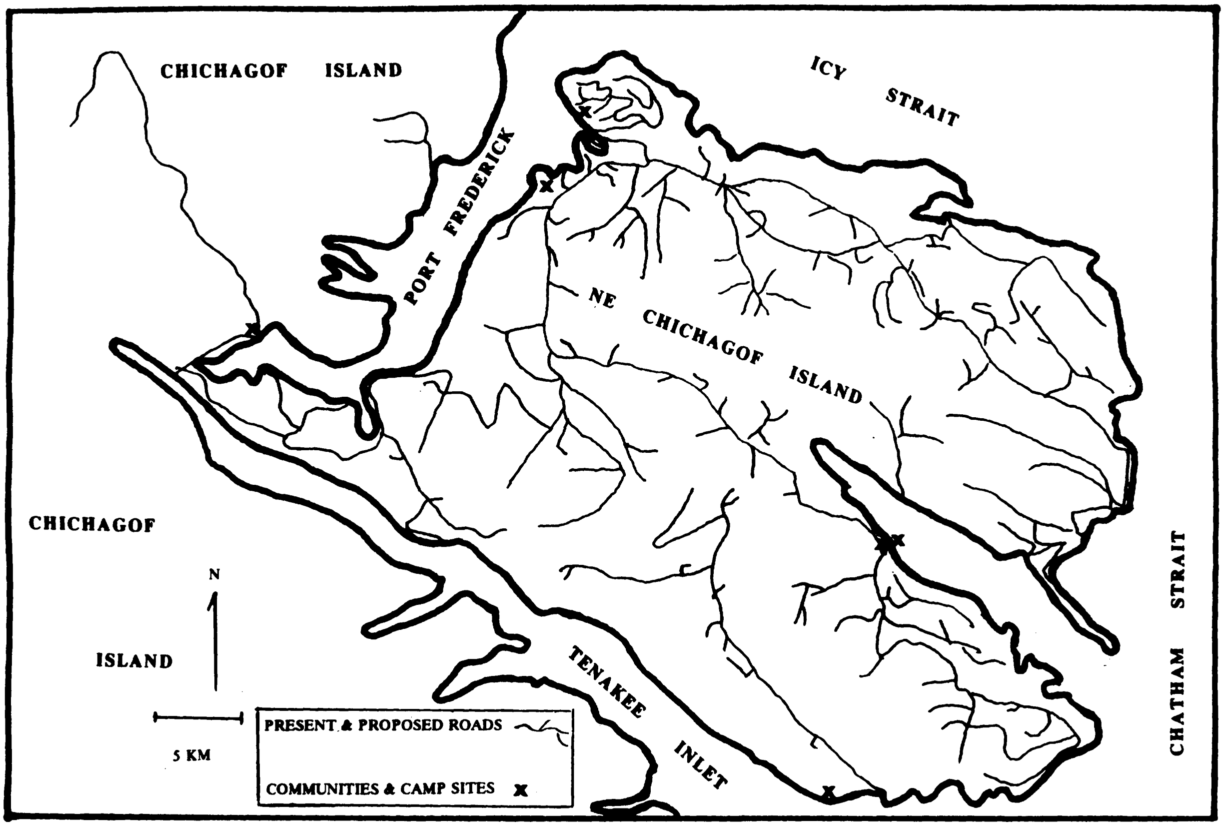


Fig. 4. Current and proposed road system and human settlement on northeastern Chichagof Island, southeastern Alaska.

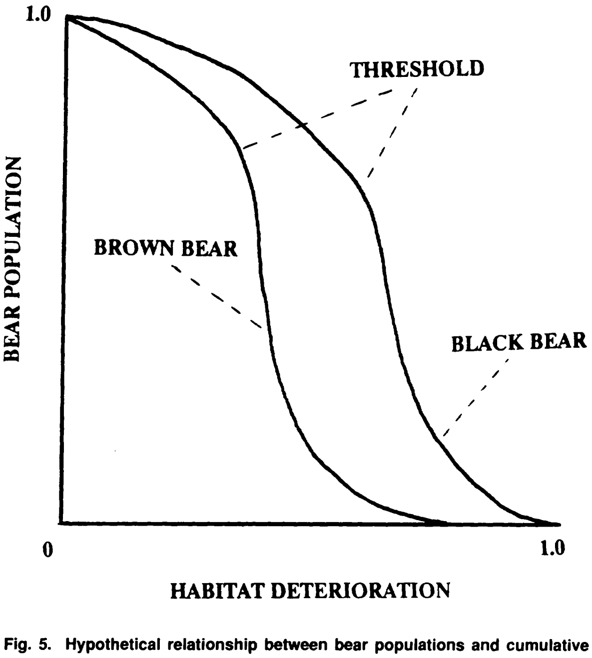


Fig. 5. Hypothetical relationship between bear populations and cumulative habitat impacts denoting thresholds of habitat deterioration.

old point is reached, even a small additional deterioration of habitat may drive the population below long-term viable levels.

Several investigators have suggested habitat thresholds for variables like road densities (Stone and Brody 1986, Brody and Pelton 1989) and conversion of forest to farmlands (Rogers and Allen 1987). Thresholds of habitat deterioration are likely complex, interactive, and vary significantly relative to geographical location and species as portrayed in the hypothetical relationship between black and brown bears (Fig. 5). Unfortunately, it may be many decades after habitat thresholds are exceeded before we can measure their long-term effects on the population, and by then the impacts of habitat alteration may be irreversible.

It is certain that small tracts of habitat alone will not conserve species like bears. Managers must approach bear habitat management on a landscape scale and consider the influences of human activities and land uses both within and adjacent to occupied bear habitat.

## Habitat Management

Because the habitat requirements of bears vary significantly among species (as well as geographic populations within a species), it is beyond the scope of this paper to provide specific guidelines for habitat management. More specific habitat reviews and guidelines for bears have been presented elsewhere (Craighead et al. 1982, Zager and Jonkel 1983, Contreras and Evans 1986, Herrero et al. 1986, LeFranc et al. 1987, Rogers and Allen 1987, Schoen et al. 1989). Rather, I will discuss several management tools and general approaches to habitat management.

Until recently, habitat management for bears was really management by default. No longer is this kind of approach acceptable, however. Instead, we must clearly define specific, long-term population goals, and then determine what quantity, quality, and juxtaposition of habitats within the larger landscape mosaic are necessary to meet those goals. This will require a close liaison with research, which should provide data on bear habitat relationships (Hamilton and Archibald 1986, Mattson et al. 1986, Rogers and Allen 1987, Schoen et al. 1989). In addition, accurate, ecologically based habitat maps (Banner et al. 1986, Craighead et al. 1986, Despain 1986) and computerized geographic information systems (Winn and Barber 1986) offer bear managers valuable new tools for inventorying and assessing bear habitat on a landscape scale.

With the above information and tools, the habitat manager can evaluate the effects of different land uses on bear populations through computer modeling, such as the cumulative effects analysis (Weaver et al. 1986) or habitat suitability index models (Rogers and Allen 1987). We must recognize, however, that the output of such models is only as good as the input. Though it may be expedient for some managers to apply cookbook models, this could prove disastrous for bear conservation if the models are inappropriately applied or used without valid data.

One potential tool in assessing alternative land management options on bear populations is the quantification and application of habitat thresholds. Hypothetically, consider 2 adjacent but separate tracts of land with equal habitat value to bears (Fig. 6). If 50% of the combined region of areas 1 and 2 will be developed, what allocation of habitat to development will maintain the highest overall population of bears assuming the threshold depicted? If we develop 50% of both areas, the threshold will be exceeded in each area and the entire bear population will be eliminated. However, if we develop 1 area entirely and reserve the other for bears, we will maintain (at the same level of development) 50% of the original combined

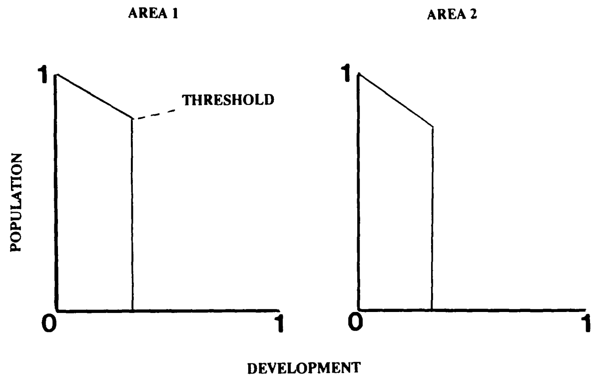


**Fig. 6. Hypothetical effects of alternative habitat management on bear populations sensitive to habitat thresholds. If 50% of both areas are developed, the threshold will be exceeded and populations in both areas will be eliminated. However, the same total development, allocated to 1 area entirely and not the other, will result in the maintenance of 1 population or 50% of the original combined population.**

population. This simple example suggests possible management applications for using habitat thresholds in evaluating allocation problems of multiple areas and increased complexity.

As habitat modeling becomes more commonplace and is routinely incorporated into land use planning, we must ensure that the models be "ground truthed" in the field by knowledgeable experts. Currently, most habitat models are still basically hypothetical. For those data-based models, initial input was likely collected over relatively short time frames. However, what was optimal bear habitat when the data were collected may not be optimal under different environmental conditions. Temporal variability in habitat quality may result in the misinterpretation of commonly collected use/availability data sampled over short time frames (<5 yrs). For example, annual variability in food production results in significant among-year differences in bear habitat use and can substantially influence the degree of bear-human interactions (Jonkel and Cowan 1971, Garshelis and Pelton 1980, Mattson and Knight 1987, Rogers 1987, Knight et al. 1988). Clearly, there should be an ongoing, dynamic interchange between habitat managers and researchers throughout model development and use. Additionally, habitat models for bears should follow the Yellowstone example in being specific to adult females and driven by the "worst-year" scenario (D. Mattson pers. commun.).

In conjunction with habitat modeling, it is also becoming necessary (particularly with small and/or isolated populations) to estimate minimum viable populations through population vulnerability analyses (Gilpin and Soule 1986). Shaffer (1981) approached this problem by distinguishing 4 distinct factors — environmental, demographic, and genetic stochasticity, and catastrophe — that contribute toward driving populations to extinction. The likelihood of population survival depends on population size and time (Shaffer 1987, Soule 1987). Thus the critical question for conservationists is: what degree of persistence constitutes preservation and how much habitat is necessary to achieve that goal (Shaffer 1987).

A classic case of population viability analysis is the Yellowstone grizzly population (Shaffer 1983, Knight and Eberhardt 1985). Through population viability analysis, the manager can also estimate minimum area requirements. By interfacing habitat modeling and population viability analysis, managers can incorporate a quantitative risk analysis into planning and decision making (Samson et al. 1985). This would provide decision makers and the public a better opportunity to evaluate resource tradeoffs.

As large tracts of wild lands disappear throughout the world, bear populations are declining and becoming fragmented. To halt this trend and conserve bears, several management options have been considered; these include the establishment of a few large preserves, protection of a large number of smaller critical habitats or "ecocenters," and integrated management. Integrated management — balancing a variety of uses on the same land base — for a species like the brown bear is speculative at best. Because bears are species of landscapes, the option of protecting many small geographic areas is unlikely to improve the outlook for bear conservation. On the other hand, the size and number of current nature reserves are considered inadequate for providing long-term conservation for most large or rare mammal species (Shaffer 1987), and there are rapidly becoming fewer places in the world that could still be acquired and protected and are large enough to provide all the requirements to sustain viable populations of bears over time (i.e., 95% probability of persistence for 100 years).

The management and conservation of bears throughout the world is a complex and difficult problem facing natural resource managers. Our approach to this problem will require imagination, persistence, cooperation, *long-term* planning, and a willingness to apply a variety of techniques. For example, on a regional and species-specific basis, we could establish 1 (or preferably several) relatively large preserves surrounded by buffers that protect smaller critical habitats (perhaps connected with travel/security corridors). However, to ensure the future of most bear populations we will have to work quickly and cooperatively on an interagency and international scale. The development of conservation networks incorporating multi-institutional cooperation (Salwasser et al. 1987) would greatly enhance bear conservation efforts.

Mysterud and Falck (1989*b*) recently proposed several management plans designed to provide long-term protection to populations of the Norwegian brown bear. In their plans, they considered concepts of theoretical island biogeography and recent findings in conservation biology, and proposed reducing the effects of population isolation by establishing a large continuous management range through international cooperation.

Our options for conserving bears decline with each passing year as humans and new land-use developments continually encroach on bear habitat throughout the world. The time for bear managers to consider comprehensive, long-term planning on a global scale is now.

## Research Needs

As land-use activities intensify throughout bear range, we must quantify the nutritional carrying capacity of bear habitats. Because among-year variation in food production can significantly influence bear distribution and habitat use, long-term studies are necessary. Additionally, it will be important to better quantify how zones of human influence affect habitat use and population viability. Conceptual models can provide a foundation for identifying common denominators necessary for contrasting bear populations under different environmental conditions. To do this, bear researchers need to collect comparable data. *Long-term* studies of unexploited populations in undeveloped habitat would provide valuable "benchmark data" for comparing populations exposed to habitat modification and various human influences as well as provide new and better insights into among-year variation in habitat relationships.

Determination and quantification of thresholds of habitat disturbance would provide managers an additional tool for comparing the effects of alternative land-use allocations on bear populations. Research directed toward increasing our understanding of the extinction process, determining minimum viable populations, and linking this to minimum habitat area is particularly needed. The Yellowstone grizzly population continues to offer a good field laboratory for such efforts. Incorporating a landscape perspective into our habitat studies, including the effects of habitat fragmentation, should also be a major focus of bear research.

Bears are intelligent, long-lived species with high capacity for learning. Increased emphasis on behavioral studies may provide managers new insights into bear-habitat relationships as well as how humans influence bear behavior and habitat quality.

Modeling of cumulative effects in combination with geographic information systems offers bear researchers and managers an opportunity for evaluating various and complex habitat relationships. Finally, to maximize the limited resources of bear researchers and managers, better interdisciplinary, interagency, and international cooperation will be necessary.

## IMPLICATIONS FOR THE CONSERVATION OF BEARS

Bears as a group are facing a difficult future fraught with habitat destruction and fragmentation as well as increased mortality rates resulting from human intolerance. As a result, bear populations throughout much of the world are declining and becoming isolated, thus increasing their vulnerability to extirpation or even extinction. Unfortunately, decades may pass before resource managers recognize when a bear population's viability is threatened.

Just as bear populations are facing an increasingly uncertain future, there is a new and urgent recognition among ecologists and natural resource managers throughout the world of the importance of maintaining the earth's biodiversity (Wilson 1988). Conservation biology is a relatively new but rapidly expanding field of applied science. The goals of conservation biology are to maintain the diversity of life — the genetic diversity within species, the species diversity within ecosystems, and the diversity of ecosystems in the biosphere (Temple et al. 1988). I think it is time for biologists facing the difficult and challenging task of bear management and conservation to join forces with this new field, which incorporates the diverse disciplines of genetics, demography, and community and ecosystem ecology.

Armed with a broad ecological background and committed to long-term planning on a global scale, we will be better equipped to deal with the challenge of providing sound stewardship for the earth's bear populations. This will not be easy, however. It will require that we: 1) quantitatively define the biological requirements of bears; 2) develop, in cooperation with an informed public, objectives for the management and conservation of bear populations and their habitat; 3) develop models to predict the effects of human activities on bear habitat and populations; 4) develop a clear and objective public education program describing bear habitat requirements and the influence of human activities; and 5) recognize the significant impacts on bear populations throughout the world created by the economic, political, and social pressures of the 5 billion people now inhabiting the earth.

Professor E. O. Wilson (1988) in his introduction to the book *Biodiversity* eloquently identified an additional element inextricably linked to our stewardship of the earth and all its inhabitants: "In the end, I suspect it will all come down to a decision of ethics — how we value the natural worlds in which we evolved and now, increasingly, how we regard our status as individuals. We are fundamentally mammals and free spirits who reached this high level of rationality by the perpetual creation of new options. Natural philosophy and science have brought into clear relief what might be the essential paradox of human existence. The drive toward perpetual expansion — or personal freedom — is basic to the human spirit. But to sustain it we need the most delicate, knowing stewardship of the living world that can be devised."

The future of most bear populations throughout the world will depend on how seriously we take our responsibility of knowledgeable stewardship. It is highly probable that if we can maintain a region's capability for supporting bears, we will also have achieved the greater goal of maintaining the earth's biodiversity. The degree of our success will depend on how willing humans are to balance short-term economic gain with long-term ecological and economic sustainability.

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