Models for park management

Cumulative effects assessment

The use of statistical modeling to test management techniques is an effective tool for improving overall management plans. When applied correctly, habitat and population models can be helpful in evaluating the consequences of human land uses on bear populations. It is well known, however, that "the output of . . . models is only as good as the input . . . [which] could prove disastrous for bear conservation if the models are inappropriately applied or used without valid data" (Schoen 1990: 150). Even though computer models can be powerful management tools, their effectiveness depends on the quality of the data, on the assumptions built into the model, and on the general soundness of methodology used. For this reason, the cumulative effects models used by ESGBP researchers and Parks Canada to determine the amount and quality of habitat needed to secure a viable grizzly bear population in and around the national parks deserve careful scrutiny. Federal and provincial laws increasingly require analysis of the cumulative effects of various land uses and management activities as part of the environmental assessment process. The governing idea is that, although individual impacts or activities may be minor, they become collectively or cumulatively significant. Cumulative Effects Assessment (CEA) for grizzly bears is an integral part of biological evaluations prepared for projects proposed within grizzly recovery areas and now figure prominently in regulatory hearings for energy and recreational development proposals in Alberta and elsewhere. Unfortunately, the accuracy of environmental impact assessments (EIAs), especially in terms of the cumulative effects of many small disturbances is notoriously low. According to Kumar *et al*. (1993: 160) "the average accuracy of quantified, critical, testable predictions in EIA for Australia is only 44%."

Habitat effectiveness targets

The Habitat Effectiveness (HE) model used by the ESGBP researchers is designed to assess the quantitative and qualitative effects of human actions on grizzly bears and their habitat. It has become the chief means of evaluating the predicted impact of various human activities on what is now seen primarily as grizzly bear habitat (Gibeau 1998; Jalkotzy *et al*. 1999; Gibeau 2000; Herrero *et al*. 2000) and allegedly shows that CRE grizzlies are on the road to extinction. Gibeau, for example, claims that "with continued erosion of grizzly bear habitat in what is supposed to be core refugia hanging in the balance, time is clearly not on the park manager's side" (1998: 235).

The HE model was based on a standard US Department of Agriculture (USDA) cumulative effects model (CEM). The American CEM was intended to be "just one of the many tools used to review potential effects" of management and policy (USDA Forest Service 1990: 1). It has become, however, the most important and sometimes the only tool for grizzly management in Banff, and thus for human use in the park as well. Even though the CEM is superior to the HE model used by the ESGBP researchers, respected scientific groups such as the National Wildlife Federation have still criticized it as deficient and in need of improvement and refinement. France (1994: 524), for example, stated that the development of this CEM is distinctive because "some of the research has been unspeakably expensive and produced results of questionable worth." The questionable results have been rendered more questionable still by "minor changes" Gibeau (1998: 236) made to the USDA model.

Mortality risk index eliminated

The "minor" alterations to which Gibeau referred constitute about half of the modeling apparatus, including mortality risk estimators. In the original USDA model, habitat effectiveness is one of two main outputs, and a mortality risk index is the second. As Leighton (2000) observed, the original American model "could distinguish between a hiker and a bear hunter . . . [because it] assesses the 'risk of bear mortality associated with human activities.'" However, as Benn (1998: 14) noted, ESGBP omitted any determination of mortality risk coefficients, leaving it as "future work."

In fact, subsequent ESGBP work (Herrero *et al*. 2000: 63), has not tackled the postponed question of lethality. The issue of lethality is important for the obvious and common-sensical reason that a habituated bear that either flees or ignores human presence coupled with benevolent non-hunting human users will face a mortality threat significantly lower than that it faces when encountering bear hunters. That is, if bear mortality risk is a function of the rate of human contact *and* lethality, if lethality risk is low, then so is mortality risk.

This proposition results in the formula:

$$\text{Mortality} = f\,((\text{human encounter rate})\,(\text{lethality of encounter}))$$

or $$M = f\,(H \times L).$$

However, in ESGBP research, this formula is immediately modified to

$$M = f\,(H),$$

apparently on the grounds that "as access expands, human beings exploit it, which leads to the decline of bear populations" (Herrero *et al*. 2000: 63). This last statement assumes a lethality risk of $L = 1$, which means that human presence in an ecosystem necessarily leads to population declines through increased mortality.

In reality, matters are not so simple: all humans are not bear hunters. In a 1996 paper published in the journal *Conservation Biology,* Mattson *et al.* describe the complexities involved in modeling grizzly bear mortality caused by humans. Beginning from the hypothesis that "human-caused grizzly bear mortality is determined by the rate of encounter between humans and grizzly bears and the probability that such an encounter will result in a grizzly bear's death," the authors go on to detail the numerous variables that would influence the lethality of an encounter:

- human population numbers;
- concentration of humans in the area;
- behaviour of humans, influenced by any number of individual and cultural factors;
- grizzly bear population numbers;
- distribution of dominant bears within that population;
- distribution of bear food;
- behaviour of grizzly bears, depending on the level of their aggressiveness and whether or not they are food-conditioned (Mattson *et al*. 1996: 1014–15).

While falling short of weighting the differential effects of these conceptual variables, this detailed description of the complex nature of the interactions between humans and bears shows that the HE model used by ESGBP researchers is fatally flawed. Without the ability to assess the difference between a hiker, a hunter, and park visitor driving down the road at 70 kilometres per hour, the model ignores a vital risk assessment obvious even to someone unschooled in grizzly biology. There is no reasonable comparison between the risk posed to a grizzly by a hunter, actively pursuing a bear, and that posed by a hiker, out for a weekend jaunt in the mountains. Absent mortality-risk coefficients, however, the two are treated equally by the ESGBP model.

To compensate for this deficiency in the model, ESGBP researchers have used "human disturbance," by which they mean human presence, as a primary means of deriving habitat effectiveness values. As Leighton says, this method of rating disturbance levels is "hopelessly simplistic" (2000: 25). A key assumption in stratifying human use is that it must be either high or low: "High use was defined as more than 100 vehicles or people/month, low use was defined as under 100 vehicles or people/month" (Gibeau 1998: 237). The USDA CEM used 80 as the division point between high and low but in neither model was there consideration or argument regarding the notion that 100 (or 80) users per month may be too low to serve as a division point; there was no consideration given to the possibility of moderate levels of use. Thus high use amounts to more than three users a day; low is three or less.

As a result of this bivariate stratification, nearly all areas in the national parks that allow human use will receive a *de facto* "high" human disturbance rating, which biases HE modeling coefficients toward a low habitat effectiveness rating. Once four users drive through on a highway or hike on a trail in one day, a maximum impact has been made on grizzly habitat. According to this logic, four hikers or 4,000 hikers per day would have the same impact on the grizzly population. Given that Parks Canada safety information very sensibly encourages park visitors to hike or bike in groups of three or more or, in restricted bear areas, six or more (Parks Canada 2000c), basic human safety standards will ensure that HE levels will not be met. When Parks Canada applied the ESGBP formulations of habitat effectiveness to Banff Townsite (HE = 48.6) and the Village of Lake Louise (HE = 46.6) (Parks Canada 1997: 44), the implication became particularly clear: in order to achieve the HE targets of 60 or above, the human population and development will have to be significantly reduced or eliminated.

The use of ESGBP HE targets as a model for park management reinforces the notion that human presence is a "disturbance" that is necessarily damaging to bears. As Jalkotzy *et al*. wrote:

> levels of human use on trails appeared to affect habitat use in the vicinity of trails. For example, bear use of habitat close to the heavily used trail to Boulder Pass and Deception Pass, a trail in open terrain, typically occurred in late September only after human use of the trail declined from high summer levels. Even at low [human] use levels, crepuscular or nocturnal feeding along these trails was the norm. (1999: 8)

According to the argument made earlier (as well as a common-sensical interpretation of the information included in this quotation), for whatever reason, the bears used the trail in the evening or at night and humans used it during the day. Such dual use might be considered a good thing since both bears and humans can use the same space at different times. Even if bears used the trail less during the day *because of* human presence, it does not follow that dual use, by bears and humans, is harmful to bears—or to humans.

The "working assumption" of the ESGBP researchers, however, is that "as access expands, human beings exploit it, which leads to the decline of bear populations" (Herrero *et al*. 2000: 63). The policy implication of that assumption is clear: restrictions on human use are necessary whenever bears are inconvenienced. Thus Gibeau noted that, "disturbance can influence bear use through actual displacement and change in use patterns reducing the time available for a bear to use an area (e.g., 24 hour to nocturnal use only)" (1998: 237). For both ESGBP advocates and Banff National Park management (Parks Canada 1997: 43), human use is either to be allowed, restricted, or removed based on desired habitat effectiveness of each Carnivore Management Unit (CMU). This reflects ESGBP recommendations that "all land use decisions will take place within the context of cumulative effects models that utilize grizzly bears as key indicators" (Herrero *et al.* 2000: 10). To date, ESGBP research has been the primary factor in deciding what constitutes "desired habitat effectiveness" (Herrero *et al.* 2000: 3) and, as a result, disturbance, which is to say, human use, is always secondary to bears in the strategy of parks management.

Jalkotzy *et al.* (1999) defend using bears as the primary and, in effect, the only, determinant of park management strategy by stating that "drastic changes in human use" and "significant changes to human land use patterns are required in the Lake Louise area to reverse these trends" of grizzly habituation and mortality (1999: 93). Such a reversal would allow habitat effectiveness ratings to approach the numerical targets for HE set out in the 1997 Banff Management Plan (Parks Canada 1997: 44). Reducing human use to the minimum necessary to keep the ski area in repair and reducing still further the impact of humans on a popular hiking area with a historic destination lodge, such as Skoki, might or might not meet some arbitrary habitat effectiveness target. The cumulative effects of the several layers of assumptions, however, have introduced a remoteness and abstract quality to the numerical targets. It is not at all clear what they have to do with the actual behaviour of real humans and real bears on the ground in Banff National Park.

Current restrictions on human use, however, are already very near the point of diminishing returns when considered in light of even the most simple cost/benefit analysis: massive closures would be needed throughout Banff to increase habitat effectiveness by even a small amount. However, research and policies continue to recommend that "legislation to restrict/close access" be passed, and that "physical blockage" be used to enforce human use strategies limiting the number of people "to under 100/month" as a means of limiting encounters between humans and bears and of meeting the habitat effectiveness targets (Herrero *et al.* 2000: 66; Parks Canada 1997: 44). Notably absent is any discussion of whether those targets need to be reconsidered. They are simply accepted without question along with the consequence that human use must be eliminated to ensure the targets are met.

Focus on "wary bears"

The second "minor" change introduced by Gibeau to the USDA model was to focus solely on so-called wary bears. The American model considers the entire study population, not a preferentially selected sample. Probably the most important divergence between the two, however, is that the HE model used by the ESGBP researchers does not include a rational assessment of "security cover," the amount of brush, for instance, between a bear (or a deer) and a human: thick security cover gives an animal more room to hide or to escape undetected from human presence. Moreover, the ESGBP researcher collapsed the five categories of security cover in the USDA model into two on the grounds that, following "consultation with knowledgeable individuals" (here he named D. Mattson of the University of Idaho and T. Puchlerz of the USDA Forest Service), it was reasonable to conclude "that the Yellowstone situation is analogous to the three Canadian mountain parks" (Gibeau 1998: 237).

However, if the situation in Canada and the United States is analogous, then both Yellowstone and the Canadian parks ought to have been modeled using the same number of security cover categories and reasonable, assessment-based classifications. By reducing the number of categories from five to two, Gibeau drastically reduced the predictive ability of the model and oversimplified the complexity of the physical environment being modeled. Under the HE model, Banff is classed as either secure or non-secure, an "either/or" proposition with no room for variability or gradients more approximate to reality. The Lake Louise HE model (Jalkotzy *et al*. 1999) is different again; it appears to use four classes of security cover; and Gibeau (1998) did not deploy the HE model for Banff National Park. Because the 1997 Banff National Park management plan HE model was created by the privately operated Geomar consulting, it is not available for public review.

More problems

Additional problems with the HE model further reduce its usefulness. For example, the HE model attempts to compare "disturbed" contemporary habitat to an imaginary "pristine" environment, an environment uninfluenced by humanity. To attain a habitat effectiveness rating of 100%, zero human disturbance is allowed, which is precisely what ESGBP researchers claim is needed to stem "grizzly bear extinction" within the CRE (Gibeau 1998: 235). The accuracy of this alarming prediction, even when the correct term, extirpation, is substituted for extinction, is highly dubious because of the limitations of the HE model, limitations that have been acknowledged by ESGBP researchers:

> The CEM [sic] process is still under development, and the information needed to state the actual effects on the grizzly bear population (numbers of bears) is not known. *Therefore, it oversteps the bounds of the model to attempt to determine the number of bears that could be supported by restoring an area to natural conditions.* Likewise, population losses resulting from further development cannot be determined. (Gibeau 1998: 238; emphasis added)

Herrero has also noted the limitations of the habitat effectiveness model:

> No standardized means for determining habitat values has emerged; rather, in each application, available data have been interpreted and modeled. Until a consensus emerges regarding habitat quality evaluation this activity should not be regarded as firmly rooted in science. (1998: 67)

Kansas and Riddell quite properly advised of a need "to explain [scientific] processes, assumptions, strengths and weaknesses … in plain English" (1995: 6). In plain English, the HE model is unable to predict any measurable benefit of restoration or negative effects of development. Why, then, is it used at all? And, why does it play any part in the formation of park policy?

More to the point, while Gibeau acknowledged that the HE model is unreliable, he maintains that unreliability is no reason not to use it, an opinion consistent with the nature of conservation biology as a "crisis discipline" in which decisions and actions must be taken despite scientific uncertainty: "because of time constraints, conservation biologists must be willing to express an opinion based on available evidence, accepted theory, comparable examples, and informed judgment" (Gibeau 1998: 240).

This sense of crisis is palpable in what Gibeau calls the "reasonable prediction" of the model, namely that "if management practices do not change, we will continue to erode grizzly bear habitat and, if unabated, the population will become extinct" (Gibeau 1998: 240). Obviously, this remark expresses the persistent sense of crisis widely found in ESGBP literature; in order to accept the prediction as "reasonable," however, requires an unscientific leap of faith. And, there are several reasons to question the reasonableness of this prediction. First, as we have indicated, ESGBP researchers have an equivocal, not to say idiosyncratic, understanding of the meaning of "extinction." Second, the "available evidence" is based on an HE Model that is of questionable value. Third, the "accepted theory" is the mission-driven, "highly value-laden" agenda of conservation biology. Finally, his comparable examples are taken largely from other ESGBP work and other preservationist researchers.

The foregoing evidence and analysis compels the following minimal conclusion: the HE model used by the ESGBP requires serious review. There is, however, no point in reviewing the model and its application at present. Without the inclusion of adequate cover or of any mortality risk coefficients, the HE model is incapable of approximating real-world conditions. In any case, ESGBP researchers and national park managers should be using this model, after its deficiencies are corrected, only as part of a suite of management techniques. Basing human use levels on the predictions of the HE model leaves both researchers and managers in the dark and carries the regrettable implication that wildlife management decisions regarding Canada's national parks are made in the absence of valid and reliable wildlife biology.

Analysis of security areas

The other key tool now being used by Parks Canada for cumulative effects assessments is analysis of security areas. Leighton (2000: 52) described the increasingly strict definition of what constitutes a secure area in ESGBP literature from the 1996 Banff-Bow Valley Study (BBVS) to the PHVA Report (Herrero *et al*. 2000). The 1996 study called for a security area of 4.5 square kilometres. By 1998, the target had become a security area of 9 square kilometres in which "adult female grizzly bears will have a low probability of encounters with people" (Gibeau *et al*. 2001: 124). Finally, by the time a population and habitat viability analysis (PHVA) was completed by ESGBP researchers in 2000, the definition of a "secure area" had become a "9km² bubble [that] surrounds an adult female bear and moves with the animal around the landscape in the bear's home range" (Herrero *et al*. 2000: 73). Gibeau added that the areas involved were needed to maximize "the reproductive potential of the population" (2000: 4). This marks a considerable change from the 1997 Banff Management Plan developed a scant three years earlier, which contained only a commitment to maintaining a viable population of grizzlies (Parks Canada 1997: 21). Such security areas would also be designed to insulate bears from any human encounter, thus maintaining the wary grizzly bear behaviour that ESGBP and Parks Canada management solutions seek to maintain. Maximizing a population, however, represents quite a different goal than maintaining a viable grizzly bear population.

One conclusion to be drawn from the changes in the understanding of a security area—from bears choosing to avoid people to the moving bubble of 9-square kilometres—is that they are simply artifacts of a continually refined concept used to ensure that habitat security levels in the Banff-Bow Valley will never be good enough. The requirement of a mobile 9-square-kilometre personalized security bubble as a necessary component of a secure habitat marks a distinct rise in the perceived needs of female grizzlies. Conceptually, however, by abstracting from real-world conditions in order to create a simple formula that ignores the behavioural variability in bears, the security areas concept reflects the same defects as the HE model. Even more significantly, this notion of a moving bubble refuses to recognize that human users of these natural areas are vastly more sensitive to the needs of grizzlies than they used to be. Contemporary human populations are far more benign toward grizzly populations than they were during the 1950s and 1960s when park wardens would shoot grizzlies as "dangerous pests" whenever they came near humans (Burns 2000: 3; MacMahon 2001). Indeed, accounts of being "blessed" by a bear's aggressive embrace indicates that some contemporary encounters between bears and humans are decidedly mystical—at least from the human perspective (van Tighem 2001).

There is no disputing the fact that bears require a certain amount of space within which to live. What is open to dispute are the models used to measure the amount of space that each bear requires. Herrero *et al*. (2000: 31) demonstrate that, within the central Rockies, bear densities range from highs of 40 per 1000 square kilometres down to none. Home ranges vary in size from as little as 10 square kilometres to as high as 500 square kilometres depending on the bear and the season when measurements are taken. Within these ranges, adult female bears have average daily movement areas of 0.1 square kilometre to 4.7 square kilometres. The smaller movement and range areas are those of bears living in higher-quality habitat ranges. It is obvious that there is a wide range of habitat quality, to say nothing of different habitat requirements. Even so, ESGBP researchers confidently claim that a 9-square-kilometre moving bubble will accurately represent the habitat needs of all adult female CRE grizzlies, and secure the persistence of grizzly bears throughout the landscape (Herrero *et al*. 2000: 73, 79). They make this claim despite the fact that the 9 square kilometres would encompass as much as 90% of the entire home range of some bears during berry season. Moreover, they also admit security areas vary with bear densities, habitat productivity, and season (Herrero *et al*. 2000: 20, 31, 73).

One size does not fit all

Defending this one-size-fits-all requirement, Gibeau offered the following explanation (2000: 37–44): "much of the basis for security area analysis relies on defining the average daily foraging radius and subsequent daily area requirements for an adult female grizzly bear." He then studied Alberta and British Columbia provincial lands, Kananaskis Country, and national park lands in both British Columbia and Alberta. From these areas, he "removed areas of unsuitable habitat (e.g., rock and ice),[6] habitat within 500 m. of high human use (>100 human visits per month), and areas of insufficient size based on an average daily feeding radius (polygons <9 km^2)." The remaining lands were identified as "secure areas." In this way, nearly half (48%) of the land surface of the mountain parks was determined to be "unsuitable." The removal of "unsuitable" habitat inevitably led to the conclusion that "the ability of our National Parks to support bears has been significantly reduced by widespread human presence" (Gibeau 1998; 2000: 38). Given the methodology employed, this finding could hardly have come as a surprise.

Focus on wary bears

Only the most sensitive bears were included in the study. Throughout his study on security areas, Gibeau ignored habituated bears and focused only on "a subset of radio telemetry data from intensive tracking of wary adult female bears gathered ... by the [ESGBP] ... to establish a mean daily movement distance" (Gibeau 2000: 41). That is, the original research design and data collection were restricted to the activity of those bears most likely to be disturbed by, and *to move away from*, any human activity. Before beginning any measurements or data analysis, the constrained methodology ensured a biased measure, not a representative sample. The measurement methodology maximized the movement ranges to be mapped. Subsequent applications of those maxima to establish broad management recommendations for the entire CRE grizzly population is not what most biologists would consider sound science because the conclusion had been pre-established by the methodology before data were either collected or analyzed. (Further problems with the bivariate distinction between "wary bear" and "habituated bear" will be discussed below.)

Nevertheless, despite the questionable overall procedure, which used a sample of 28 radio-collared "wary" adult female bears, nearly 70% of the study area was found to be secure for the most hypersensitive individuals in the CRE grizzly population. This also means that nominally "secure" areas up to 8.99 square kilometres were not included in the study because they were seen to be notionally or conceptually "insecure" for those select "wary" bears with daily movement ranges exceeding 1.7 kilometre (i.e., those that were unable to accommodate human presence within their nine-square-kilometre security bubble). However, the remainder of the "habituated" bears that were purposefully left out of the study, continue to exist and breed in both the conceptually "secure" and "insecure" areas, thereby adding to the actual, not conceptual, overall population. This deliberate removal of a large component of the population from the modeling process for methodological reasons greatly diminishes the predictive ability of the model.

No one seriously questions the need for wildlife to have secure habitat for concealment and thermal cover. No one could question the importance of secure habitat for rearing young. However, when this reasonable and common-sensical understanding is conceptualized in such a way as to measure only the extreme tail of a normal distribution, which then is used as the basis for developing and applying management schemes to the entire population, the usefulness of the exercise is seriously degraded. At the very least, therefore, this model must be reworked to include a random sample of the entire grizzly population and not just the most hypersensitive bears. After such a sample is collected, the movement data should be separated (where possible) to recognize use based on habitat quality. Where a bear inhabits relatively high-quality habitat, as on the western slopes in British Columbia, and, consequently, has a small daily movement and small overall home range, the security area requirements could be decreased to represent the bear's actual needs. Where bears occupied habitat with marginal quality, as on the eastern slopes in Alberta, the security area requirements could be expanded accordingly. These necessary changes must be made before the security areas model will provide any valid and useful numbers for real-world, on-the-ground grizzly management.

Managing grizzly bear behaviour

A basic assumption in ESGBP research, currently reflected in the management policies of Canada's Rocky Mountain national parks, is that "fundamental to maintaining a wary, healthy grizzly bear population is managing habituation ... and food-conditioning in Banff National Park" (Gibeau 2000: 54). Behavioural distinctions are vitally important to ESGBP research, because many of their models—including the habitat effectiveness and security areas models and accompanying policy recommendations just discussed—assume that bears belong to either one group ("wary bears") or the other ("habituated bears").

The "wary bear" label is applied to bears that avoid humans. A bear that experiences regular encounters with humans without being harmed will learn to get used to people, will tolerate them at closer distances, and may even largely ignore them. A bear that display these behavioural characteristics is considered "habituated" (Herrero 1985: 51). Food-conditioning is considered to be a special kind of habituation. Some habituated bears learn to eat human food and garbage, and associate people with food. Such bears become "food-conditioned." While food-conditioned bears are necessarily habituated to human presence, habituated bears are not necessarily food-conditioned (Herrero 1985: 51).

Simple as it may seem, there are, nevertheless, significant problems associated with a bimodal categorization of grizzlies. Primarily, classifying a complex and intelligent animal as either "wary" or "habituated" is both arbitrary and, in the case of ESGBP research, difficult (if not impossible) to replicate. Secondly, the basic assumption that human presence is damaging to grizzly survival ignores the adaptive benefits of habituation in areas (such as a national or provincial park) where the management goal is the coexistence of humans and bears. Finally, the restriction of research to so-called wary bears ensures research findings will be biased, unreliable, and of doubtful validity. This has serious implications for what is considered to be "effective" and "secure" grizzly bear habitat in and around Canada's national parks.

The problems with black-or-white behavioural categories begin at the most basic level of ESGBP research methodology:

> Based on field experience (M. Gibeau and C. Mamo, pers. observation), I then assigned a level of habituation to each female bear. Following Mattson *et al*. (1992) "bears that were known to exhibit considerable tolerance of humans were considered to be habituated." (Gibeau 2000: 6)

No specific methodology besides the connoisseurship of the ESGBP researchers is indicated or provided. Future attempts to replicate this research would be necessarily futile, because researchers would need the accumulated and particular field experience of Gibeau and Mamo.

A second problem is that, by making gross dichotomies (as was noted above with respect to changes in the USDA cumulative effects model), the result is invariably to transform aspects of reality into artifacts of a model (or, more technically, to hypostatize the concepts included in the model), which is a major categorical error (Feyerabend 1999). The philosopher Alfred North Whitehead called this mistake "the fallacy of misplaced concreteness" (Whitehead 1936).

Finally, their idiosyncratic method of labeling the behaviour of a complex and intelligent animal simply ignores extensive research detailing the ability of a bear to learn and to apply new knowledge to various situations. "Wariness" is not a tag that can be placed on a bear and left to describe its behaviour in all situations. As Herrero himself notes:

> Bears don't behave like robots. Each bear is an individual with a personality and a specific set of experiences. The outcome of experience is learning. Bears learn where to find things to eat. They learn where people are often encountered. They learn about their environment. Because of learning, each bear is able to tailor its response to a specific situation . . . The outcome of a given confrontation is the result of bringing the variable behaviour of a given bear into interaction with the much more variable behaviour of a given person. No wonder the outcome is hard to predict! (1985: 200–01)

Similarly, French explains that their intelligence allows bears to develop "individual behaviour, shaped by both experience and memory" (1999: 5).

This draws attention to the fact that habituation and wariness are not immutable qualities but simply descriptions of a bear's behaviour at a particular time and under particular circumstances. As Leighton (2000: 71) notes "a bear may appear 'habituated' beside a road and 'wary' 100 metres from it." This is supported by Craighead's research on grizzly bears in Yellowstone, which found that "the same animals that ignore human scent at the dumps are quickly alerted by it in the back country. Tolerance of man . . . is definitely linked to specific sites" (1971: 846). Even Gibeau (2000: 34), who relies on this stark behavioural distinction to back up his thesis that the presence of humans causes unsustainable rates of grizzly bear mortality, is aware that the reality of grizzly life is more complex than his bimodal categories allow. One conclusion that may be drawn is that by itself, a division of a complex behavioural repertoire into two categories—wary and habituated—is likely to produce unreliable and invalid data.

Ultimately, it is Gibeau's own findings that provide the greatest reason for avoiding the use of such broad labels to study bears. Studying how grizzly bear behaviour and habitat use is affected by various levels and distributions of human activity in Banff National Park, Gibeau found that "no [statistically] significant difference was detected in daily distance traveled . . . between wary and habituated bears." Nevertheless, Gibeau went on, "I chose to continue with the distinction between wary and habituated bears given that the statistical power indicated a high probability of committing a Type II error [the probability of rejecting a true hypothesis] and separation may provide biologically meaningful insights. Evidence is strong from other research that there are differences between wary and habituated bears" (Gibeau 2000: 8). While differences were detected between the distances traveled at night ("human inactive period") and at day ("human active period") by wary and habituated bears, "they were not statistically significant." In other words, ESGBP researchers found no statistical reason to continue with the distinction between wary and habituated—but they used it anyway. The conclusion we are told to accept is that "consistent differences in movement rates between wary and habituated adult females, although not statistically significant, further suggest the influence of humans" (Gibeau 2000: 4).

Two aspects of this observation are worth closer analysis. First, the claim that bears moved less during periods of human activity than of human inactivity carries the implication that human activity reduces bear movement. However, when the claim is looked at in terms of distance moved per hour, the opposite implication can be drawn: during the 9 hours of human activity (8 am to 5 pm) bears move 1.3 kilometres (or 140 metres an hour). During the 15 hours of human inactivity, bears move 1.9 kilometres (or 130 metres an hour)—10 metres an hour *slower* than they move during human activity. Even though comparing overall movement during a 15-hour period with overall movement during a 9-hour period is inappropriate, the conclusion, that movement is restricted by human presence in this example, is simply unsupported. The inconclusiveness of these results is compounded when one accounts for the standard deviational error inherent in radio telemetry tracking methods. While Gibeau accounts for tracking errors of ±150 metres, other field research involving similar radio relocation techniques have found errors as large as ± 250 metres (C.E. Kay, pers. comm. with Barry Cooper, February 27, 2002). Such levels of error seriously compromise study results.

A second aspect of the correlation between human activity and grizzly behavioural modification is more important. If there were no statistically significant differences between wary and habituated bears, the obvious question is: why use the distinction at all? Here Gibeau cites other research that has found differences between wary and habituated bears but he does not explain how this other evidence compensates for the lack of statistical significance in his own data. His answer is that he wished to avoid the commission of a "Type II error" and because retaining the distinction between wary and habituated "may provide biologically meaningful insights." This, however, is but a technical way of disguising an equally serious misuse of the precautionary principle.

Misuse of the precautionary principle

In common-sense language, the ESGBP researchers' concern over committing a Type II error is a way of invoking the statistical version of the precautionary principle. Concern over the probability of committing a Type II error, which, to repeat, is the probability of rejecting a hypothesis when it is true, permits them to use a statistically insignificant distinction. This is analogous to saying that humans using the central Rockies are guilty of an impact on grizzlies until proven innocent. Notwithstanding the absence of supporting statistical evidence, the claim was advanced that making the distinction between wary and habituated bears "may" provide insights; what the unsupported distinction unquestionably does provide is support for restrictions on human use as the single best way to protect "wary" grizzlies from increased mortality. In short, by presenting the recommended list of options that managers should consider and dressing that list in the scientific sounding language of probability theory, ESGBP researchers have ensured that their precautionary demands prevail over all other interests. This version of the precautionary principle "may sound reasonable in theory," write Burnett and Mitchell but "it would be disastrous in practice. One cannot prove a negative. Every food, product, and tool poses some risk of harm" (2001: 1) to humans or to the environment.

Such an understanding of the precautionary principle begins and ends with shifting the burden of proof in such a way that "prudence" will always demand avoiding a Type II error. Noss explained:

> The philosophy underlying conservation biology and other applied sciences is one of prudence: in the face of uncertainty, applied scientists have an ethical obligation to risk erring on the side of preservation. Thus, anyone attempting to modify a natural environment and put biodiversity at risk is guilty until proven innocent. This shift in burden of proof is consistent with the precautionary principle, which is gaining increased support in many professions . . . when the burden of proof is shifted from conservationists to developers, this poses serious questions about the enjoyment of private property rights, "taking" of property, and just compensation. (1994: 3)

Armed with this understanding of the precautionary principle and with such an "ethical obligation," researchers are compelled to oppose any development or human use of the central Rockies that *might* cause damage to the environment. Any person disagreeing with a concern for the possibility of damage is then given the impossible task of proving their proposed actions are "innocent" in the face of hypothetical concerns for unknown numbers of unknown species that might be impacted. All that is required to stop human use is the discovery (or invention) of a new subspecies or a "last remaining example" of a heretofore unknown ecosystem, which is itself an intellectual construct.

Prudence, properly understood, demands a clear knowledge of probabilities before invoking the precautionary principle because its application depends upon "the level of uncertainty, the direction of that uncertainty, and then particularly [on] the likely costs and benefits of different levels of action" (Lomborg 2001: 349). Indeed, if we were to "apply the precautionary principle to itself—ask what are the possible dangers of using this principle—we would be forced to abandon it very quickly" (Burnett and Mitchell 2001).

Burnett and Mitchell are correct with regard to the version of the precautionary principle advanced by Noss and his followers. A more balanced and usable concept of the precautionary principle could play a valuable role in mitigating environmental damage. In describing "a framework for applying the precautionary principle under competing uncertainties," Goklany (2001: 8), for example, sets out specific criteria, by which managers can determine the feasibility of implementing a management scheme when that scheme could have both positive and negative outcomes. He notes: "The only way to implement the precautionary principle intelligently under such conditions is to formulate hierarchical criteria and rank various threats based upon their characteristics and the degree of certainty attached to them" (Goklany 2001: 8). Goklany's criteria include:

- the *Public Health Criterion*, which includes:
  - the *Human Mortality Criterion*: the threat of death to any human outweighs similar threats to members of other species;
  - the *Human Morbidity Criterion*: non-mortal threats to human health take precedence over threats to the environment, with exceptions based on the nature, severity, and extent of the threat;
- the *Immediacy Criterion:* immediate threats are given priority over future events;
- the *Uncertainty Criterion*: threats that have a higher probability of occurring are given priority;
- the *Expectation-Value Criterion*: if threats are equally certain, those that have a higher expectation of harm are given priority;
- the *Adaptation Criterion*: available technological protection allows the discounting of potential impacts to the extent that the technology can mitigate the harm;
- the *Irreversibility Criterion:* priority is given to persistent or irreversible outcomes.

If the precautionary principle is restricted to a set of fixed and replicable criteria to indicate probable costs and benefits, it can be a useful management tool. Leaving the principle as an open-ended moral trump to any human activity ensures that it will be consistently derided and eventually abandoned.