

### Box 3.1 The costs of large-mammal extinctions

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When humans alter ecosystems, large mammals are typically the first species to disappear. They are hunted for meat, hides, and horns; they are harassed and killed if they pose a threat; they require expansive habitat; and they are susceptible to diseases, such as anthrax, rinderpest, and distemper, that are spread by domestic animals. Ten thousand years ago, humans played at least a supporting, if not leading, role in extinguishing most of the large mammals in the Americas and Australia. Over the last 30 years, we have extinguished many large-mammal populations (and currently threaten many more) in Africa and Asia—the two continents that still support diverse assemblages of these charismatic creatures.

The ecological and economic consequences of losing large-mammal populations vary depending on the location and the ecological role of the species lost. The loss of carnivores has induced trophic cascades: in the absence of top predators, herbivores can multiply and deplete the plants, which in turn drives down the density and the diversity of other species (Ripple and Beschta 2006). Losing large herbivores and their predators can have the opposite effect, releasing plants and producing compensatory increases in the populations of smaller herbivores (e.g. rodents: Keasing 2000) and their predators (e.g. snakes: McCauley *et al.* 2006). Such increases, while not necessarily detrimental themselves, can have unpleasant consequences (see below).

Many species depend on the activities of particular large mammal species. Certain trees produce large fruits and seeds apparently adapted for dispersal by large browsers (Guimarães *et al.* 2008). Defecation by large mammals deposits these seeds and provides food for many dung beetles of varying degrees of specialization. In East Africa, the disturbance caused by browsing elephants creates habitat for tree-dwelling lizards (Pringle 2008), while the total loss of large herbivores dramatically altered the character of an ant-plant symbiosis via a complex string of species interactions (Palmer *et al.* 2008).



**Box 3.1 Figure 1** White-footed mice (*Peromyscus leucopus*, shown with an engorged tick on its ear) are highly competent reservoirs for Lyme disease. When larger mammals disappear, mice often thrive, increasing disease risk. Photograph courtesy of Richard Ostfeld Laboratory.



**Box 3.1 Figure 2** Ecotourists gather around a pair of lions in Tanzania's Ngorongoro Crater. Ecotourism is one of the most powerful driving forces for biodiversity conservation, especially in tropical regions where money is short. But tourists must be managed in such a way that they do not damage or deplete the very resources they have traveled to visit. Photograph by Robert M. Pringle

These examples and others suggest that the loss of large mammals may precipitate extinctions of other taxa and the relationships among them, thus decreasing the diversity of both species and interactions. Conversely, protecting the large areas needed to conserve large mammals may often serve to conserve the greater diversity of smaller organisms—the so-called umbrella effect.

The potential economic costs of losing large mammals also vary from place to place. Because

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**Box 3.1 (Continued)**

cattle do not eat many species of woody plants, the loss of wildlife from rangelands can result in bush encroachment and decreased pastoral profitability. Because some rodents and their parasites are reservoirs and vectors of various human diseases, increases in rodent densities may increase disease transmission (Ostfeld and Mills 2007; Box 3.1 Figure 1). Perhaps most importantly, because large mammals form the basis of an enormous tourism industry, the loss of these species deprives regions of an important source of future revenue and foreign exchange (Box 3.1 Figure 2).

Arguably, the most profound cost of losing large mammals is the toll that it takes on our ability to relate to nature. Being large mammals ourselves, we find it easier to identify and sympathize with similar species—they behave in familiar ways, hence the term “charismatic megafauna.” While only a handful of large mammal species have gone globally extinct in the past century, we are dismantling many species population by population, pushing them towards extinction. At a time when we desperately need to mobilize popular support for conservation, the loss over the next 50 years of even a few emblematic species—great apes in central Africa, polar bears in the arctic,

rhinoceroses in Asia—could deal a crippling blow to efforts to salvage the greater portion of biodiversity.

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“sampling-competition effect” the presence of more species increases the probability of having a particularly productive species in any given environment (Tilman 1997). Furthermore, different species’ ecologies lead to complementary resource use, where each species grows best under a specific range of environmental conditions, and different species can improve environmental conditions for other species (facilitation effect; Hooper et al. 2005). Consequently, the more complex an ecosystem is, the more biodiversity will increase ecosystem function, as more species are needed to fully exploit the many combinations of environmental variables (Tilman 1997). More biodiverse ecosystems are also likely to be more stable and more efficient due to the presence of more pathways for energy flow and nutrient recycling

(MacArthur 1955; Hooper et al. 2005; Vitousek and Hooper 1993; Worm et al. 2006).

Greenhouse and field experiments have confirmed that biodiversity does increase ecosystem productivity, while reducing fluctuations in productivity (Naeem et al. 1995; Tilman et al. 1996). Although increased diversity can increase the population fluctuations of individual species, diversity is thought to stabilize overall ecosystem functioning (Chapin et al. 2000; Tilman 1996) and make the ecosystem more resistant to perturbations (Pimm 1984). These hypotheses have been confirmed in field experiments, where species-rich plots showed less yearly variation in productivity (Tilman 1996) and their productivity during a drought year declined much less than species-poor plots (Tilman and Downing 1994). Because