Next steps in recreation ecology

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Research on the ecological impacts of outdoor recreation has made long-standing contributions to threatened species conservation and protected area management. It is also politically important, as tourism enterprises lobby for access and development rights, and park administrative agencies are required to demonstrate evidence-based management. The accumulated knowledge – over a thousand individual studies – also adds to the theoretical understanding of ecological stress-response relationships (see Monz *et al.* p 441).

Patterns have proven to be elusive, however, because there are many different species and ecosystems, types of recreation, and impact parameters. Localized, direct, and easily measurable effects are studied often. Diffuse, delayed, indirect, and difficult-to-detect effects (eg introduction of pathogens or disruptions to animal energetics and reproduction) are studied much less frequently, despite being more important ecologically. Sophisticated experiments, for example using remote telemetry to monitor hormones and heart rates in birds disturbed by tourists, are expensive and uncommon.

It is inexpensive and straightforward, however, to measure loss in herbaceous plant cover with increased intensity of experimental trampling, so this is an often-repeated test. The stress-response curves of cover loss are asymptotic, with numerical parameters dependent on: type of ecosystem; type, intensity, and timing of trampling; and the impact parameters measured. The dominant belief is that this curve applies for all forms of recreational impact, but that is incorrect. Another oft-repeated experiment is to walk toward feeding shorebirds and measure how close one can approach before they take flight. This yields a stress-response curve with a vertical step from no-flight to flight. Other types of activities and impacts yield different curves again, as Monz *et al.* point out.

Several further perspectives now also deserve attention. (1) Some impact parameters are ecologically more important than others: populations more than individuals, and mortality more than behavior. There are cases where a single disturbance to the sole breeding colony of a threatened bird species has led to the loss of an entire season's reproductive output. (2) The ecological importance of any impact parameter depends on the susceptibility of the species concerned. Most species are more susceptible during reproduction or periods of energetic or nutrient stress. Similarly, human noise has little effect on high mountain summits, but considerable impact in fauna-rich forests. (3) Interval and timing of repeated disturbances are as important as intensity. Repeated interruptions to feeding by migratory birds en route to breeding or overwintering grounds may cause considerable mortality. (4) Recovery trajectories after or between disturbances are as important as initial disturbance trajectories; for instance, cryptogamic crusts (algae and lichens) on desert soils take longer to recover from trampling than estuarine mudflats. (5) Impacts can occur in cascades. (6) Some disturbances are self-limiting, whereas others are self-propagating. For example, loss of plant cover can lead to continuing rain erosion of underlying soils, while introduction of weed seeds, pathogen propagules, or insect pests can change entire ecosystems. All of these have been studied case-by-case, but more research is needed to extract general patterns.

Most of the stress-response models used in recreation ecology are static, considering end effects rather than trajectories, and elastic, assuming that the same stress always produces the same response. Few studies have investigated disturbance regimes and recovery pathways. In contrast, researchers in related fields (eg restoration ecology) have known for 30 years that ecosystem recovery may be incomplete and may follow different pathways. Paleoecological and successional studies show that ecosystems are rarely in equilibrium but respond at different spatial and temporal scales to a wide range of disturbances. In addition, recreational impacts interact with large-scale effects such as climate change, as demonstrated for Alaskan tundra by Monz *et al.* in 1996.

As recreation ecology matures, I would argue that it has more to contribute to analysis of ecosystem dynamics. Most disturbances can be examined experimentally only at small scales. Larger scale drivers, such as deforestation, invasive species, or climate change, are typically uncontrolled. The impacts of tourism and recreation occur at meso-scales, and this allows controlled manipulation of ecosystems with a sufficient variety of impact types and intensities to examine a wide range of stress-response-recovery regimes, relationships, and trajectories. This is a valuable analytical tool for the development of ecological theory. It also improves practical management of protected areas, given that tourism is used to generate revenue and political support for conservation.

Repeating similar experiments in different ecosystems was a necessary phase in recreation ecology research. The next step requires broader horizons: identifying different kinds of impacts, analyzing trajectories and interactions, deducing general lessons in ecosystem dynamics, and applying them in conservation. Surely this represents an inviting prospect for ecologists worldwide.

