

The Boundary Approach To The Analysis Of Conservation of Nature Reserves

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The theory of island biogeography was put forth in 1963, and in the 1980s we finally began to see its contribution to research and conservation. Island biogeography is a fine concept and biogeography a fine discipline – lacking only the single most important factor that stands in opposition to species survival and park protection: the *human element*. However, were it not for initiatives taken by biogeographers, many of us interested in design and protection of parks and other reserves would be looking for a starting point.

In the National Park Service, we have correctly identified people and their effects as the primary threat to endangered species in particular and to parks in general. The disciplines of ecology and biogeography take into consideration only non-human animal species in the contributing theories to conservation biology. Both disciplines are essential, representing underlying systems in the same way that physics and chemistry underlie biology. But decidedly the most important variable to park preservation is the human response to the laws protecting park resources including the uses of lands external to parks. These resources comprise the most powerful inducements to ecological change. So, even ecology and biogeography are not sufficient in the planning or analysis of protection.

With this in mind, we have developed a "model" and an approach to the design and conservation of nature reserves. The approach is a geographic one that brings together the multi-disciplinary aspects of conservation, including humans, their effects, influences, and attitudes besides the traditional biological sciences. This approach recognizes physical qualities of the environment, the biological role of enforcement and resources management in park protection, and focuses on the **administrative boundary** as one of two major thresholds across which numerous constructive and destructive processes occur.

The administrative boundary is like a filter. It separates two types of human social activity. While on the outside, people may farm, build cities, hunt and gather, they may not do so on the inside. The rules that govern human behavior on the inside, once people cross the administrative boundary of the park, constitute the filter. If the rules are enforced, the filter is effective; thus, enforcement "activates" the filter. The filter controls only humans and/or human behavior. Neither animals nor plants, wind nor water can read or heed the exit and entrance signs.

While enforcement activates the filter, resource management responds to the effects of human behavior that move through the filter. When people release exotic species into the park, management responds by attempting to remove the species. When people break through the filter and are found poaching in the park, enforcement attempts to remove and punish the people. What occurs at the administrative boundaries of a national park is a series of opposing forces interacting across the administrative filter. The net sum of these interactions is the effectiveness of

park protection for each protected species, item, incident, and/or location. (Fig. 1)

What park relevant changes are induced by the filter processes?

The first change is the development of a "generated ecological edge," the result of activation of the administrative boundary filter. This edge is the second threshold and acts as the "ecological" filter affecting directly species movements and survival. It is different from the so-called "natural ecological edge," but is often mistaken for it. The development of a generated edge may stimulate the development of additional "secondary" changes we associate with natural edges. The two may overlap each other. The generated edge responds primarily to human effects. The generated edge is of varying thickness and the area between the two sides of the generated edge is subject to segmentation along the perimeter of the park administrative boundary; it constitutes a new and different context for approaching preservation.

The development of segmentation of the edge and boundary, results from variability in land use and biotic communities developing in response to the ownership and use patterns of the land surrounding the park, and from enforcement, zoning and management within the park. All of these factors together give the boundary a *segmented* quality, with each boundary segment a separate habitat, requiring more or less management and more or less protection. Some segments can be identified as "leaks", where erosion of inner resources is taking place. Other segments can be shown to be very steep in contrast from inside to outside and therefore are tantamount to unsupported dams—ready to collapse. The generated edge holds similar properties with regard to segmentation.

The third change that develops is establishment of a gradient across the edge segment – a gradient of increasing density to decreasing density, or vice versa, for a particular species or distribution. The nature of this gradient indicates the potential risk of invasion or loss. For example, where a very high concentration

of a species (such as an exotic) exists outside the park, the potential for an invasion exchange is very high. If the gradient exists over a large (shallow) distance (from outside to inside), the exchange is likely to be slow and potentially easier to control. If, however, it takes place over a small distance, it is likely to be comparatively rapid. Persistence of the exotic also has an effect (augmenting the potential for exchange). This suggests that national parks should try to maximize the distance across such gradients where the gradients are steep. The creation of buffer zones is especially important in these situations. And, these should be adapted, as feasible, to segment characteristics.

In cases where little or no gradient exists, there is either no protection (effectively speaking) or little or no need for a buffer or for management and enforcement at the site (for the moment!); namely, the inside and outside habitats are in the same condition relative to internal protection. Unfortunately, the characteristics of gradients are subject to constant change and need to be monitored.

Boundary Processes

Our conception of our protective function is that it is both active and passive. Protection affects internal and external processes that contribute toward or undermine protection of the park. Below are some ways in which changes in the park condition take place.

1. Organisms dependent upon the park's protection may move freely across the boundary but return in smaller numbers than when they exited (less protection outside) (e.g., prairie dogs, alligators, grizzly bears);
2. Organisms in the park may not move freely across the boundary, or may be lost completely when crossing the boundary to the exterior and are, consequently, isolated (e.g., bison, swamp orchid, redwood);
3. Organisms undesired by the park may move freely across the boundary and reduce populations of other species that are dependent upon protection for

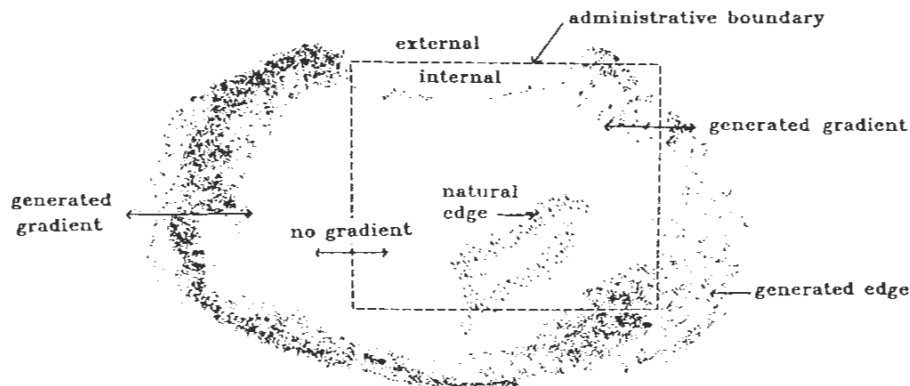


Figure 1. This hypothetical reserve illustrates the variable location of generated and natural ecological edges with respect to the administrative boundary. The generated edge develops in response to enforcement of regulations associated with the administrative boundary. Generated gradients are mapped perpendicularly to the length-axis of generated edges. Where there is no generated edge there is no generated gradient (from Schonewald-Cox et al. *Biol. Cons.* 38:305, 1986).

survival (e.g., kudzu, honeysuckle, starlings);

4. Humans may move across the boundary and defy regulations to remove desired organisms that depend upon protection for survival (e.g., cactus, parrots, tree snails);

5. Humans may intentionally or accidentally import organisms that may cause internal losses (e.g., gypsy moth, japanese beetles, feral cats, brook trout);

6. Humanly generated pollutants may enter, move over, seep, or flow into the protected system and change microclimates, flora and faunal distributions, or the food and water supplies, reducing survival of organisms dependent upon protection for survival (e.g. trail erosion, acid rain, off road vehicles, cave lichens and mosses brought in by human hair and skin flakes);

7. People may independently buy land or engage in activities outside of the park that are intended to expand the park's protection and increase its effectiveness (such as has been encouraged by Nature Conservancy or Sierra Club);

While a few species may be isolated, the ecosystem within a park is never cut off completely from its surroundings. So, total genetic isolation of most park species is not likely to occur. On the other hand, humans and their effects are quite capable of intruding into every known isolated area on the face of the earth. The extent of isolation of the park community can be described by patterns of species distributions and movements in relation to the park, as seen in vegetation mapping and monitoring.

As mentioned earlier, rate and ease of movement of organisms across the administrative boundary filter is influenced by the generated edge. In addition, the number of individuals moving across the administrative boundary is affected by classic measures such as group size, average distance maintained between individuals, manner of obtaining resources, susceptibility to competition and predation, species mobility, amount of directional movement, population density gradient, the nature of any coinciding natural edges with the generated edge, suitability of habitat within the generated edge, and human influences that encourage or discourage movement.

For example, organisms that form associations or clones will tend to move into habitats that are not saturated. The movement may be reversible, but movement overall will tend to favor one direction in the short term. Directional movement can also be manifested for species that are dissipated when they leave the park under conditions such that none return. If recruitment does not compensate for this directional movement out of the park, then the species is extinction prone.

Several reports in the last five years suggest tremendous pressure from external impacts. Those that traverse park boundaries and come into the park accelerate losses not only across the boundary (by movement) but also within the park by reducing recruitment and survival. It should not be overlooked that tourism in the National Parks constitutes a multiple use industry that can severely impact park resources from within, bringing the generated edge into the center of the park and threatening to make protection ineffective.

Shape and Size of the Protected Habitat.

We recently measured roughly the area-to-perimeter ratios (A-P) for 106 of the most sizable parks in the National Park System. An A-P ratio of 5 describes a park that is almost linear, essentially; there were 10

of these.

In the A-P = 15 ratio, were 22 parks. Only 11 parks showed an A-P ratio of 25 or higher, constituting essentially round or square parks. Between the A-P = 15 and the A-P = 25, fell 54 of the parks.

What this means is that in terms of the boundary effect, most of the parks in the National Park System are highly exposed; i.e., there exists only a short distance from any interior point to an administrative edge. These parks will need strong cooperation among all elements of the full park staff and between them and surrounding land owners and managers.

The most positive avenue for dealing with exposure seems to be cooperation with adjacent land agencies to create buffers surrounding the most vulnerable segments of the administrative boundary and a resource management effort to push the generated edge outward, so that the gradient becomes so shallow as to be almost undetectable.

If two areas adjacent to each other cooperate in protection (even if the work is done in slightly different ways) the generated edge then may coincide with the outer boundaries of their combined units.

If adjacent areas are not available, it's important that parks begin to look into techniques of gene flow used by the leading zoological parks and botanical gardens for species at risk. While such manipulation of populations is not preferred, sometimes there is no alternative if a species evolution is to continue. Or, we may decide to favor process at the expense of species not deemed important or that we believe are undergoing a natural extinction.

Three important functions associated with parks are enforcement and resource management. Each has a discernible role in determining where and to what extent the generated edge will develop. Enforcement activates the boundary filter and keeps out humans engaged in deleterious activities. Resource management treats the effects of human activities across the filter. Researchers can decipher the impact that the boundary has on the very crucial generated edge. Until now, there has been little recognition of the enforcement, resource management and research roles as part of the biological functioning of the park. The

boundary approach to management clearly suggests at least these ecological roles for each of these functions.

CONCLUSIONS

It is likely that the current rate of extinctions cannot be mitigated by merely reducing the impact of area effects resulting from habitat fragmentation. The extinction rate is also influenced by human behavior. How this behavior translates into ecological processes across park boundaries, we believe, will strongly influence the effectiveness of protection.

The boundary model suggests that knowledge of changes in local human activities, traditions and attitudes relating to protection and location of natural and generated edges is critical. Populations in protected habitats may decline dramatically, but extinction is not the inevitable consequence, nor is available habitat size necessarily the limiting factor. The boundary model suggests that the results of studies examining the area effects may inadvertently be confounded by several physical and biological factors and it also reassures us of the proneness of some species to extinction in parks of high exposure and small size — due to stress caused by human generated impacts.

We believe that generated gradients and other components of the boundary model and approach to analysis of protection will alter our views on the probability of extinction in protected habitats. It will make us more aware of the fragility of even the largest protected sites. Incorporation of human societies, behavior, and welfare into the planning and design process in land-based conservation efforts is sorely lacking at present.

We believe that "Boundary" represents an advance derived from synthesis built on the best information present theories have to offer. It has the flexibility to incorporate specific mandates and localities for dealing with real-world conservation issues, and it can incorporate the models and metaphors of numerous contributing disciplines.

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