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THE NATURALNESS OF BIOLOGICAL INVASIONS

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The National Park Service has precise policies regarding biological invasions. These place specific burdens on park management. In considering how to handle biological invasions in the United States national parks, we need to be cognizant and sensitive to these requirements. The problems posed by these policies are revealed by an interesting conundrum about invasive species.

Conundrum

A serious conundrum exists about invasive species: Biological invasions are natural and necessary for the persistence of life on Earth, but some of the worse threats to biological diversity are from biological invasions. It was once believed, both among scientists and in prescientific history in Western thought, that nature undisturbed was in a steady state. If this were true, then biological invasions would be unnatural, and management of biological invasions would be simple: prevent them or, if that failed, eliminate the invaders and restore the "natural" steady state. But findings in environmental sciences in the latter part of the 20th century confirm that natural ecological systems are always changing, that they do not have a single steady state, and that biological invasions are natural and, more important, necessary for the persistence of life. If species never invaded new territories, they would be extinguished by catastrophic events in their previous habitats. An additional conundrum is revealed. One can either preserve a "natural" condition, or one can preserve natural processes, but not both. The preservation of natural processes requires change. The resolution to this second conundrum is, however, simple: either preserve the natural processes and therefore preserve life over the long run, or preserve a single condition and either threaten the persistence of life or else substitute a great amount of human intervention for natural, dynamic processes.

Salmon exemplify the necessity of change and of biological invasiveness. Contrary to the folktale that salmon always return to spawn in their natal stream, approximately 15% of adult salmon find their way to a different stream from the one in which they were born (Botkin et al. 1995). This might seem to be a "mistake," but without such "mistakes" salmon could not persist. Salmon are cold-water fish and make use of cold rivers and streams near northern continental glaciers. As glacial ages wax and wane, streams once suitable to salmon become iced over, while others, previously too warm, become sufficiently cold to support salmon. Other natural disturbances make individual streams temporarily unusable. Salmon require gravel of a specific size range and composition in which to lay their eggs. The source of these gravels is the failure of bedrock headwalls at the upstream end of streams. When such a failure occurs, the gravel dumped into a stream temporarily blocks water flow and makes the stream unusable by salmon. But without such temporary blockages, gravel would slowly erode from all salmon streams. Salmon streams must become temporarily clogged with gravel and therefore temporarily unusable for salmon to survive. Therefore, the requirement for a supply of gravel also requires that salmon be able to shift among streams over time. Fires and storms create conditions that temporarily eliminate salmon from a specific stream, thus also requiring that salmon can move among

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streams. Thus, for salmon to survive over a long time, invasiveness and reinvasiveness are necessary characteristics.

Biological invasion is a natural process everywhere, requisite for the persistence of essentially all species on Earth over the long term. Being able to seek new habitats and survive in them is essential in an environment that changes at all scales of space and time. A striking example occurred with the creation of Surtsey, a new island 25 km off the coast of Iceland as a result of volcanic activity (Botkin and Challinor 1998). In 1964 scientists camping on Iceland's south coast saw the view from the shore dominated by a vertical plume of ejecta and smoke from an open fissure about 100 m below the water surface on the mid-Atlantic ridge. When ocean water met molten lava at that shallow depth, the water pressure was insufficient to contain the resulting explosion, which hurled large pieces of the seabed through the water column as high as 300 meters into the air. Pulsed explosions occurred with each contact of cold seawater and molten lava at the fissure. The rapid cooling of the lava resulted in fine-grained crystal particles called tephra.

About three and one-half years later, in 1967, the explosions ceased, and the volume of tephra that had rained from the sky created Surtsey, roughly two kilometers in diameter and rising at its highest point about 100 meters above sea level. A few weeks after the eruptions ceased, the lava that formed Surtsey had cooled and hardened just enough so that it was safe for a person to walk on the surface, although molten lava was still visible flowing deep below through occasional surface cracks. Now the island could be visited by people. A group of scientists went to the island, and one, a botanist, found the first flowering plant invader: the sea rocket, a small flowering plant less than 5 cm high, and it was already in bloom. That the sea rocket flowered so soon after the lava solidified illustrates the speed with which biological invasions can occur.

Other botanists later discovered mosses and grasses that continued the biological invasion of Surtsey. Scientists formed the Surtsey Research Society, which stimulated long-term monitoring of the invasion process. The invasion of Surtsey by the sea rocket had no negative effects and can only be viewed as a positive event, beginning the transformation of a new but lifeless island into one rich with vegetation and other forms of life.

Another recent, ongoing example of a natural biological invasion that has had little if any negative consequences is that of the Cattle Egret, a ubiquitous white bird familiar to travelers who view African wildlife. This bird probably evolved in the flood plains of the African tropics but adapted to irrigated crop fields, especially in southern Africa. Cattle Egrets eat insects stirred up by or on large grazing mammals. In Africa these birds readily made the transition from following only the wild, native mammalian herbivores to following domestic cattle as the number of buffalo and other large, wild herbivores declined. More surprisingly was the transoceanic migration of this species, which flew from west Africa to South America. Eventually, enough egrets arrived to establish a New World breeding population. In hindsight, this transoceanic invasion was not such a difficult feat for this amazing bird because, if helped by favorable winds, Cattle Egrets can fly the 2900 km from West Africa to South America in about 40 hours.

First reported in South America in the 1880s, the birds rapidly expanded their range, especially as coastal tropical forests were cleared for cattle ranching in the 20th century. Once established in South America, they migrated north, reaching the United States in 1951. Just 5 years later they had spread from Texas to New England—several thousand kilometers!

A similar process took place in Australia, where these birds became common in the western part of the continent in 1952. They reached New Zealand in 1963, and breeding pairs were found about a decade later. The Cattle Egret expanded its range from Africa to virtually all tropical and temperate areas of the Earth within a century. Its expansion was fueled by its ability to exploit pastures with high cattle densities—an artificial habitat more suitable for its feeding behavior than its original one in Africa. So, in part, the egret's migration was assisted by effects of people on nature. But egrets took advantage of these human actions on their own; they were not transported by people. The widespread invasion by egrets seems so far to be benign because it fills a niche heretofore unoccupied by New World birds.

In contrast is a long list of invasions of exotic species that have had disastrous effects. Embarrassing to human judgment, many of the worst cases result from intentional human introduction, fostered with the belief that each would be beneficial. As an example, people in Great Britain intentionally introduced the American grey squirrel into the British Isles, believing this would add aesthetically to their woodlands. But the North American squirrel is forcing out the native British red squirrel, which has been extirpated from much of its original range and persists today only where habitats are inhospitable to the North American squirrel. Another famous example is the gypsy moth, introduced into Massachusetts by a well-meaning scientist who believed these insects could be used to establish a silk industry in North America. He also believed the moth could not spread westward because he introduced it in eastern Massachusetts, and the prevailing westerly winds would keep the moth along the coast.

The history of both positive and negative effects of biological invasions is essential background for the consideration of National Park Service policy regarding biological invasions.

NATIONAL PARK SERVICE POLICIES AND BIOLOGICAL INVASIONS

What are the implications for National Park Service policies toward invasive species, given the conundrum about biological nature—that it is both necessary and natural, and can create major problems in certain situations? According to National Park Service administrative policies, "Non-native species of plants and animals will be eliminated where it is possible to do so by approved methods which will preserve wilderness qualities." This is interesting because (1) the goal is complete elimination, not control, and (2) the definition brings in the term *wilderness quality,* which remains ambiguous and therefore presents operational difficulties.

Furthermore, NPS administrative policies define an exotic species as "a species occurring in a given place as a result of direct or indirect, deliberate, or accidental actions by humans." This definition focuses on the *mode of transportation and arrival* rather than on the *effect* of the species on others and on ecosystems. Further affirming this emphasis on the mode of transportation, National Park Service administrative policies define a native species as "a species that occurs and evolves naturally without human intervention or manipulation." Species that move into an area without the direct or indirect aid of humans are considered native by NPS definition. Based on this definition, a species that arrived without human intervention but completely altered a park's ecosystem from what it was prior to European settlement would be considered acceptable and would be allowed to persist within a park. However, a species that directly or indirectly arrived as a result of human actions, even if its presence was obscure and its effects innocuous, would be a target for elimination. But what if a species that arrives on its own, without human intervention, greatly disrupts the biological diversity of a park and alters its landscapes from the way they appeared just prior to European settlement? And what if a human-introduced species has little effect if any, or increases the bountiful appearance of a park?

This emphasis on the condition of a park prior to European contact appears in NPS administrative policies, which state:

> Plant or animal species introduced by indigenous peoples may be preserved and protected where they were introduced to the site prior to European settlement, and were culturally significant, and where their presence does not have any demonstrated impact of native species.

This means that, by NPS policy, species introduced after 1492 by Europeans are bad and to be exterminated, but those introduced before 1492 by peoples not of European origin are acceptable. In selecting a specific cut-off time for introductions that are to be allowed, there is an arbitrariness in this last policy. Underlying this policy also is the assumption that a single time, which therefore indicates a single state of nature, is the only one that is natural. This policy fails to acknowledge that natural ecological systems always undergo changes, and that a single time period is not an adequate measure of what is "natural."

A goal of returning a park to a specific time is consistent with earlier ideas about nature, in particular with the belief in a balance of nature. This is the idea that nature, left alone, will achieve a single state—a constancy of

form and structure that will remain indefinitely (Botkin 1990). As stated earlier, research among environmental sciences in the last 30 years of the 20th century demonstrated this was false, that natural ecological systems are dynamic and changing. The one thing we can be sure about nature in the future is that it will be different from today, because nature is always changing. Therefore, a goal of maintaining a park's ecosystems and species list to conform with what was the condition at a single past time cannot be obtained by a hands-off, do-nothing policy. It requires extraordinary effort. Recently, much lip service has been paid to the idea of the naturalness of change, but policies and actions have lagged behind, most of which are based on some kind of steady-state notion.

The NPS policy is mixed in regard to steady state. It allows natural introductions and introductions by American Indians, but not by those that occurred afterward. The implicit assumption is that introductions following European settlement have had only bad effects while those prior to European settlement had good or neutral effects. This is not true a priori, and it is not necessarily true in fact, as salmon, the sea rocket, and the Cattle Egret demonstrate. As explained earlier, these policies confuse the origin and mode of transport of a species with the effects of that species on the ecological system where it arrives.

Setting Goals

Are we claiming that an invasive species is a problem for the physical system—the ecosystem or a species—that an ecosystem or set of ecosystems cannot persist with *any* invasive species? Or do we desire to eliminate invasive species because of our appreciation of landscape beauty and a belief that the only landscape that can be beautiful in North America is one that was not affected by European civilization? Or do we desire to eliminate invasive species because of a spiritual value, perhaps reasoning that such a landscape might serve as a source of creative inspiration, but again only if it appears as it did prior to any European influence? Do we fear that introduced species, no matter how innocuous or beautiful, will take away from that spiritual or aesthetic quality of an American national park? Or is our justification a moral judgment—that only those species that arrived on their own or were helped by pre-Europeans are morally acceptable?

Let us consider the scientific basis for the argument that all invasive species should be eliminated. While there is ample evidence that many introduced species have led to disasters, I am aware of no evidence to support the generalization that all invasiveness is always negative. The Cattle Egret would appear to provide a sufficient contrary case in terms of ecosystem and landscape dynamics. Therefore, it would seem that a completely general policy opposing invasion of new species since European settlement must be based on nonscientific justifications, such as I have reviewed. These nonscientific reasons are value judgments, which are a personal and societal choice. They can be taken as good or bad, my point being that they cannot be justified on scientific grounds alone.

Discussions of the importance of native species and the negative effects of invasive species typically focus on the scientific basis—on the effects of ecosystem functioning and of the persistence of native species, including the potential extinction of a native species. We tend to shy away from discussing the complex mixture of goals I have mentioned. I think this is in part because of a belief that the intangible values—beauty, spirituality, inspiration, morality—won't sell in our modern, materialistic world. But to the contrary, the history of Western civilization is the history of the great power of ideas and beliefs. Somehow, when it comes to the environment and to life on Earth, we doubt this power.

I submit it is more logical, easier to justify theoretically, and pragmatically simpler to construct policies for invasive species based on truly held values about the intangibles—beauty, spirituality, creativity, morality—than it is to base them on poorly understood and often misused science.

Consider the introduction of wolves into Yellowstone National Park. The introduction of wolves is typically justified on 2 grounds: that they were present in pre-European settlement times, and that they perform a necessary function in the Yellowstone ecosystems, usually stated in terms of the natural control of their prey species. If this is taken to be an introduction, then it might be interpreted as

contrary to written national park policy. If it is assumed that the presence of wolves will bring the abundance of its prey species back to the level at some specific year, such as 1492, then modern ecological research has shown that this will not be the case. While large mammalian predators can reduce the abundance of their prey, the idea that they could create a precise control and return a wilderness to a fixed, steady state has been abandoned by the science of ecology. The reintroduction of wolves can be justified on mechanistic grounds (that is, on the basis of their function in Yellowstone ecosystems) only if reduction in abundance, rather than precise control, is acceptable.

These policies and assumptions are not unique to the National Park Service. As I wrote in *Discordant Harmonies,* there are 3 basic kinds of natural areas or nature preserves, when people use that term in North America: (1) an area with no human action, (2) an area set aside to conserve a specific species or species assemblage, (3) an area set aside to represent a particular time, usually taken to be that just before European settlement. In regard to invasive species, NPS policies are consistent with the last of these conceptions of "natural."

The naturalness of biological invasion gives some substance to the fear of those who live near but outside the park: that a truly successful reintroduction of wolves within the park will lead to their invasion (or reinvasion) of surrounding areas. As long as policies are based on restoring ecological systems to specific prior conditions, but allow little other direct actions, then preventing the spread of wolves beyond the park might not fall under park policies.

Suppose we took a different approach: justifying the introduction (or reintroduction) of wolves into Yellowstone on the grounds that they were once part of the ecological systems, and that people want to see them there, for aesthetic, spiritual, and moral reasons. We abandon the arguments about the ecological role of wolves as a necessary condition for sustaining the Yellowstone ecosystems. If the goal is justified from one of these points of view, then less burden in placed on science. Science does not have to provide the rationale for the presence of wolves. Instead, science can tell us how we can attain the goal of maintaining wolves within the Yellowstone ecosystem with minimal effects outside the park. In this case science plays its natural societal role. Scientific findings tell us what the natural characteristics of Yellowstone ecosystems are, and these include change over time. They tell us what species were present, but provide little information about actual abundances (because of a lack of historical data, both before and after the establishment of modern ecological science). Scientific findings tell us what goals are possible, how we can attain them, and what we gain and give up in achieving a goal.

SUMMARY

A dominant idea in ecology in the 20th century was the belief in a balance of nature—that there is a single true condition for any ecosystem, and therefore a single truth for that system. But modern ecological research shows us that ecological systems can persist under a variety of states and, in fact, generally require some level of variation. Rather than there being a single true condition to which a park must be returned, there are options, which depend on our goals. Allowing the possibility of several options for a park may make some conservationists uncomfortable. It may seem to open up the management of a park to conditions that specific interest groups would find undesirable. What becomes clearer through this discussion is that the management of a national park, rather than simply the restoration of a wilderness by abandonment of human intervention, resembles more the activities of a landscape architect who works to choose a landscape design that meets the real needs of a client. In this case, the client is the citizens of the United States and the visitors to the national parks.

Given the naturalness of biological invasions and the manifold rationales for the conservation of species and restoration of national park ecosystems, I believe that the path I have laid out provides a methodology more consistent with the goals of a democracy, more likely to achieve what people want to see in a park, and more likely to allow flexible management that will maintain biological diversity within a park.

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