Surrogate Species: Piecing Together the Whole Picture

by Andrea R. Litt & Andrew M. Ray

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National parks, such as Yellowstone National Park (YNP), are ecologically and socially important resources conservatively valued at $92 billion (Haefele et al. 2016). To properly protect and conserve these places, decision makers require reliable information to track and understand the manifestations of environmental change. However, national parks are large and infinitely complex ecosystems and available financial resources are wholly insufficient to measure and monitor all pieces (i.e., species) and environmental factors that are shaping them. As a result, scientists often select a subset of species and environmental factors (i.e., vital signs) to monitor and characterize ecosystem health ("Vital Sign Monitoring is Good Medicine for Parks," this issue). The idea being that these precious few pieces can provide enough information to see and understand the whole picture. Although physical and chemical characteristics are very instructive vital signs, scientists and decision makers are also interested in monitoring the status of plants and animals in parks. In essence, plants and animals can serve as "sensors" for tracking change, and these biological indicators can offer unique insights into future changes (Whitfield 2001).

Biological indicator species, or **surrogate species**, are species of plants and animals "used to represent other species or aspects of the environment to attain a conservation objective" (Caro 2010). In modern conservation science, using pieces to provide a broader picture of the whole is an increasingly common practice; however, the practice also raises several logical questions: What subset of species provides the most reliable information possible? What species' characteristics should be considered when evaluating potential surrogates? How do we ensure the information gleaned from the monitored subset "speaks" for the rest of the component parts? Although addressing all of these questions is beyond the scope of this article, we will attempt to clarify the types of species' groups considered useful for monitoring environmental change.

There are many types of surrogate species which can be subdivided based on three main conservation objectives. First, some types of surrogate species (e.g., umbrella species, keystone species) can help to identify, designate, or manage areas of high conservation importance and, in doing so, safeguard surrogate species in a manner that provides benefits to countless other species. Second, some types of surrogate species (e.g., flagship or iconic species) can be used to raise public awareness, begin conversations, and secure funding for conservation actions or to support monitoring initiatives. Finally, some types of surrogate species (e.g., indicator, proxy, or sentinel species) can be used as trail markers of environmental change because these species respond predictably to changes or because they reflect the responses of a suite of species. Because of the ever-expanding environmental challenges facing protected areas (Rodhouse et al. 2016), surrogate species that accomplish the last conservation goal are likely most relevant for vital signs monitoring in national parks (see below). However, surrogates that span objective boundaries by also raising awareness of conservation issues and generating support for monitoring can be particularly important to decision makers. What follows are definitions of surrogate species types and examples from YNP for each group. Some of these species are already part of ongoing vital signs monitoring programs or are studied by other researchers, whereas others could be considered as part of an expanded monitoring campaign.

Umbrella species are those "whose conservation confers protection to a large number of naturally occurring species" (Roberge and Angelstam 2004, in Caro 2010). These types of surrogates tend to be species that have large home ranges or extensive travel and migratory routes (e.g., elk). The principal assumption being if the large area required by the umbrella species is protected and habitat quality and corridors are maintained, other species also benefit. Often species that require large areas are large bodied, such as grizzly bears, wolverine, and wolves; however, if a species' habitat is patchily distributed, as with butterflies, smaller-bodied animals also may fit the bill. For park managers, maintaining a park or larger collective of protected areas so it provides safeguards for an umbrella species will pay dividends to countless other species of the region that occupy this large protected area. Umbrella species could also be helpful in bolstering public or political support for the protection of areas with exceptional levels of biodiversity, thus promoting connectivity.

Keystone species are species that have substantial influence on an ecosystem, to a degree that is disproportionate to their size or abundance. While umbrella species ensure protection of large areas, protecting keystone species ensures parks and ecosystems are diverse and high functioning. Species that greatly modify areas through their activities include beaver, pocket gophers, and prairie dogs. Because of their engineering feats, these species are commonly referred to as **ecosystem engineers**, a type of keystone species. Conservation or restoration of keystone species and ecosystem engineers is often desired in areas where they were previously extirpated. Unfortunately, scientists often don't know a species serves as a keystone or engineer until that species is lost or removed. This latter situation creates challenges in identifying and using these species as surrogates to achieve conservation objectives.

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Flagship or **iconic species** are those that can increase awareness and support, engage the public, and raise funding for conservation efforts. Although there are few concrete characteristics of this group of surrogates, these species tend to be described as charismatic or symbolize some unique aspect of the area where they occur. Often these species are large mammals (e.g., grizzly bears, wolves, bison) or birds (e.g., trumpeter swans, loons), but also include pika and other species that are readily recognized as sensitive to a changing climate. These species of conservation concern may also be species listed as threatened or endangered under the Endangered Species Act. Species that are easily recognizable and appreciated by most people are uniquely suited to garner political, public, and financial support, essential for any conservation or monitoring effort. The American pika, for example, is an iconic species that served as the face for multi-year studies (e.g., the NPS I&M Pikas in Peril Project; Wilkening and Ray 2015) focused on the impacts of a warming climate to mountain ecosystems.

Finally, multiple terms are associated with the type of surrogate species that indicate environmental change and ecosystem health, including **sentinel**, **proxy/substitute,**

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and **indicator species** (indicator species hereafter). These species serve as sensors in an early-warning system because they directly reflect environmental change or reflect responses of multiple species. Clearly, indicator species must be sensitive to one or multiple environmental stressors, but they must also convey something about the environmental change or disturbance that is compelling and possibly serving as the justification for management action. Further, indicator species should provide a response in a timely manner. Rapid responses are characteristic of species with short generation times, high reproductive rates, limited mobility, as well as specialized habitat and dietary requirements (e.g., amphibians, butterflies, bats, some plants). Useful indicator species, therefore, are less likely to be able to leave an affected area and less able to switch food resources or habitats when these resources become unavailable. Ideally, these species are also widely distributed, easy to find and identify, and inexpensive to monitor. Scientists may monitor these species by simply documenting presence/absence, collecting more detailed data on population characteristics (e.g., abundance, reproduction), or characterizing the entire community (e.g., how many species are present, which species are most abundant). Scientists often subdivide a taxonomic group (e.g., amphibians, bats, or insects) based on life history traits to identify and monitor just a few species (e.g., one from each sub-group) that might provide the most complete picture about the whole. Since different types of species will respond differently to the same disturbance or environmental change, monitoring several species from multiple, complementary groups can provide a more complete picture and help diagnose problems, prescribe management actions, improve policies, and increase awareness.

Each type of surrogate species outlined above provides unique advantages to a monitoring program and helps to achieve different conservation objectives. As a result, scientists aim to incorporate an amalgam of species as part of a comprehensive vital signs monitoring program. Although some of these types of surrogates are currently included as vital signs (e.g., amphibians) or are measured by other researchers in YNP (e.g., grizzly bears, wolves, bats), additions of other species or taxonomic groups (e.g., insects, aquatic plants, fish pathogens) might be helpful when envisioning a comprehensive monitoring program. Despite our inability to monitor everything due to logistic and financial limitations, carefully considering the most appropriate subset of species can be likened to trying to find at least some pieces in all quadrants of a puzzle to get the best sense of the overall scene depicted. Ideally, the collective suite of diverse monitored species will provide the most comprehensive, early-warning signs to help ecological "doctors" diagnose potential problems and intervene before irreversible damage occurs. Expanding our ecological viewpoint and monitoring out from YNP to the entire Greater Yellowstone Ecosystem or beyond (see Assessing the Ecological Health of the Greater Yellowstone Ecosystem, this issue) could help us to better detect and respond to future environmental changes.

Literature Cited

Caro, T. 2010. Conservation by proxy indicator, umbrella, keystone, flagship, and others surrogate species. Island Press, Washington, D.C., USA.

Haefele, M., J. Loomis, and L. Bilmes. 2016. Total economic value of US National Park Service estimated to be $92 billion: implications for policy. The George Wright Forum 33:335-345.

Roberge, J.-M., and P. Angelstam. 2004. Usefulness of the umbrella species concept as a conservation tool. Conservation Biology 18:76-85.

Rodhouse, T.J., C.J. Sergeant, and E.W. Schweiger. 2016. Ecological monitoring and evidence-based decision-making in America's National Parks: highlights of the Special Feature. Ecosphere 7(11):e01608.

Whitfield, J. 2001. Vital signs. Nature 411:989-990.

Wilkening J.L., and C. Ray. 2015. Parks, pikas, and physiological stress: implications for long-term monitoring of an NPS climate-sensitive sentinel species. Park Science 32:42-48.

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