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Commentary

Redefining Baselines in Endangered Species Recovery

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ABSTRACT Baselines rooted in historical records or concepts of previous conditions are necessarily used to identify and generate recovery goals for endangered species. However, strict adherence to various spatial, temporal, and genetic baselines can limit endangered species recovery actions, success, and the broader conservation of biodiversity. Recent approaches that deviate from historical baselines such as assisted colonization and intentional hybridization have been used to facilitate recovery but lack broad acceptance and an underpinning conceptual framework to guide their use in practice. We here present a novel framework for addressing when baseline-abandoning approaches should be implemented that requires both scientific input and management-defined thresholds. We submit that in cases where species face extreme endangerment and managers have little chance of reducing or ameliorating future threats within a species' historical range, it is better to embrace a more flexible recovery model that includes taking action that deviates from historical baselines. Embracing this reinterpretation of management baselines not only has the potential to advance endangered species recovery but could have important cascading effects on ecosystem-based approaches to conservation. Further, rethinking adherences to baselines can affect our broader social–psychological relationship with wildlife conservation and management. Overall, although historical data on baseline conditions will remain vital to the initial setting of recovery goals, many situations will require more dynamic interpretations of paths to recovering endangered species.

KEY WORDS assisted colonization, endangered species, historical baselines, intentional hybridization, shifting baseline syndrome.

The use of historical baselines is fundamental to the way in which we currently approach the conservation of fish and wildlife populations. In the early 1900s, ecologist Charles C. Adams identified bionomic baselines measured in undisturbed areas as being vital for gaining insight into ecological processes through comparative studies (Adams 1913). Building on this framework for ecological study, Aldo Leopold emphasized the need for use of wilderness areas as base-datum for normality or controls from which to measure the effects of wildlife management practices (Leopold 1941). Subsequently, throughout the history of wildlife management, the hypothesized or documented historical condition of a population, community, or ecosystem (i.e., management baseline) has been, and remains, the benchmark to which the degree of degradation or conservation impact is comparatively assessed (Noss 1991, Block et al. 2001, Morrison 2009).

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The use of baselines is pervasive in national and international endangered species recovery policy, often being used to guide how recovery actions are undertaken. The International Union for the Conservation of Nature (IUCN) prioritizes the active recovery and restoration of species within their indigenous range because of high risks associated with translocations (IUCN 2013*a*). However, despite these risks, there have been increasing calls to conserve and restore species in ways that contradict historical baselines because achieving management objectives may not be possible without doing so (Hobbs et al. 2009). For example, in the United Kingdom, 2 species of butterfly have been successfully introduced outside of their historical range (a spatial baseline) to help save the species from extinction (Willis et al. 2009). By contrast, in the United States, despite a similar level of endangerment and the existence of policy that supports the use of assisted colonization under the Endangered Species Act, assisted colonization outside of historical ranges has thus far received limited attention from managers as a species recovery tool for most listed species (Shirey and Lamberti 2010). The question then becomes, when should managers use more flexible interpretations of such spatial baselines to prevent extinction of fish and wildlife species?

In addition to issues associated with spatial baselines, other types of baselines are apparent and increasingly being questioned in nearly all aspects of endangered species recovery. Most management baselines are based on reference conditions that pertain to a specific place or time period (White and Walker 1997), but baselines also can be rooted in social–psychological perception and ecological theory. In isolated cases, departures from each of these types of baselines are already occurring (e.g., Chauvenet et al. 2012, 2013; Miller et al. 2012), but they are not yet widely embraced by managers (Hoegh-Guldberg et al. 2008, Olden et al. 2011, Schwartz et al. 2012). At the same time, there is increasing evidence that the planet has reached a condition in which human impacts and global change require a new paradigm in recovery planning that acknowledges that recovery objectives rooted in replicating historical states (i.e., strict adherence to historical baselines) may be unachievable in some situations (Hobbs et al. 2009, Hiers et al. 2012). As a result, there is a need to guide scientific studies, human values, and conservation urgency toward more flexible recovery practices that evaluate when abandoning the goal of restoration to historical conditions is preferable to losing a population or species to extinction.

We provide the first collective review of the 3 major types of historical baselines currently being challenged by recent endangered species recovery actions (spatial, temporal, and genetic), and we present evidence supporting the position that in some cases embracing more flexible recovery goals could enhance our ability to conserve biodiversity now and into the future. We then present a framework for prioritizing recovery action that identifies when conservationists should move beyond historical baselines. Finally, we offer insights into how redefining baselines in species recovery approaches could affect ecosystem-based conservation and broader social–psychological support for fish and wildlife conservation.

ENDANGERED SPECIES MANAGEMENT BASELINES

Spatial Baselines

Understanding the historical ranges of species has long been a key component of natural history investigations (Brown et al. 1996), and the results of those works have been extended to become spatial management baselines. The very definition of an endangered or threatened species under the United States Endangered Species Act of 1973 is based on the disappearance of a species, subspecies, or in some instances a distinct population segment "throughout all or a significant portion of its range" (U.S. Fish and Wildlife Service 1996). Similarly, the IUCN determines threat categories for species based on extent of occurrence and area of occupancy within their indigenous geographic range (IUCN 2013*b*). Range contractions are often associated with populations, sub-species, or species in decline, and those that are likely to disappear throughout all or a significant portion of their range have high priority for conservation action (e.g., potential listing for legal protection; U.S. Fish and Wildlife Service 2007*a*, Waples et al. 2007). Correspondingly, recovery plans and actions have traditionally focused on restoring endangered species within their historical range (Clark et al. 2002, IUCN 2013*a*).

However, for imperiled species, there is increasing pressure to extend recovery action beyond spatial baselines that are confined to historical ranges (Seddon 2010, Shirey and Lamberti 2010). For example, because of introduced predators and severe degradation of suitable habitat within their native range that made restoration unfeasible, the continued persistence of the Micronesian kingfisher (*Todiramphus cinnamominus*) and the Guam rail (*Gallirallus owstoni*) in a wild state might be possible only through assisted colonization into areas outside of their historical range (U.S. Fish and Wildlife Service 1989, Laws and Kesler 2012). Indeed, the Guam rail has recently been released on the island of Rota where it did not historically exist, and potential releases are being considered for Wake Island (U.S. Department of Defense 2008), another island on which the species did not historically occur. In other cases such as the black-footed ferret (*Mustela nigripes*), more subtle shifts in recovery planning have occurred that emphasize the identification of reintroduction sites based on current habitat assessments rather than historical distribution (Jachowski and Lockhart 2009). Thus, in some cases we will doom species to extinction, at least in a free-ranging state, if we are not amenable to introducing them to sites outside of historical ranges.

Defining and establishing spatial baselines is further complicated by state, provincial, and international boundaries. These socio-political boundaries often lead to differing management goals for species, where a species can be endangered within 1 area, despite healthy populations existing in neighboring areas. For example, greater sage grouse (*Centrocercus urophasianus*), which are not listed as endangered in the United States, regularly disperse north from Montana into southwestern Canada, where the species is considered endangered (Tack et al. 2012). Therefore, managers must increasingly embrace a more flexible, collaborative approach to recovery planning and decision-making that transcends spatially derived conservation baselines based on socio-political boundaries.

Temporal Baselines

Concordant with defining a spatial baseline, temporal baselines need to be identified when setting species recovery goals. In other words, wildlife managers often attempt to recover endangered species to a reference condition such that recovered populations are comparable to those from some specified time in the past. However, populations are temporally dynamic. Paleoecological studies have revealed how ecosystems change in configuration and function over time, and there is great debate about which historical time periods should be used for management baselines (Harris et al. 2006). Further, successive waves of more recent human colonization, and changes in anthropogenic impacts based on technological developments have had dramatic, and often poorly understood, impacts on species abundance and community composition (Steadman 2006). For example, North American ecosystems were drastically altered upon the first arrival of humans, during subsequent waves of Native American societies, with the arrival of European settlers, and then again with modern industrialization (Flannery 2002). In western North America, government agencies, including the United States National Park Service, often attempt to recover and manage plains bison (*Bison bison bison*) populations with conditions that existed at the time of European colonization (National Park Service 2000). Whereas the pre-colonial bison management baseline is appealing for several reasons, bison population sizes and herd demographics varied greatly prior to the arrival of European settlers, particularly in relation to the presence of Native American societies and horses (Millspaugh et al. 2005). Thus, science can reveal multiple potential temporal baselines for use as species recovery goals, and social values, economics, and conservation urgency will dictate which time frame is desired, or conversely, which should be abandoned.

Because of increasing impact of human activities and global change (Walther et al. 2002, Hoegh-Guldberg et al. 2008, Hiers et al. 2012), endangered species recovery will likely increasingly be challenged if we adhere to a strict interpretation of fixed temporal baselines. To conserve and recover species in such a dynamic and novel future landscape, spatial and temporal baselines will have to be evaluated simultaneously. For example, future recovery of species such as the New Zealand hihi (*Notiomystis cincta*) and the Tuamotu kingfisher (*Todiramphus gambieri*) may require proactive assisted colonization to new areas as climate change renders habits permanently unsuitable within their historical range (Walther et al. 2002, Hoegh-Guldberg et al. 2008, Kesler et al. 2012, Miller et al. 2012, Chauvenet et al. 2013). Thus, there is a need for a decision-making framework (see below) that explicitly evaluates a suite of site- and species-specific spatio-temporal factors in determining when to use or abandon historical baselines in endangered species recovery.

Genetic Baselines

Genetic baselines are also increasingly used to guide species recovery programs. The growing use of historical or ancient DNA, as well as methodological advances in non-invasive sampling, have led to broader and more nuanced understandings of evolutionary histories (Frankham 2010), which have been used to resolve taxonomic uncertainties and set endangered species recovery goals (Pennock and Dimmick 1997, Fallon 2007). For example, despite considerable scientific debate regarding its taxonomic status (e.g., vonHoldt et al. 2011), the red wolf (*Canis rufus*) has received federal protection as an endangered species since 1967 (U.S. Fish and Wildlife Service 2007*b*). Beginning in 1999, a priority of red wolf recovery has been to enforce a coyote-free (*Canis latrans*) buffer zone around the red wolf recovery area to limit the risk of coyote hybridization and further genetic introgression (Stoskopf et al. 2005). Thus, a genetic baseline has been established from which red wolf recovery is monitored.

Despite the comparative benefit of using genetics to identifying baselines for endangered species conservation and management, strict adherence to genetic baselines can limit endangered species conservation when species persistence might rely on taking active management actions to increase genetic diversity (i.e., genetic rescue; Hedrick and Fredrickson 2010, Miller et al. 2012). A classic example concerns the Florida panther (*Puma concolor coryi*). Due to an exceptionally small population size in 1995, Florida panthers were at high risk of genetic deterioration and extinction (Pimm et al. 2006). Careful analyses determined that introducing cougars from Texas would likely restore population viability to the Florida population (Hedrick and Fredrickson 2010), despite the Florida and Texas animals being distinct subspecies. Because of the impending extinction of the Florida panther, managers elected to augment declining resident populations with outside stock. After the augmentation, successful interbreeding occurred and hybrids exhibited increased survival and expanded their distribution when compared to purebred individuals; thus augmentation contributed to the overall recovery of the species in Florida (Hostetler et al. 2012) while simultaneously altering the genetic status of the population forever (Morrison 2009).

Small population sizes and the prospect of extreme loss of genetic diversity and extinction might justify the initiation of genetic rescue through intentional hybridization (Allendorf et al. 2001, Goossens et al. 2013), but such practices are not broadly accepted. An early example is the now extinct dusky seaside sparrow (*Ammodramus maritimus nigrescens*), which was not vigorously outbred with a closely related subspecies when only 5 males remained (U.S. Fish and Wildlife Service 1990). Although conservation decisions for this species occurred without the benefit of the detailed knowledge of genetic management and captive breeding techniques available today, current examples exist of species that may benefit from hybridization. The Devil's Hole pupfish (*Cyprinodon diablois*) currently numbers less than 50 individuals and there is strong evidence that hybridization with an adjacent pupfish population could release a genetic load that has depressed survival and recruitment (Martin et al. 2012). However, intentional hybridization of this species in the wild, or at a larger scale in captive breeding centers, has thus far been blocked and there is no framework in place to determine when hybridization must occur to save what is left of the species. To reduce the likelihood that arguments concerning genetic integrity delay recovery action (such as intentional hybridization) until it is too late, a structured decision-making framework is urgently needed to determine the extent that strict genetic baselines are followed.

A FRAMEWORK FOR PRIORITIZING SPECIES RECOVERY STRATEGIES

We have attempted to make the case that species extinctions will sometimes be unavoidable without including increasingly flexible interpretations of management baselines when establishing recovery goals. However, as a general rule in endangered species recovery, activities that deviate from historical baselines should be used only as a last resort because of the often unpredictable and potentially negative consequences. For example, the introduction of species to areas beyond their historical range alters community assemblages and could perturb ecosystem function, and the introductions might have other unanticipated effects such as competitive release or hybridization between released and resident species (Ricciardi and Simberloff 2009). In addition, one might argue that abandoning baselines, such as through intentional hybridization, might cause a species or system to be inextricably altered such that it can never be recovered. Overall, the concerns detailed above have led to calls for wide embrace of the precautionary principle, which dictates that no action should be taken unless there is assurance of no potential harm (Sax et al. 2009).

Facing such uncertainty about the consequences of abandoning historical baselines and the existence of widespread support for the precautionary principle, when should recovery practitioners begin to move beyond historical baselines? Multiple authors have overviewed the ethical, legal, and ecological questions needing to be addressed prior to the use of proactive actions that contradict historical baselines (Hoegh-Guldberg et al. 2008, Olden et al. 2011, Chauvenet et al. 2012, Schwartz et al. 2012). However, we submit that it is better to take action when likelihood of benefit clearly outweighs risk of harm in the face of extreme endangerment, instead of only taking action if it will surely cause no harm (McDonald-Madden et al. 2011, Schwartz et al. 2012).

We recommend a new framework that entails a flexible operational model to identify when to use baseline-abandoning recovery actions to conserve a species (Fig. 1). Additionally, although we have so far focused on endangered species, our framework could be expanded to species of conservation concern prior to reaching an official endangered status (Miller et al. 2012). First, after threats to the species are identified, recovery practices should focus on improving the status of the species within its historical range (Osborne and Seddon 2012). However, if the threats cannot be removed or conditions within the historical range of the species are so perturbed as to render them unsuitable for its well being, managers must evaluate the possibility of recovering favorable conditions. If prospects for restoration are low, managers must either sanction extinction of the species through strategic triage (Bottrill et al. 2008) or consider baseline-abandoning actions (Fig. 1). Finally, if a baseline-abandoning action such as assisted colonization outside of a historical range is deemed to be appropriate, managers must consider the suitability of a release site for the species and the manner in which its introduction is likely to adversely affect the biological community and other attributes of that site (Ricciardi and Simberloff 2009, Schwartz et al. 2012).

This framework logically flows from experiences in several recovery efforts mentioned above and in which historical baselines were abandoned (e.g., Guam rail, Florida panther, and black-footed ferret). Whereas we appreciate that attaining consensus on specific approval or rejection of baseline-abandoning methods is often difficult, we present this framework as a conceptual approach to rethinking and refocusing recovery efforts. To illustrate, consider freshwater mussels, the most endangered group of organisms in the United States, with 72% of species endangered or threatened with extinction (Williams et al. 1993). Intensive captive breeding (Jones et al. 2006) and population restoration have included reintroductions (Jones et al. 2012). However, the long-term future of many species is uncertain because of limited potential for habitat restoration within the relatively small historical ranges (National Native Mussel Conservation Committee 1998). Under our framework, practitioners should consider a variety of baseline-abandoning approaches, including the managed introduction of endangered mussel species into streams and drainages outside of known

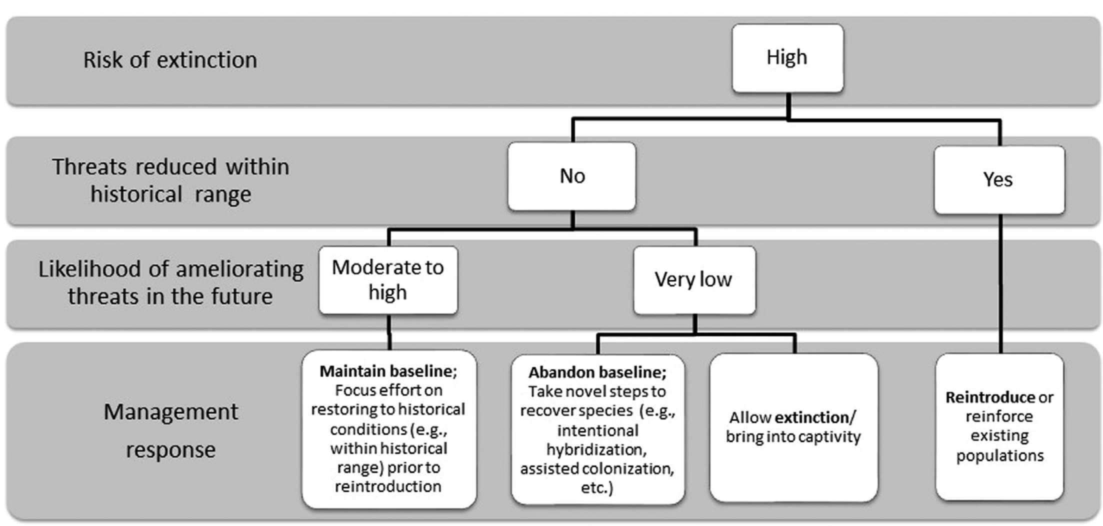

Figure 1. Conceptual decision framework for prioritizing recovery action for species under high risk of extinction. Assuming a source for animals is available (i.e., captive or donor stock) and threats that caused extirpation were ameliorated, restoration of endangered species in accordance with baselines is preferred. Alternatively, when threats to a species cannot be mitigated and there is little hope of restoration based on traditional baseline approaches (e.g., habitat restoration, reintroduction), managers should consider abandoning traditional recovery approaches and adopting approaches that abandon strict spatial or temporal historical baselines such as assisted colonization.

historical ranges. A logical first step is to evaluate the reliability of historical records (i.e., how certain are we a species did not occur outside its known historical range), followed by evaluations of the potential suitability of recovery sites outside their historical range, and precautionary studies of the socio-economic and ecological impacts of undertaking a managed introduction.

IMPLICATIONS TO ENDANGERED ECOSYSTEMS

Redefining baselines for endangered species recovery presents challenges to current ecosystem-based approaches to wildlife management and broader biodiversity conservation. Justification for restoration of natural disturbances and the management of populations has long been rooted in the concept of maintaining or restoring conditions to a historical ecological state (Leopold et al. 1969, Morrison 2009). Similarly, ecosystem-based species recovery approaches that call for the conservation of highly interactive species or communities (e.g., Grumbine 1993, Soulé et al. 2003) often are based on restoring an ecosystem to a predefined ecological baseline. For example, the restoration of grey wolves (*Canis lupus*) in western North America, dingos (*Canis lupus dingo*) in portions of Australia, and elephants (*Loxodonta africana*) in southern Africa have been justified in part by the ecological benefits of these species to ecosystem structure and function (Smith et al. 2003, Wiseman et al. 2004, Dickman et al. 2009). It remains to be seen how redefining conservation baselines could undermine or increase support for these types of approaches to species conservation.

Ecosystems are often dynamic and without long-term stable states (Botkin 1990), so managers need to think critically about using static ecological baselines to set long-term species recovery goals. Even when there is consensus among stakeholders on a desired temporal–ecological baseline, rapid global change means that all systems are affected by anthropogenic disturbance (Walther et al. 2002, Hiers et al. 2012). Thus, novel approaches are required to set recovery goals that mitigate biodiversity losses by embracing long-term ecological dynamism (Hiers et al. 2012, Stein et al. 2014) and predicting future conditions (Hobbs et al. 2009, Yakob and Mumby 2011). Further, the arguments we have outlined here regarding endangered species conservation could be used to advance conservation of endangered habitats and ecosystems (Morrison 2009).

SOCIAL–PSYCHOLOGICAL IMPACT OF REDEFINING BASELINES

Redefining management goals under the framework we have described here (and away from historical baselines) has clear implications to the social–psychological biases inherent in fish and wildlife management. Differing interpretations of historical biotic baselines by managers over time have been described as shifting baseline syndrome, a social–psychological condition that describes current uncertainty in setting management goals because perceptions of what is considered natural are sequentially readjusted with each human generation, a phenomenon termed generational amnesia (Pauly 1995, Papworth et al. 2009). Even though the passage of information to successive generations is better facilitated in the 21st century by increased monitoring and enhanced access to information, information gaps persist (Rick and Lockwood 2013). Examples abound from both terrestrial and aquatic systems (Papworth et al. 2009), indicating that the degree to which humans have exploited species or facilitated population or range expansion of species may often be greater than revealed by the limited historical data (Steen and Jachowski 2013).

Beyond concerns of setting reliable, objective baselines, there are larger philosophical issues involved in the abandonment of historical baselines. A common goal is to return altered systems to natural pre-colonial or pre-human reference conditions (Block et al. 2001); however, there are increasing calls for wildlife biologists, and society as a whole, to embrace human-altered habitats and ecosystems (Miller and Hobbs 2002, Bernhardt and Palmer 2007). This conceptual shift could change the social–psychological baselines we use to set management goals and priorities, enlarging the group of stakeholders involved in wildlife conservation and management (Middendorf and Grant 2003). Human-altered systems also can be employed for restoring extirpated species, as was demonstrated with the release of the endangered peregrine falcons (*Falco peregrinus*) into cities (Savard et al. 2000) and reintroductions of extirpated elk (*Cervus elaphus*) to reclaimed surface mining sites (Larkin et al. 2001). Thus, by abandoning strict adherence to the wilderness-based social–psychological baselines that have dominated wildlife conservation and management priorities over the past century (Noss 1991), we not only make new locations available and enhance the potential to recover species but engage additional portions of society that may begin to value and support conservation efforts.

CONCLUSIONS

Wildlife management was founded based on a growing awareness of society's increasing impacts on the environment compared to previous historical states, but the discipline's guiding principles also prescribe recognition of ecological dynamism and the changing effects of humans on natural systems (Leopold 1949, Block et al. 2001). For the same comparative reason that baselines are used in basic ecological research, baseline information will always be part of the initial management decision process when recovering endangered species. However, strict adherence to baselines can restrict endangered species recovery action, success, and the broader conservation of biodiversity. In the face of the current extinction crisis, we now more than ever need to consider the use of a structured decision framework to occasionally deviate from historical baselines (Fig. 1). Such actions will not only force managers to define thresholds based on scientific input and shifting social and political interests but also require us to collectively embrace a wildlife management paradigm that involves more dynamic interpretations of paths to recovering endangered species.

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