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INTRODUCTION

The natural areas movement is one of North America's distinct contributions to conservation. In the July 2023 issue of the *Natural Areas Journal*, we provided a brief history of this movement (Noss et al. 2023). The history article was excerpted from a report by the Scientific Advisory Committee (SAC) of the Natural Areas Association (NAA), produced in August 2022. The full report is now available on the NAA web site (https://www.naturalareas.org/docs/NAA_21st_century_6_2.pdf). The SAC report addressed several questions relevant to the NAA and its future. These questions include: Are natural areas still relevant to the public in the twenty-first century? Do they still serve the purposes for which they were established? How might natural areas be better designed, managed, and marketed to meet changing environmental and social conditions over the remainder of this century? In the present article, we summarize the SAC report.

What Qualifies as a Natural Area?

We favor a broad, relativistic definition of natural area: "*A natural area is an area of land or water of any size where relatively natural geomorphological, ecological, and evolutionary processes predominate over anthropogenic processes and where assemblages of native species in natural communities generally prevail over non-native species.*" Given this definition, many kinds of formally designated areas in the United States and Canada may qualify as protected or conserved natural areas. These kinds of conservation areas are listed in the full report. Because "natural" is a relative concept, for all kinds of natural areas there are two continua: a continuum of naturalness (or quality) and a continuum of protection. A worthwhile objective is to use management and restoration to help guide natural areas toward higher-quality states and higher-protected states.

Role and Function of Natural Areas Historically and Today

To what extent are the traditional perceived values of natural areas still accepted and relevant? Below, we summarize some of the long-recognized values of natural areas and offer some suggestions of emerging values that are likely to become more important within the near future. Values in addition to those summarized below are discussed in our full report.

As Places to Protect Biodiversity: Biodiversity (short for biological diversity) can be defined as "the variety of life and its processes. It includes the variety of living organisms, the genetic differences among them, the communities and ecosystems in which they occur, and the ecological and evolutionary processes that keep them functioning yet ever changing and adapting" (Noss and Cooperrider 1994, modified from Keystone Center 1991). The loss of biodiversity, particularly species extinctions, has become one of the most prominent global crises, and it is occurring in North America as well as on other continents. For example, a recent study showed that 51 species and 14 subspecies and varieties of vascular plants have become extinct in the continental United States and Canada since European settlement (Knapp et al. 2021). This is undoubtedly a gross underestimate of the true extinction rate given the dearth of plant surveys in many areas.

Direct destruction as well as fragmentation and degradation of habitat is generally considered the greatest proximate threat to biodiversity, even more so in these times of rapidly changing climate (Noss and Cooperrider 1994; Wilcove et al. 1998; Haddad et al. 2015; Fletcher et al. 2018). Protection, restoration, and management of habitat is therefore the most promising strategy for reducing extinction rates and maintaining the healthy ecosystems and ecosystem services upon which all species, including humans, depend.

Among the kinds of species and habitats most in need of protection, restoration, and enlightened management are (1) imperiled and vulnerable taxa; (2) endemic taxa and disjunct and peripheral populations; (3) ephemeral habitats for migratory species; (4) representative, under-represented, or imperiled ecosystem types; and (5) areas of high ecological integrity.

As Benchmarks or Control Areas for Scientific Comparison with Anthropogenic or More Strongly Manipulated Areas: The value of natural areas as benchmarks—where natural processes dominate—was recognized right from the beginning of the natural areas movement. As Leopold (1949) commented, "A science of land health needs, first of all, a base datum of normality, a picture of how healthy land maintains itself as an organism." Manipulative research in land management benefits from having relatively unmanaged control areas, which represent the same ecosystem types as those being managed, to better gauge the success of management experiments. Natural areas are not ideal controls because no landscape is a perfect replicate of any other, and many human impacts (such as air pollution and climate change) are far-reaching, but they can be the best available and are far superior to an absence of unmanipulated areas.

Historical, Cultural, Scenic, and Recreational Values: Non-biological factors, such as historical, scenic, and recreational values, may be as important as biological values for stakeholders engaged in many conserved natural areas. The key consideration for managers is to ensure that these values are supported in ways that are compatible with the primary natural area values present on site. Scenic and recreational values of natural areas are important because people appear to have a psychological need for nature, whether they realize it or not. A substantial body of research has confirmed the salubrious effect of nature on human physical and emotional health and intellectual development (e.g., Louv 2011; Flies et al. 2017; Oh et al. 2017; Aerts et al. 2018).

Natural Areas as Important Functional Components of Ecosystems and Landscapes

Historically, most attention from natural areas professionals has been given to species populations and to natural communities defined narrowly (e.g., a calcareous fen) and at a fine spatial extent. Beginning in the 1980s, several authors called for more attention to planning on a regional landscape scale (Noss 1983), for an expanded coarse filter that includes functional landscape mosaics (Noss 1987; Aplet and Keeton 1999; Poiani et al. 2000; Groves 2003), and for generally greater attention to ecosystem dynamics and the landscape matrix (Franklin 1993; Lindenmayer and Franklin 2002) in conservation planning and management.

As noted by Franklin (1993), "Designing an appropriate system of habitat reserves is one landscape-level concern. Understanding and appropriately manipulating the landscape matrix is at least equal in importance to reserve issues, however, since the matrix itself is important in maintaining diversity, influences the effectiveness of reserves, and controls landscape connectivity." The landscape context of sites, specifically their connectivity or proximity to other protected areas, is just as important as the content of sites (Noss and Harris 1986). This consideration has grown more urgent with increased recognition of the need for species to shift their distributions in response to climate change (Heller and Zavaleta 2009).

Challenges for Natural Areas in the Twenty-first Century

Natural areas managers now face unprecedented challenges that will continue well into the future. Many of these issues are not new threats to biodiversity and typically can be managed using conventional conservation approaches (e.g., managing for species viability, removing invasive species, and restoration of altered natural disturbance regimes). Visitor usage rates also can be managed or regulated to mitigate risks to natural and cultural resources. However, when these threats are experienced synergistically, or as extreme events, they can cause increased stress on species and ecosystems, especially those that are already degraded or endangered. Below, given space limitations, we address just a few of these challenges; others are discussed in our full report.

The Effects of Climate Change and Frameworks for Response: The twenty-first century has seen increasing calls for the consideration of climate change in conservation planning and action (e.g., Noss 2001; Millar et al. 2007; Heller and Zavaleta 2009; Aplet and Cole 2010; Cross et al. 2012; Stein et al. 2013; Prober et al. 2019; Peterson St-Laurent et al. 2021). Growing recognition of this problem indicates an urgent need for new skills, tools, and improved understanding of ecological responses and transformations to help make informed decisions for conservation action (Abrahms et al. 2017; Belote et al. 2017a, 2017b; Lam et al. 2020; Hylander et al. 2022).

One crucial consideration is that climate change is occurring in landscapes that have been highly fragmented and degraded by human activities. Species that once could have tracked shifting climate zones through natural dispersal no longer can do so. They must now attempt to disperse across landscapes containing fragments of natural or seminatural habitat, and the landscape matrix is occupied by various human land uses that create movement barriers. Also, many invasive nonnative species may fare better than native species under future climate scenarios, though outcomes are uncertain (Hellmann et al. 2008).

Many of Earth's ecosystems are undergoing major transformations with uncertain endpoints. Ecosystem transformations can sometimes be rather abrupt, as when an ecosystem passes some tipping point or is subjected to a major disturbance and flips relatively quickly into an alternative stable state. An example is a fire-excluded pine savanna becoming increasingly less combustible as mesic hardwood trees with nonflammable leaves invade and gain dominance while grasses and other flammable ground cover diminishes. Eventually a point is reached where the community will not burn, except perhaps a small distance in from the edges or during extreme drought (Noss 2018). Alternately, a woodland may convert to a grassland after invasion by flammable nonnative grasses and an increase in fire frequency or intensity.

Various strategies have been proposed for coping with transformations of ecosystems due to climate change. One well accepted framework, called "resist-accept-direct" (RAD), recognizes three basic strategies: resist change, accept change (at some point), or try to direct or guide change in a desirable or tolerable direction (Aplet and McKinley 2017; Jackson 2021; Lynch et al. 2021). Resistance is the most common strategy applied today, as natural areas managers struggle to maintain ecosystems in their historical states, or restore them to those states, even as climate change makes that increasingly difficult. Often resistance eventually becomes futile or at least too expensive to continue over long periods of time, so managers must ultimately switch to another strategy. Thus, identifying the appropriate timeframes for adaptive responses is crucial.

Guidance for Responding to Climate Change in Natural Areas Management: Natural areas managers increasingly recognize that they not only need to consider climate change in the conservation planning process, but they must also actively invest in the implementation of climate adaptation actions. Given the conundrum of options, none of which is entirely satisfying, some **best management practices** (or at least guidance) for addressing climate-driven environmental change include the following:

- Understand that adaptation in a broad sense includes evolutionary, ecological, and social changes that are likely to reduce the vulnerability of ecosystems to climatic disruption (Moore and Schindler 2022).
- Recognize that climate change is not just a long-term, gradual threat; rather, changes in the frequency and magnitude of climatic extremes are an immediate threat (Butt et al. 2016) and major changes in disturbance regimes (e.g., fire severity) linked to climatic change may result in drastic near-term change.
- Identify and protect climate refugia, which range in spatial extent from small, localized habitats such as sinkholes, seepage areas, north-facing slopes, and edaphic communities (hypothetically) to entire landscapes with relatively stable climates due to topographic heterogeneity, proximity to moderating ocean currents, disturbance regimes (such as frequent fire) that produce resilient ecosystems, and other factors (Noss 2001; Dobrowski 2011; Keppel et al. 2012; Bátori et al. 2017; Harrison and Noss 2017).
- Avoid simplistic “solutions” to climate change, such as massive tree-planting for carbon sequestration. Afforestation of natural and seminatural grasslands is a major threat to global biodiversity (Veldman et al. 2015, 2019).
- In geophysically or geoclimatically diverse landscapes, with heterogeneous topographic and edaphic conditions, allow for opportunities for species to adjust to climate change by moving relatively short distances into newly favorable habitats (Ackerly et al. 2010; Anderson and Ferree 2010; Beier and Brost 2010; Anderson et al. 2015).

Invasive Nonnative Species Control: Most natural areas suffer to some degree from invasions by nonnative plant species and sometimes animal species. Managers of natural areas have often assumed that all nonnative species are bad and should be eliminated as soon as possible. However, many studies have found that some nonnative species play useful roles in ecosystems, often substituting for native species that have experienced population losses or have gone extinct and can actually increase native biodiversity (Davis et al. 2011). Moreover, management to eliminate invasives and restore native plants can have unintended negative consequences on rare native species of conservation concern (Buckley and Han 2014; Casazza et al. 2016).

On the other hand, nonnative species often can have devastating impacts on native biodiversity. One of the most problematic impacts stems from the effects of nonnative plants on disturbance regimes, which in turn affect the structure, composition, and function of the ecosystem in multiple ways. Exotic annual grasses not only are highly competitive with native vegetation (Humphrey and Schupp 2004), they also are often highly flammable and increase the amount and continuity of fine fuels as well as the length of time that these fuels are dry enough to burn (Knapp 1995; Davies and Nafus 2013).

Clearly there is a need for more research and monitoring of invasive species to inform adaptive management interventions. Based on existing evidence, the following are some **best management practices** for invasive nonnative species on natural areas:

- Gather evidence through research and monitoring to determine which nonnative species should be eradicated or controlled and which can potentially be left in place. This is a cost-effective strategy, as controlling invasives can be expensive.
- Remember that native species can be invasive as well, for example oaks and other hardwoods invading fire-excluded pine savannas (e.g., Brockway and Outcalt 2000).
- Be careful that restoration treatments to remove exotics and restore native plant cover do not harm native species of conservation concern.
- Monitor the effects of invasive species management to determine if expected responses of native ecosystems to management actually occur.
- Recognize that the optimal strategy for addressing nonnative plant invasions may be to develop and maintain a natural community with high ecological integrity and resistance to invasion (Sheley and Krueger-Mangold 2003).

Viability of Species of Conservation Concern: Many species of conservation concern will require species-specific management and recovery actions, but the following **best management practices** have considerable generality:

- Strive to maintain ecologically effective populations of species of conservation concern, not just minimally viable populations. Species exist in communities and ecosystems and their interactions with other species and processes will vary with their abundance.
- To simplify consideration of conservation needs and actions for large groups of species, consider clustering species according to shared ecosystem types or geophysical habitats, shared threats, or shared functional traits (Clark and Harvey 2002; Kooyman and Rossetto 2008; Noss et al. 2021).

Conclusions: Lessons for Success in the Twenty-first Century

None of the current or foreseeable future challenges to natural areas addressed in this paper are completely new. The magnitude of these challenges is, however, becoming unprecedented. Given these major threats, important lessons emerge from our research and experiences and our understanding of the values of natural areas.

First, we should not rush to discard the values and norms that mobilized the natural areas movement through the twentieth century and remain prominent today. These values all are still relevant and true. Many recent criticisms of natural areas preservation (e.g., Rohwer and Marris 2021) are caricatures of the movement. Few, if any, conservationists seek to prevent ecological change. Most conservationists would agree that evolutionary change, such as improved adaptation to changing climate, is highly desirable. Awareness of the dynamism of nature has grown, however, in concert with improvements in our understanding of disturbance ecology and observations of the impacts of climate change. This new level of awareness of environmental change and the dynamic nature of ecosystems should stimulate questions about some long-cherished assumptions about natural areas conservation, restoration, and management. For example, a long-unquestioned assumption in ecological restoration is that seeds for plantings should be locally sourced. But is this assumption still valid given knowledge of the rapidity of climate change? Or would sourcing from lower latitude populations be more defensible?

Second, as environmental change accelerates, the value of natural areas as benchmarks increases, as does their role in safeguarding biodiversity and ecological integrity. Novel ecosystems are already emerging inside and outside of natural areas, and they are not devoid of conservation value (Hobbs et al. 2009). Recognizing the conservation value of "historic, hybrid, and novel ecosystems" (Hobbs et al. 2014) is consistent with the resist change, accept change, or guide change options for addressing climate change (Aplet and McKinley 2017; Jackson 2021; Lynch et al. 2021).

Third, one major development in ecology and conservation biology in the late twentieth and early twenty-first centuries is increased recognition of landscape ecology. Large natural areas are landscapes in themselves, but they are still influenced by activities and processes in the larger landscape that surrounds them. In many regions, most natural areas are small sites embedded in human-dominated landscapes. The effects of the surrounding landscape are more profound for these small natural areas, due to edge effects, dispersal limitation, and other processes (Laurance and Yensen 1991; Murcia 1995). Natural areas managers, where possible, should work with land-use planners to improve the landscape context surrounding natural areas. Expanding the size of reserves to mitigate deleterious edge effects may be possible in some cases.

Fourth, conflicts between species-level and ecosystem-level management remain problematic today. Most natural areas managers are aware that both species and ecosystems deserve conservation attention. Because the needs of individual species sometimes conflict, managing for ecosystems seems a sensible way to reduce disputes (Noss 1996). Especially in regions with many conservation-reliant species, there are only so many species that we can conserve or manage individually without being overwhelmed. The biological status of species is usually linked directly to the condition of the ecosystems with which they are associated. Protecting and managing ecosystems is therefore a cost-efficient way to protect multiple species with shared biological needs and shared threats (Noss et al. 2021).

On the other hand, among the best indicators of the quality or integrity of ecosystems is the presence and viability of species that are characteristic of that ecosystem. Hence, species-based indices such as the Floristic Quality Index (FQI) are used to assess the quality and conservation importance of natural areas (Wilhelm 1977). Moreover, foundation species, apex predators, ecological engineers, and other strongly interacting species commonly control the structure and diversity of the ecosystem (Soulé et al. 2003, 2005); these species must be maintained in ecologically functional, not just minimally viable, populations. Some species demand individual attention because they are so highly imperiled that they would perish without it. It is inescapable that natural areas managers must attend to at least some individual species as well as to the ecosystems in which they occur.

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