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Analogies for a No-Analog World: Tackling Uncertainties in Reintroduction Planning

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Species reintroductions involve considerable uncertainty, especially in highly altered landscapes. Historical, geographic, and taxonomic analogies can help reduce this uncertainty by enabling conservationists to better assess habitat suitability in proposed reintroduction sites. We illustrate this approach using the example of the California grizzly, an iconic species proposed for reintroduction.

Species Reintroductions and Altered Ecosystems

Species reintroductions are among the most complex and high stakes of all conservation projects. Given the challenges these efforts face, it is not surprising that they often fail [1,2]. To improve their chances of success, conservationists need more and better information. In a rapidly changing world of increasingly altered ecosystems, however, acquiring the information necessary to support sound reintroduction planning is growing more difficult by the day.

Conservationists often rely on analogies [3], logical arguments that compare two or more things or cases [4], to fill gaps in their knowledge and help them predict how reintroduced species may fare in today's altered ecosystems. We argue that by making their analogies more explicit and interdisciplinary – and by integrating them to paint a more coherent and comprehensive picture – conservationists can better understand the conditions under which reintroduced species can thrive, anticipate how they may fare in altered ecosystems, and support better-informed decisions. Scientists like to say that we live in a 'no-analog world' of increasingly unprecedented ecological conditions [5]. When assessing suitable habitat for species reintroductions, useful analogies are more important than ever.

Analogies can aid a range of species reintroduction projects. Here we use the example of the California brown (grizzly) bear (*Ursus arctos*). Apex consumers with low fertility rates, large home ranges, diverse ecological roles, and complex human relations, grizzlies represent many of the greatest challenges in species reintroductions. California's grizzly population, estimated to have numbered as many as 10 000 in 1848, went extinct by 1924 [6]. In 2014, the Center for Biological Diversity, a nongovernmental conservation organization, proposed reintroducing grizzlies to California, launching a new era of research on this state's missing mascot.

Why Analogies?

A key goal of reintroduction planning is to assess the quantity and quality of suitable habitat available for a species in a proposed reintroduction site. 'Suitable habitat' refers to the site's biophysical features – including its climate, vegetation, connectivity, and hazards [7] – as well as key social factors such as cultures, laws, and institutions [8]. Conservationists use several methods to reduce uncertainties [9,10] when assessing suitable habitat [11]. In cases where reintroducing a species would involve placing it in an altered ecosystem, however, these established methods may leave many questions unanswered.

Analogies can help reduce these uncertainties. The best analogies are those that are most useful – raising new questions, offering original insights, or suggesting novel or counterintuitive solutions for real-world conservation problems. Building more useful analogies means making them more *explicit* by clearly identifying them and describing the similarities and differences among comparable cases. It means making them more *interdisciplinary* by assembling diverse teams of scholars and practitioners, drawing from varied sources of information, and using multiple methods to collect and analyze data. And it means *integrating* them by cross-checking results to gauge their validity and find emergent patterns, a procedure known in the social sciences as *triangulation* [12].

Three Essential Analogies for Assessing Suitable Habitat

Historical analogies compare past conditions with current conditions in a reintroduction site to assess the site's suitability as habitat. They often start with baselines: descriptions of the past that enable conservationists to measure change. Baselines are problematic because they tend to represent snapshots in time and because historical records are often vague, biased, or incomplete. Most restoration projects no longer attempt simply to recreate historical baseline conditions, but documents, artifacts, fossils, and other such records still contain a wealth of information that can inform reintroduction efforts.

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The case of the California grizzly (Figure 1) shows how integrating diverse evidence produces more useful historical analogies. Prior to European contact, grizzlies ranged throughout nondesert California but likely favored the region's rich coastlines, valleys, and foothills. Grizzlies ate diverse foods, including some of marine origin, but after 1800, they started to consume more terrestrial protein, a portion of which may have come from livestock. This brought grizzlies into conflict with farmers, ranchers, and other settlers who poisoned, trapped, and shot them to extinction [6]. These insights suggest that although grizzlies lost much of their best habitat, persecution rather than habitat loss eliminated them from California. Large areas of suitable habitat probably remain in this state's vast protected areas.

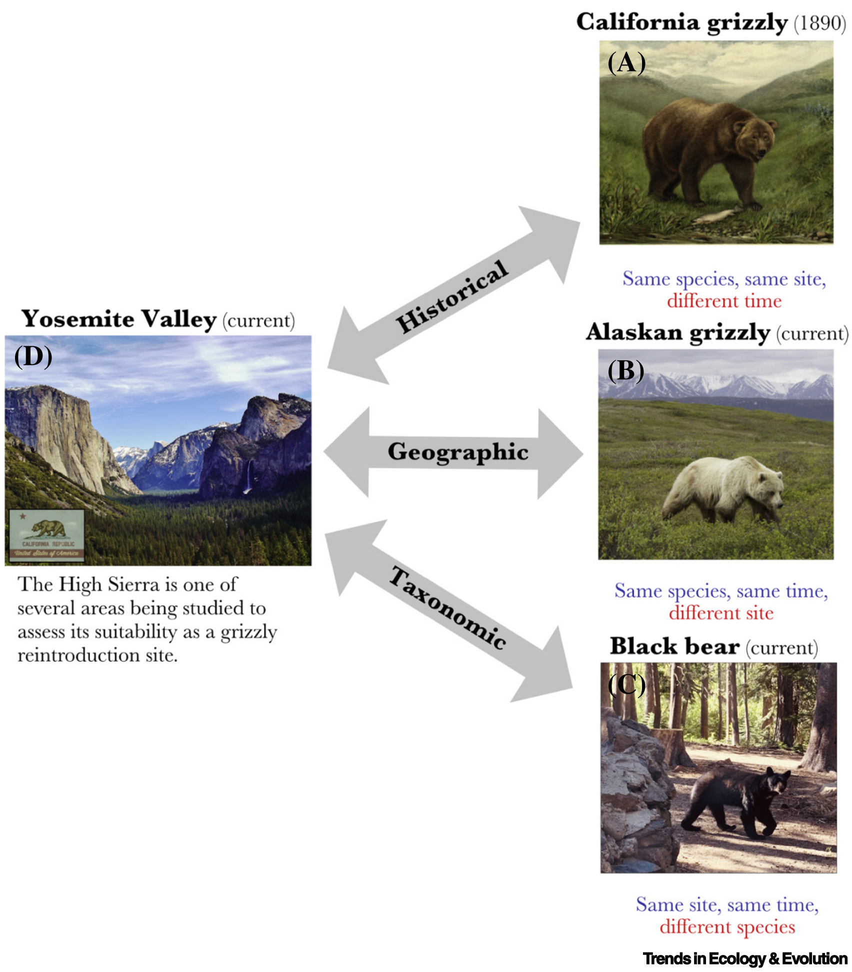

Figure 1. Three Analogies: The Case of the California Grizzly. *Historical analogies* compare past conditions with current conditions in a reintroduction site to assess the site's suitability. In the case of the California grizzly, *past conditions* (A) refers to the social and ecological conditions prior to 1925, when grizzlies are presumed to have gone extinct in this state. *Geographic analogies* compare current conditions in a reintroduction site with conditions in other areas of a species' range where it still exists. Brown bears currently live in North America, Europe, and Asia; the above image (B) was taken in Alaska, which is home to around 30 000 brown bears. *Taxonomic analogies* compare the species being proposed for reintroduction with other species that currently live in the reintroduction site and have similar traits. California now contains as many as 40 000 American black bears (C) distributed throughout diverse habitats. Credits: (A) 'Grizzly bear fishing' (circa 1890), courtesy of the Bancroft Library, University of California. (B) 'Grizzly bear in Denali, AK,' by Gregory Smith, Creative Commons. (D) American black bear in Mammoth Lakes, CA, courtesy of Peter S. Alagona. (D) Yosemite Valley from Wawona Tunnel, Mark J. Miller, Creative Commons.

Geographic analogies compare current conditions in a reintroduction site with conditions in other areas of a species' range where it still exists. Geographic analogies are useful because they may reveal that a species can persist across a wider variety of suitable habitats than those it historically encountered in the reintroduction site. Building useful geographic analogies requires diverse methods, including biogeographic research comparing habitats across a species' range; public opinion surveys identifying patterns of ecological knowledge or sentiment; and ethnographic fieldwork exploring how attitudes, values, beliefs, and behaviors shape human relations with other species.

Geographic analogies suggest that although much suitable grizzly habitat probably exists in California, the success of a reintroduction effort would depend on human management and tolerance. Montana and Slovenia are each home to brown bears living in habitats that, in various ways, resemble California's alpine, woodland, and grassland ecosystems. Yet, the people in these regions manage bears differently. In Montana, conservationists are working to avoid conflicts with people by ensuring that brown bears cannot access human foods. In Slovenia, supplemental foods may constitute more than one-third of an average brown bear's diet [13]. These alternative approaches stem from differing histories, cultures, laws, and institutions. Studying these and other regions reveals a spectrum of ecological conditions, social arrangements, and management techniques that could support brown bears in modern, human-dominated landscapes.

Taxonomic analogies compare the species being proposed for reintroduction with other species that currently live in the reintroduction site and have similar traits. Although most species differ in their social or ecological roles, comparing species with similar behaviors, habitat preferences, or human relations can generate useful insights about a reintroduction site's opportunities and challenges. Using the same methods as those employed in geographic analogies, conservationists can examine similar species to map suitable habitat, gauge support for reintroduction, plan essential management actions, and avoid conflicts.

The case of the American black bear (*Ursus americanus*) shows that human coexistence with grizzlies in California would require sustained commitment to managing human behavior. California's black bear population grew from an estimated 10 000 in 1980 to as many as 40 000 by 2020. Black bears tend to be smaller, more herbivorous, and less aggressive than grizzlies, but these qualities can change when black bears gain access to human foods [14]. Since the 1990s, agencies and communities in California have worked to prevent black bears from acquiring human foods by investing in education, infrastructure, and law enforcement. In Yosemite National Park, for example, these efforts have dramatically reduced both black bears' consumption of human foods and the number of black bear–related conflict incidents [15]. Similar efforts to manage human behavior and reduce conflict would undoubtedly be required to support a population of reintroduced grizzlies.

To get the most out of their analogies, conservationists must integrate them. Comparing historical with geographic analogs increases knowledge about the species; comparing historical with taxonomic analogs deepens knowledge about the reintroduction site; and comparing geographic with taxonomic analogs improves knowledge about the current forces that could shape a reintroduction effort. Cross-validated information can then be used to identify common themes, search for emergent patterns, and generate new questions.

This process can have surprising results. Without the perspective of historical, geographic, and taxonomic analogies, reintroducing grizzlies to California – a state with 40 million residents whose ecosystems changed dramatically over the past 250 years – may seem outlandish. Our group's ongoing research suggests that, like other species reintroductions, this is a complex and high-stakes decision that can only be made wisely with the best possible information.

Applying the Analogy-Based Approach

This analogy-based approach can aid any reintroduction, or even any conservation translocation. This includes projects involving species that are more specialized than brown bears, have narrower distributions, for which fewer data exist, or that disappeared longer ago (e.g., Tasmanian devils in mainland Australia [15]). The key is to focus on analogies that provide the best and most useful information.

Conservationists seeking to apply this approach to other cases should begin by assembling interdisciplinary networks of experts with diverse perspectives on what may constitute suitable habitat (Figure 2).

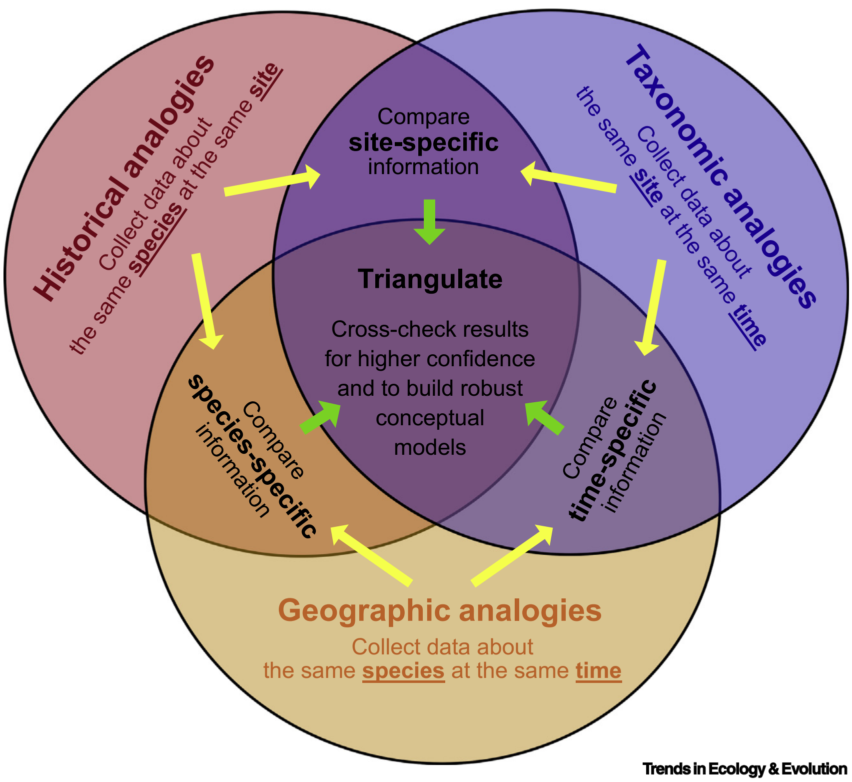

Figure 2. Integrating and Triangulating the Analogies. Historical, geographic, and taxonomic analogies provide conservationists with a wider range of information than would otherwise be available to use in assessing the suitability of altered ecosystems for species reintroductions. Combining this information increases site-specific, species-specific, and time-specific knowledge and can help define the range of conditions that could support a reintroduced population. Conservationists can then cross-check this information – a process known in the social sciences as *triangulation* – to identify, validate, and increase their confidence in the information that is most likely to be relevant for a given reintroduction.

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These networks can then divide into teams with the skills to conduct historical, geographic, and taxonomic comparative studies. Networks will need to convene regularly so that teams can generate discussion, receive feedback, and integrate their results. Participants can then use the insights derived from these question-driven projects to build conceptual models that inform habitat suitability maps, population viability models, conflict mitigation strategies, environmental impact statements, species recovery plans, monitoring protocols, educational curricula, and public outreach campaigns.

The past is not the present, there is not here, and no two species are exactly alike. Taken together, however, analogies can help tackle uncertainties for reintroduction planning in altered ecosystems. With the benefit of more and better information, reintroductions that at first seem untenable may turn out to be more feasible than we think.

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Forum

Imminent Extinction of Australian Myrtaceae by Fungal Disease

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Myrtle rust is a fungal disease that has spread rapidly across the globe, arriving in Australia in 2010. The tree species *Rhodomyrtus psidioides* is nearly extinct in the wild as a result of the disease, leading to potential disruption of ecosystem function. Many other Myrtaceae may also be threatened and unprecedented impacts of the disease are predicted.

A New Fungal Disease in Plants

Infectious fungal diseases in the plant kingdom usually have a small number of host species and rarely push species to extinction [1]. There are some exceptions, the American chestnut (*Castanea dentata*) has declined dramatically in the wild through the impact of chestnut blight (*Cryphonectria parasitica*) [2], and the Florida torreya (*Torreya taxifolia*) has suffered a similar fate due to an unidentified fungal pathogen [3]. The iconic ōhi a (*Metrosideros polymorpha*) has declined suddenly in Hawaii some 20 years following the introduction of *Ceratocystis* spp. [4], and in southern Australia the cinnamon fungus (*Phytophthora cinnamomi*) has taken locally endemic plant species to the brink of extinction [5]. Infectious diseases are only rarely invoked as a threat to plant species using formal listing procedures [6], despite an assessment of global disease alerts suggesting that fungal pathogens pose a particularly egregious future threat [7].

A newly established plant disease in Australia is having novel, dramatic, and sudden effects. The disease is known as myrtle rust, caused by the fungus *Austropuccinia psidii*, and is simultaneously impacting many species in an extremely large and iconic plant family, the Myrtaceae. The wild origin of the fungal pathogen is theorised to be South America and was first identified in common guava (*Psidium guajava*) in Brazil [8].

The invasive nature of myrtle rust has become evident as over the past 12 years