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Rethinking "Native" in the Anthropocene

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"The Anthropocene" is challenging the established conceptions of biogeography. In an age of widespread disturbance, global commerce, and a rapidly changing climate, some species have the opportunity to access new, vast areas while others disappear at unprecedented rates and scales, along with the environments to which they are adapted. The "native vs. alien" conceptual framework for determining which species "belong" in an environment is naive and insufficient in facing the novel biogeographic dynamics of the Anthropocene, as are the wilderness management practices derived from it. Though conservation practitioners have come a long way in addressing some limits of the native/alien dichotomy, there are many domains where this paradigm persists and continues to influence. Here, we argue that no species will be truly "native" in the Anthropocene, and a new set of criteria to determine the "belonging" of a species to a locality is necessary for the establishment of management practices that reconcile the veracity of global change with realistic options for the preservation of biodiversity.

The native/alien dichotomy has been used by biologists since at least the nineteenth century (Richardson and Pyšek, 2008), and remains pervasive in public, scientific, and conservation spheres today. Within this paradigm alien species are often cast as villains, and natives as paragons, in environments where they are found. This vilification of alien species is not entirely arbitrary—alien species have a higher propensity than natives to become invasive and have been known to incite extreme damage in both ecosystems and human systems. Hereafter we will use "invasive" to refer to "exotic invasive species". In monetary terms, it is estimated that invasive species cause $120 billion/year worth of damage in the US alone (Pimentel et al., 2005). Invading species can profoundly impact ecosystem function by altering the historic nutrient cycles, disturbance regimes, and/or physical habitat of local environments (Simberloff, 2011a). Invasives are widely regarded as a critical threat to biodiversity, and 45% of surveyed biologists agree that "invasive species are a direct and leading cause of extinctions" (Young and Larson, 2011).

Despite the pressing need to better understand invasive species dynamics to inform pragmatic conservation practices in the wake of the Anthropocene, invasion biology has been rife with disagreement about what the terms "invasive" and "native" actually mean (Pyšek et al., 2004; Warren C. R., 2007; Richardson et al., 2008; Colautti and Richardson, 2009). Although these debates have been important for furthering our understanding of the relationship between species and their environment, most arguments are not framed in the context of the Anthropocene and the different biogeographic dynamics associated with it. Landscape disturbance and transformation, extinction, globalization, and climate change are proceeding at unprecedented rates and scales and have yet to climax. We argue that the Anthropocene will call for a conceptual overhaul of what it means for a species to "belong" to a given environment.

In a world where the frequency of alien species introductions is dramatically increased, land managers, and conservationists are pressed with more decisions on which species should be removed or protected. The alien/native dichotomy has been useful because of its apparent simplicity and its ability to identify potentially dangerous species for removal. "Alien" has been used as a reliable proxy for harmfulness (Van Der Wal et al., 2015), and

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can facilitate the removal of species before they cause damage. However, it can be very difficult to distinguish native from alien when atmospheric and biological systems are extremely dynamic and where humans have had direct influence on the ecosystem—especially in systems that have not yet had adequate assessment of biodiversity. When a species tracks its bioclimatic envelope by dispersing into new geographic space in response to a changing climate, as has been documented for species ranging from algae to mammals (Lenoir and Svenning, 2015), what is the status of the species "belonging" in the new physical environment? Are they native, alien, or neither? What about species reintroduced to areas where they have historically occurred, as with the black-footed ferret (*Mustela nigripes*) in the western U.S. (Miller et al., 1994)? Or species like the snow crab (*Chionoecetes opilio*) who are unintentionally moved to new areas by human activity (Alvsvåg et al., 2009)? How do we determine whether these species "belong" in these environments? We will argue that the current alien vs. native dichotomy is not sufficient to answer these questions and that the future of conservation depends on the establishment of a new paradigm on the foundation that there will be no "native" species in the Anthropocene.

We see two conceptions for what a species is native to: (1) a point in geographic space (i.e., place-based) and (2) a consortium of environmental variables (i.e., niche-based). At a short timescale in a less dynamic biosphere (the context in which "native" is usually considered), these two conceptions appear identical. At this timescale and slow rate of environmental change a species is native to a point in geographic space *and* the consortium of environmental variables associated with it. Place-based and niche-based conceptions of "nativeness" appear consistent over long periods of time as well, as a species adapts to novel environs or tracks its historic habitat over geographic space. However, these two conceptions of nativeness become increasingly disparate as a point in geographic space is divorced from its historic environmental variables due to rates of environmental change that species cannot migrate with or adapt to (i.e., the environment of the Anthropocene is changing at a rate that species cannot be adapted to both a locality and habitat). For example, the greater sage grouse (*Centrocercus urophasianus*) is considered native to Colorado—the geographic rectangle called Colorado as well as the sagebrush steppe and its environmental variables (Connelly et al., 2004). Both conceptions of "native" appear to be compatible here because the sagebrush steppe is in the geographic boundaries of Colorado—i.e., the geographic space is correlated with the environmental parameters. But as Colorado's projected temperature warms and precipitation declines (Ray et al., 2008), a potential future arises where the dry climate and associated vegetation migrates in from the south and the sagebrush steppe and its climatic and biotic parameters move further northward into Alberta at a faster rate than sage grouse adaptation. What will the grouse be native to then? If the sagebrush steppe is gone from Colorado along with all of the environmental variables that the grouse is adapted to, it seems incorrect to say that the sage grouse is native to Colorado in this scenario. It was native when the habitat of the grouse was in Colorado, but it would be difficult to convince anyone that it would be native to a geographic area with no suitable habitat. Therefore, species are *not* native to a location in geographic space, but instead, species are native to the environmental parameters they are adapted to which *can be* associated with points in geographic space during periods of minute/gradual environmental change. The rapid environmental changes of the Anthropocene have exposed this discrepancy, which was once masked by (1) the apparent inseparability of a geographic location and its environment at less than a geologic timescale and (2) the ability of species to stay native to a dynamic locality over time because the environment changed slowly enough that continual adaptation was possible.

A much more difficult question remains; where is the greater sage grouse considered native and where does it "belong" from a conservation perspective? A strict adherent to our proposed conception of nativeness would say that the sage grouse is native to geographic areas that contain all of the environmental variables in which the species evolved. For example, if northern Alberta developed an identical environment to the native habitat of the sage grouse—vegetation, climate, and other taxa included—then the grouse would be native to Alberta. However, the likelihood of entire assemblages of climatic features and species simply shifting to new geographic locations in the Anthropocene are unlikely—up to 39% of land is predicted to develop novel climates by the end of this century (Williams et al., 2007). The relatively rapid dissolution of historical habitats at a global scale suggest that no contemporary species will be truly native in the Anthropocene.

With the concept of "native" deconstructed and shown to be an unusable metric in the Anthropocene, conservationists and managers will need criteria to determine the right of a species to exist at a locality. Some have advocated for an ecosystem benefit/harm assessment (Warren C. R., 2007; Davis et al., 2011), whereas others claim that such an assessment would come too late, as the damage of invasive species can become apparent only at later stages of establishment (Simberloff, 2011b) when mitigation costs are highest and damage may be irreversible. Contemporary proponents of the use of the native/alien dichotomy (or continuum) in conservation would likely argue that the lack of true natives in the Anthropocene would still allow for some species to be more native than others to a suite of environmental parameters, and thus the gradient of nativeness could still be used as a proxy for potential "belonging." Though this would be a reasonable approach, its efficacy is highly contingent on the extent to which the biosphere is shuffled in the Anthropocene. Using "nativeness" as a proxy for belonging requires environments that resemble historically native habitats, but with the increasing changes to our climate (Collins et al., 2013), ever-expanding disturbance and land conversion (Lambin and Meyfroidt, 2011), and the accumulation of alien species in global environments exhibiting no signs of saturation (Seebens et al., 2017), the "nativeness" proxy will become an increasingly weak indication of "belonging."

Conservation biologists must agree on what we seek to preserve in the Anthropocene before a new framework can be established to determine which species to protect and which to regulate. Conceivably, the future of conservation will seek to foster resilient ecosystems and smooth transitions between

different stable states as the world changes. Absolute preservation of the world we have known could only be possible by reversing or negating the global impacts humans have set in motion, and the dismantling of the systems that brought us here lies beyond the purview of science. Instead, the future of conservation could be the tactical refinement of ideas and practices of the present. Assisted migrations and reintroductions are currently contentious (Hewitt et al., 2011), and have met with success in some cases (Clout and Craig, 1995; Maschinski and Duquesnel, 2007) and failure in others (Ricciardi and Simberloff, 2009), but are ongoing nonetheless (i.e., Gross, 2018). The removal of invasive "native" species, and the protection of "aliens" is uncommon despite indications that some natives can harm local communities (Nackley et al., 2017) and some aliens can benefit them (Schlaepfer et al., 2011; Gleditsch and Carlo, 2014). In a world with progressively dwindling nativeness and increasingly vague protocols for determining which species have precedence in a given environment, these practices of species manipulation may become crucial for maintaining healthy and resilient ecosystems.

We have argued that as the world stumbles deeper into the Anthropocene, the novel biogeographic dynamics (globalization, mass disturbance, and climate change) will progressively warp habitats until the species lose the collection of environmental parameters to which they were once native. Difficult conservation decisions will proliferate, like those concerning the red fox (*Vulpes vulpes*) that follows its habitat into the warming arctic, competitively excluding the arctic fox (*Vulpes lagopus*) whose habitat is progressively disappearing (Berteaux et al., 2015). Will conservationists start culling red fox or let the arctic fox languish? "Native" will carry decreasing weight in conservation decisions like these as all species find themselves in novel environments. We do not suggest a complete overhaul of current conservation practice while there are ecosystems still native to both the geographic space in which they exist and the environmental variables therein, as there are now. Instead, we call for an inclusive conversation across disciplines and societal strata to carefully consider the goals of conservation and the subsequent assessment of species "belonging" in an incrementally approaching post-native future.

AUTHOR CONTRIBUTIONS

AH and EH worked together to develop the thesis of this manuscript. AH wrote the first draft, and both authors contributed to the revision of subsequent drafts until submission.

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