The Humpty Dumpty Effect on Planet Earth

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Humans have treated the earth harshly. Degradation of extant ecosystems leaves little chance that they might function as they have in the past. Putting back the pieces and restoring what once existed is no longer possible even with re-wilding—an effect analogous to the Humpty Dumpty parable. However, we do have conservation successes after concerted efforts related to habitat protection, species and ecosystem restoration, and planning. While the changes to Earth’s biosphere are grave, necessitating immediate and exhaustive action, our Humpty Dumpty world reassembles with progressive conservation victories at all regional scales from local to global which should lead to a modicum of optimism rather than despair. We suggest that to be truly effective our work as academic scientists must be more than publishing in scholarly journals. At the least, this should include changes in how success is measured in science and how university tenure is awarded.

Keywords: ecology, conservation success, conservation failure, earth, biodiversity, ecological grief, Anthropocene

INTRODUCTION

Many know the sad fate of Humpty Dumpty. He sat on a wall and had a great fall. Depicted as a fragile egg, the nineteenth century British allegory unfolds a story in which all the kings’ horses and all the kings’ men could not put Humpty back together again. We suggest that an Anthropocene version of this parable is our fragile biosphere.

We all know that human-induced disassembly of biodiversity and restructuring of ecological relationships have resulted in fundamental planetary changes. While Earth will always be the sum of its ecological processes, these processes differ from those existing even a decade ago. Just as Humpty could not be reconstituted into his pre-fall form, we are not likely to reconfigure biotic assemblages into their previous forms, despite rewilding and restoration efforts (Navarro and Pereira, 2015; Noss, 2020). Most places are just changed. We argue, however, that we do not have the luxury to lament this Humpty Dumpty Effect (Figure 1). We need to acknowledge it and use it to galvanize our tactics, not cripple us with a yearning for the past.

We both bristled when Chris Thomas’s provocative and beautifully written “Inheritors of the Earth: How Nature Is Thriving in an Age of Extinction” appeared in 2017. Neither of us was prepared to become resigned to a new version of Earth. We did not accept the premise that we need to mourn and carry on. But we must. Yesterday’s world is not today’s nor tomorrow’s.
With this in mind, we recently published a paper on food web disassembly that contextualizes how unabated human population growth is a central, though not the sole, ecological disruptor of most large mammal communities (Berger et al., 2020). Our central thesis was that the world is messy, that the pieces cannot be put back together, and that ecological transitions in the form of regime shifts, thresholds, and tipping points (Holling, 1973, 1986; Berlow et al., 2012) are expanding globally. A major take home point of this paper was steeped in the reality of accepting biological change, a topic central in Inheritors of the Earth (Thomas, 2017). Our paper rings with words of grave acceptance, though acceptance need not be passive nor contraindicate optimism.

We remain sanguine because of success stories that provide precedents for ways forward. These successes understandably vary, ranging from local to global and of broad thematic significance to small local victory. For instance, in addition to the vast protected areas with ecosystems functioning much in the way of the past—albeit situated in high-latitude regions with low human density (e.g., Tibet's Chang Tang, Northeast Greenland National Park, Alaska's Wrangell-St. Elias, and Russia's Arctic National Park)—governments and non-governmental organizations have also invested in protected areas at lower latitudes (e.g., Serengeti, Madidi, and Yellowstone National Parks; Kennedy et al., 2019).

Examples of other successes across the globe are presented in Table 1. Rewilding via species reintroduction has proven a particularly valuable tool at broad landscape levels. The reintroduction of gray wolves (Canis lupus) into the northern Rocky Mountains of Wyoming and Idaho re-established prey fear responses and former trophic interactions (Estes et al., 2012). Other examples of highly successful reintroductions include water buffalo (Bubalus bubalis) back into the Danube River Delta, Ukraine, red kite (Milvus milvus) into Britain, and bandicoot (Isoodon obesulus) and bilby (Macrotis lagotis) into Australia (Moseby and O’donnell, 2003; Cogălniceanu, 2012; Legge et al., 2018). Lesser-known successes have been removal of railroad fencing and creation of over- and underpasses—human actions that have reinstated migratory pathways. In Mongolia's Gobi Desert, for example, khulan (Equus hemionus), now pass on both sides of a modified railroad impediment for the first time in six decades (News Wise, 2020).

We write in full cognizance of the biodiversity extinction crisis and that we are losing more species than we are recovering (Nicholson and Possingham, 2007; Kolbert, 2014). Indeed, under our current circumstances of limiting funding and resources, a tactic of conservation triage prevails (Hayward and Castley, 2018). Yet, triumphs do still occur and do so because of individual choices and institutional action—both of which are the result of labile sociocultural-political processes that can change within a generation. Scientific advances, such as those offered by the nascent but growing field of synthetic biology, can bolster such changes (Redford and Adams, 2021). Other sources of cautious optimism include more efficient urban planning, the leveraging of high-resolution geospatial data to address agricultural demands, greater opportunities for reproductive choice by women, and a decrease in the intrinsic rate of human population growth globally (Sanderson et al., 2018; Vollset et al., 2020; ACF, 2021). Calls to action, especially when voiced across generations, gender, and ethnicity solidifies support and can result in change. To wit: the civil unrest related to environmental (in)justice garnered by Greta Thunberg (Rodrick, 2020).

We believe emphatically that as academic scientists we cannot limit ourselves to the currency of our trade: peer-reviewed publications. Essays or perspectives do not accomplish conservation, nor do they typically reach the public (Strother and Fazal, 2011; Morrison et al., 2018). We must work where we can to influence decision-makers and to implement sociocultural change related to environmental policy. This involves non-academic pursuits such as working with agencies
| Continent | Locale | Key native species | Initial in situ anthropogenic change/challenge | The success |
|-----------|--------|-------------------|---------------------------------------------|-------------|
| North America | Greater Yellowstone Ecosystem, USA | Gray wolf (*Canis lupus*) | Extirpated by poisoning, trapping, and shooting | Re-introduction of gray wolves resulted in re-installation of fear in prey species (*e.g.*, *Cervus elaphus*) and trophic-level shifts in species abundance |
| North America | Great Basin Desert, USA | Large mammal community comprising two large-bodied artiodactyls: bighorn sheep (*Ovis canadensis*) and pronghorn (*Antilocapra americana*) | Livestock-induced habitat alterations (1880’s – 1980’s) with post-disturbance addition of mule deer (*Odocoileus hemionus*) and pumas (*Puma concolor*) | Societal recognition that novel species will enter landscapes as a consequence of human activities |
| North America | Pacific Coast, Colorado Plateau, USA | California Condor (*Gymnogyps californianus*) | Extirpated by poison and shooting; declared extinct in the wild in 1987 | Re-introduction; ~ 275 individuals currently Mexico and USA, in and outside of national parks |
| Africa | Ol Kinyei Conservancy, Maasai Mara Ecosystem, Kenya | Lions (*Panthera leo*), wildebeest (*Connochaetes taurus*) | Extensive and intensive habitat loss as consequence of human population growth and resource extraction | Placement of Maasai land in a conservancy has increased their revenue while enabling growth of lion and wildebeest populations |
| Africa | Rwanda, Uganda, Democratic Republic of Congo | Mountain gorillas (*Gorilla gorilla beringei*) | Poaching, habitat loss, war and civil unrest | With protection, substantive population growth (from ~270 to >1,000 individuals) |
| Asia | Gobi Desert, Mongolia | Khulan (*Equus hemionus*), Mongolian gazelles (*Procapra gutturosa*) | Governmental and corporate proposal to build large-scale industrial plant to extract soda ash from lake | Habitat protected and planned industrialization site canceled |
| Asia | Annamite Mts, Vietnam | Silver-backed chevrotain (*Tragulus versicolor*) | Poaching and habitat loss resulted in assumption of extinction | Not extinct – intensive field work and camera traps reveal existence |
| Asia | Tonle Sap Wetlands, Cambodia | Storks (*Ciconia* spp), spot-billed pelican (*Pelecanus philippensis*), ibis (*Pseudibis davisoni, Thaumatibis gigantea*) | Massive population reductions | Species protections result in upwards of 20x in population abundance |
| South America | Andes Range, Columbia | Diverse assemblage of birds and mammals | Privately owned land and reticence toward biodiversity conservation | Creation of large national parks and other protected areas |
| South America | Patagonian grasslands, Columbia and Argentina | Guanaco (*Lama guanicoe*), puma (*Puma concolor*) | Domestic sheep result in centuries of habitat degradation; recent downturn in economic viability of sheep production results in habitat regeneration | Guanaco populations increase tenfold, and pumas expand |
| South America | Rio Ucubamba Valley, Peru | Marvelous Spatuletail (*Loddigesia mirabilis*) | Deforestation via slash and burn methods results in population decline | Establishment of Huembo Reserve, and expanded protected land, community outreach projects |
| Europe | Wetlands of Danube River delta | Fish, bird, mammal assemblages | Presence of dam; water pollution, invasive species | Dam removal, re-wilding, species reintroduction (*e.g.*, water buffalo, *Bubalus bubalis*) habitat protection |
| Europe | Great Britain | Red kite (*Milvus milvus*) | Concerted removal effort via hunting, trapping, and poisoning; by mid-twentieth century, only a handful of breeding pairs throughout island | Captive breeding, reintroductions; now ~1,800 breeding pairs |
| Europe | Iberian Peninsula, Spain | Iberian lynx (*Lynx pardinus*) | Over-hunting, poaching, decline in prey species, fragmentation of habitat | Captive breeding, species reintroduction, and habitat protection; population now > 550 individuals; |

(Continued)
and policymakers, writing opinion editorials, working toward gender equity, engaging in complicated conversations with multiple stakeholders, and acknowledging iterative, structural racism that has profound impacts for environmental justice. Such actions are requisite to enact broad conservation changes (Wittenmyer et al., 2018). Though work beyond academia (e.g., outreach, advocacy) is often not rewarded at institutions of higher education, standards are readily changed by re-writing the requirements for tenure.

In the end, we can’t look backwards. Ecological restoration and rewilding will not bring us back to what Earth once was, even in the recent past (Thomas, 2017; Berger, 2018; Berger et al., 2020). But new versions will coalesce and while we may not gain identical species assemblages, we can work toward comparable ecological function (Chazdon, 2014). Working at all scales, we too can invest in where, when and how we try to impact a world we’d like to see.

### DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

### AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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