frontiers in Conservation Science

PERSPECTIVE
published: 03 February 2022
doi: 10.3389/fcosc.2022.783138

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-wildling—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

OPEN ACCESS

Edited by:
Sean Richard Connolly, Smithsonian Tropical Research Institute, Panama

Reviewed by:
Sacha Jellinek, University of Melbourne, Australia
Andy Chan, University of Nottingham, United Kingdom

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Specialty section:
This article was submitted to Global Biodiversity Threats, a section of the journal Frontiers in Conservation Science

Received: *25 September 2021*
Accepted: *10 January 2022*
Published: *03 February 2022*

Citation:
Berger J and Lambert JE (2022) The Humpty Dumpty Effect on Planet Earth. Front. Conserv. Sci. 3:783138. doi: 10.3389/fcosc.2022.783138

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 Humtpy 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.

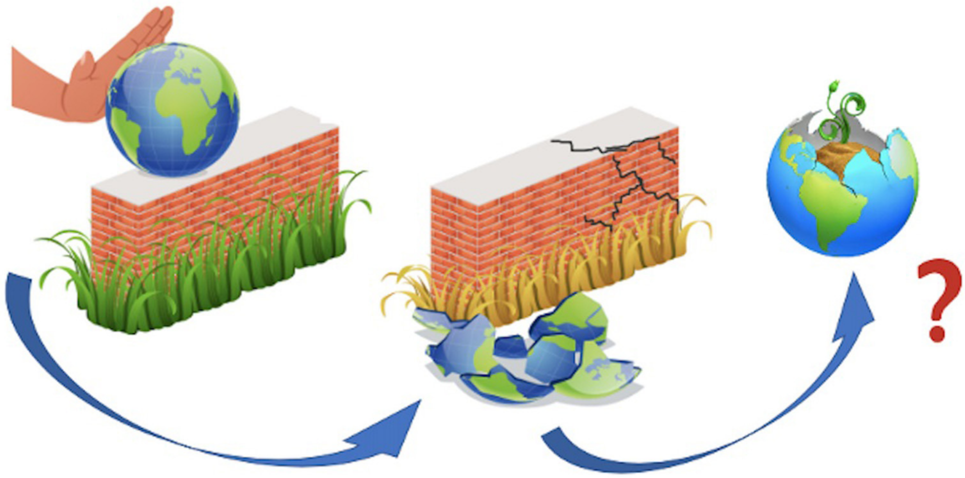

FIGURE 1 | Schematic of our Humpty Dumpty Earth. Left, a past period; center, a fractured twenty-second century Earth on a cracked foundation; right, reassembled Earth accompanied by uncertainty.

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

TABLE 1 | Exemplars of conservation success at species or ecological process levels on each of continents.

Continent	Locale	Key native species	Initial *in situ* anthropogenic change/challenge	The success
North America	Greater Yellowstone Ecosystem, USA	Gray wolf (*Canis lupus*)[a]	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
	Great Basin Desert, USA	Large mammal community comprising two large-bodied artiodactyls: bighorn sheep (*Ovis canadensis*) and pronghorn (*Antilocapra americana*)[b]	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
	Pacific Coast, Colorado Plateau, USA	California Condor (*Gymnogyps californianus*)[c]	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 taurinus*)[d]	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
	Rwanda, Uganda, Democratic Republic of Congo	Mountain gorillas *(Gorilla gorilla beringei*)[e]	Poaching, habitat loss, war and civil unrest	With protection, substantive population growth (from ∼270 to >1,000 individuals)
	Lake Natron, Tanzania	Lesser Flamingo (*Phoeniconaias minor*)[f]	Governmental and corporate proposal to build large-scale industrial plant to extract soda ash from lake	Habitat protected and planned industrialization site canceled
Asia	Gobi Desert, Mongolia	Khulan (*Equus hemionus*), Mongolian gazelles (*Procapra gutturosa*)[g]	Migration curtailed due to construction of railroad and fencing	Fencing impediment restructured to enable migration
	Annamite Mts, Vietnam	Silver-backed chevrotain (*Tragulus versicolor*)[h]	Poaching and habitat loss resulted in assumption of extinction	Not extinct – intensive field work and camera traps reveal existence
	Tonle Sap Wetlands, Cambodia	Storks (*Ciconia* spp), spot-billed pelican (*Pelecanus philippensis*), ibis (*Pseudibis davisoni, Thaumatibis gigantea*)[i]	Massive population reductions	Species protections result in upwards of 20x in population abundance
South America	Andes Range, Columbia	Diverse assemblage of birds and mammals[j]	Privately owned land and reticence toward biodiversity conservation	Creation of large national parks and other protected areas
	Patagonian grasslands, Columbia and Argentina	Guanaco (*Lama guanicoe*), puma (*Puma concolor*)[k]	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
	Rio Utcubamba Valley, Peru	Marvelous Spatuletail (*Loddigesia mirabilis*)[l]	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[m]	Presence of dam; water pollution, invasive species	Dam removal, re-wilding, species reintroduction (e.g., water buffalo, *Bubalus bubalis*) habitat protection
	Great Britain	Red kite (*Milvus milvus*)[n]	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
	Iberian Peninsula, Spain	Iberian lynx (*Lynx pardinus*)[o]	Over-hunting, poaching, decline in prey species, fragmentation of habitat	Captive breeding, species reintroduction, and habitat protection; population now > 550 individuals;

(Continued)

TABLE 1 | Continued

Continent	Locale	Key native species	Initial *in situ* anthropogenic change/challenge	The success
Australia	Booderee National Park	Eastern bristlebird (*Dasyornis brachypterus*), southern brown bandicoot (*Isoodon obesulus*)[p]	Conversion and degradation of total area of habitat	Populations of both species increasing as a result of habitat protection, invasive plant species, reintroduction of bandicoots
	Mallee Cliffs National Park	Bilby (*Macrotis lagotis*)[q]	Introduced species (feral predators and rabbits) collapsed a near-continental wide distribution	Population reintroduction to a fenced, predator-free national park

[a] Ripple and Beschta (2012).
[b] Berger and Wehausen (1991) and Berger et al. (2020).
[c] Sullivan et al. (2007).
[d] Mara (2019) and Veldhuis et al. (2019).
[e] Maekawa et al. (2013) and Robbins et al. (2011).
[f] Birdlife (2017).
[g] Kimbrough (2020).
[h] Nguyen et al. (2019).
[i] Anonymous (2008) and Sithirith (2015).
[j] Tompkins (2019).
[k] Travaini et al. (2015) and Gelin et al. (2017).
[l] ABC Birds (2016).
[m] Cogălniceanu (2012).
[n] Royal Society (2020).
[o] Rodríguez and Calzada (2015).
[p] Legge et al. (2018).
[q] Moseby and O'donnell (2003) and Guardian (2019).

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 (Wittemyer 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.

FUNDING

This study was funded by Colorado State University, the Wildlife Conversation Society, and the University of Colorado.

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