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CellPress REVIEWS

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Post-Anthropocene Conservation

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Conditions capable of supporting multicellular life are predicted to continue for another billion years, but humans will inevitably become extinct within several million years. We explore the paradox of a habitable planet devoid of people, and consider how to prioritise our actions to maximise life after we are gone.

The End of the World as We Know It

> There will come soft rains and the smell of the ground,
> And swallows circling with their shimmering sound;
> And frogs in the pools singing at night,
> And wild plum trees in tremulous white;
> Robins will wear their feathery fire
> Whistling their whims on a low fence-wire;
> And not one will know of the war, not one
> Will care at last when it is done.
> Not one would mind, neither bird nor tree
> If mankind perished utterly;
> And Spring herself, when she woke at dawn,
> Would scarcely know that we were gone.
>
> Sara Teasdale, 1918

Over 100 years ago, Teasdale wrote this 12-line poem – one of the first portrayals of human extinction. In the intervening century, this blurred future has become more sharply focused. Astronomers have estimated that our planet will sustain complex multicellular life for another billion years [1,2] while futurists predict humanity will survive for the next 5100 to 7.8 million years [3,4]. Despite these projections, few scientists conceive of a habitable planet that does not include people (e.g., [5,6]). Unlike previous thinkers [3,7], we look beyond humans to consider future multicellular life on a post-Anthropocene Earth. Confronting these inevitabilities, we suggest conservation science is well placed to frame future policy discussions defining humanity's legacy. To initiate these conversations, we offer a guiding principle, a cautionary projection, and a personal challenge.

Life on Earth

Since life began, different organisms have come and gone as cataclysms wrought mass extinctions and catalysed diversification. Some life forms dominate energy flux and modify the biosphere, nudging the trajectory of subsequent taxa through altered availability of oxygen, water, or other raw materials. Dominance is necessarily transitory, changing environmental conditions favouring successive groups of organisms through space and time [8]. Humans are no different – we will inevitably go extinct [4]. Even the most optimistic scenarios (assuming no nuclear conflicts and as yet unrealised technologies to decarbonise the atmosphere and arrest ocean acidification) predict the extinction of humans within 7.8 million years [3,4]. As Thomas Malthus observed in 1806, we will unavoidably outstrip our means if we continue as we are. When and how humanity passes are unknowable, but decisions we make between now and then will determine the scenery and cast of characters for Earth's next phase.

Life on Earth will last for a very long time, with conditions supporting complex multicellular life and eukaryotes predicted to continue for 0.8–1.2 billion years [1]. In 200–250 million years, tectonic plates will have rearranged landmasses into new supercontinents, fundamentally disrupting existing biogeographic patterns [9]. Thus, multicellular life will continue for hundreds of millions of years after humans – longer than all of prehistory [1]. Redrawing the famous clock of Earth's history to include this projected future, prompts the humbling revelation that we will be gone well before the halfway point of complex multicellular life on Earth (Figure 1).

Just as Proust's writing pre-empted advances in neuroscience [10], it is the arts rather than religion or science that has given most thought to a post-human world (Box 1). Science has contributed little to this discourse, begging the question: do these considerations extend beyond the realm of scientific inquiry? Some thinkers suggest posthuman futures necessarily exceed humanity's conception [4]. We disagree and contend that science, conservation science in particular, is well placed to frame these discussions as a precursor to formulating multilateral policy frameworks. As scientists, we have wrestled with these issues, both personally and in our professional lives. Is there anything we, as individuals, can do to minimise 'collateral damage' to the places and organisms we study? Can we raise children in good conscience if we are ultimately doomed?

Lineages Matter

Unlike other life scientists, palaeontologists consider the history of life across deep time. On geological time scales, species are necessarily transitory. Rather than populations, species, or even genera, deep phylogenetic

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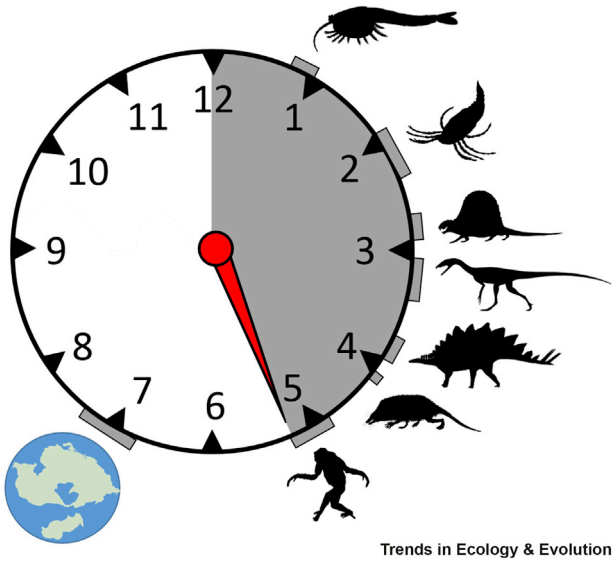

Figure 1. Doomsday Clock of Multicellular Life.
Clock face scaled to represent the extent of multicellular life of Earth; each hour corresponds to 117 million years. The shaded section depicts 600 million years of prehistory from the Precambrian until now (the hand of the clock), with silhouettes and corresponding boxes depicting the time span of selected lineages (from PhyloPic). The white section projects the next 800 million years of conditions capable of supporting complex life [1], projected tectonic plate movements creating new supercontinents 250 million years from now [7]. Humans are predicted to become extinct within the next 7.8 million years [2,3], 20 seconds from now. This figure was prepared using PowerPoint as well as silhouettes from PhyloPic (with artist in parentheses). Clockwise from 1 o'clock: *Waptia fieldensis* (Joanna Wolfe) 510–505 million years ago (mya) Middle Cambrian, *Megarachne* (Nobu Tamura and T. Michael Keesey) 306.9–298.9 mya Gzhelian, *Dimetrodon* (Dmitry Bogdanov) 295–272 mya Early Permian, *Tawa hallae* (Scott Hartman) 215 mya Late Triassic, *Stegosaurus* (Andrew A. Farke) 155–150 mya Late Jurassic, *Sinodelphys* (T. Michael Keesey) 125 mya, and Hominoidea *Oreopithecus bamboli* (T. Michael Keesey) 9–7 mya.

lineages are the lasting units of diversity – families, orders, and classes [11]. These branches of the tree of life represent different ways of living – independent solutions to shared pressures – so the more lineages that survive the Anthropocene, the greater the options for future life. The ultimate lineage in the animal kingdom is the phylum – it is worth noting that no phylum has gone extinct since the Cambrian radiation 541 million years ago. Which lineages persist in the post-Anthropocene world is up to us.

A Message Not of Hope but of Persistence

Adopting deep lineages as units, reconciling our scientific and personal perspectives, and applying a conservation-centred ethos, we offer three messages.

First, a guiding principle: life will persist. Visit a toxic industrial area or war-ravaged ruins and there will be life in the rubble: a dandelion, an ant, maybe a passing pigeon. Announcing his group's research findings on wildlife reclaiming Chernobyl [12], Jim Smith explained it best: 'We're not saying radiation is good for animals, but we're saying human habitation is worse' [13]. No matter how humanity ends or how much we degrade the planet during our demise, life on Earth will continue. We take great solace from this realisation.

Second, a cautionary projection: alongside domesticated species, invasive species are most likely to persist [14]. Invasive species management necessarily reduces impacts, minimises population declines of threatened species and arrests species extinctions in the short term, and this management must continue. However, the same traits and ecological circumstances that render some species invasive make them more likely to survive the Anthropocene. Given that some invasive species are from families, orders, even entire classes of organism experiencing global declines, we find ourselves in the perverse position of repressing those species which hold the greatest chance of their lineages persisting. As the only member of its class with an expanding distribution across multiple continents, cane toads, *Rhinella marina*, are the amphibian most likely to survive the Anthropocene. Likewise, for prickly pear, *Opuntia* sp. – listed by the International Union for Conservation of Nature (IUCN) as one of the 100 worst weeds, it is also the most widespread and climatically tolerant member of the Cactaceae, a family that is almost entirely 'Convention on International Trade in Endangered Species of Wild Fauna and Flora' (CITES)-listed. If the Testudines, Decapoda, and Commelinales orders endure, it will be thanks to their most resilient members: the red-eared slider, *Trachemys scripta elegans*; signal crayfish, *Pacifastacus leniusculus;* and water hyacinth, *Eichhornia crassipes*. Recall that the flowering plants and insects that dominate Earth's terrestrial systems began as single lineages in the Ordovician that survived both the Permo–Triassic and Cretaceous–Tertiary mass extinctions before explosively diversifying to fill empty ecological space. Paradoxically, the world's worst invaders are the most future proof.

Finally, we offer a personal challenge to everyone concerned about the

Box 1. Literary Depictions of a Posthuman Earth

While most literature follows the trope that humans become effectively immortal through technologies enabling colonisation of other planets (e.g., works by Robert Heinlein, Anne McCaffrey, Arthur C. Clarke, and Lois McMaster Bujold), relatively few writers have explored ideas of a posthuman Earth. The first was Mary Shelly's 1826 novel 'The Last Man', which ends with one man wandering the Earth after a plague destroys all human life. HG Wells' 1895 novel 'The Time Machine', portrayed a time when all traces of humanity are lost and 'crab-like creatures' live by the light of a dying Sun. Dougall Dixon went further, imagining how existing organisms might evolve in 'After Man: A Zoology of the Future', expanded upon by Kurt Vonnegut's 'Galapagos', which followed the devolution of humans to a nonsapient end. Possibly, the most realistic treatment of human extinction is the television show 'The Inner Light', a 'Star Trek: The Next Generation' episode (1992), which chronicles the extinction of a humanoid species and their world as their sun extinguishes all life in the planetary system. The conclusions of those writers who have pondered a posthuman world converge – while technology may provide a temporary reprieve, the extinction of humanity is inevitable.

Earth's future: choose a lineage or a place that you care about and prioritise your actions to maximise the likelihood that it will outlive us. For us, the lineages we have dedicated our scientific and personal efforts towards are mistletoes (Santalales) and gulls and terns (Laridae), two widespread groups frequently regarded as pests that need to be controlled. The place we care most about is south-eastern Australia – a region where we raise a family, manage a property, restore habitats, and teach the next generations of conservation scientists. Playing favourites is just as much about maintaining wellbeing and connecting with the wider community via people with shared values as it is about maximising future biodiversity. As a crisis discipline, conservation biology takes a toll on its first responders, routinely confronting us with accelerating extinctions and a society increasingly detached from wildlife and nature. Acknowledging humanity's finite future and championing our beloved groups and places affords a reassurance that our individual actions matter. The ultimate form of conservation optimism.

Although our perspective is ecocentric, maximising post-Anthropocene diversity need not be considered selfish nor altruistic. The more lineages and ecosystems that persist, the greater the likelihood that humanity's support systems will continue, extending our remaining time and improving our quality of life in the interim. Collectively, humans have the capacity to do extraordinary things. By considering our finite future and the lasting consequences of the actions we prioritise, we can minimise collateral damage to the biosphere and maximise the raw material for Earth's next phase.

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