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INVITED ARTICLE

A tale of two islands. The reality of large-scale extinction in the early stages of the Anthropocene: a lack of awareness and appropriate action.

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Abstract

The endemic biotas of oceanic islands were vulnerable and many have been lost. The more ancient, complex and dynamic biotas of continents were more resilient but are now being obliterated. Sumatra and Madagascar are large continental plate islands with very different histories and biotas that exemplify the situation on continental land masses. Both tropical islands have suffered massive habitat loss and species extinction from human population pressure, Sumatra mostly from global and Madagascar from local pressure. Snails demonstrate the complex history of faunal origins as illustrated by the relationships between Madagascan, Indian and southeast Asian snail faunas and their plate tectonic geological history. Snails also reveal our limited *knowledge of the details but not the scope of extinctions through habitat loss. International agencies are failing to address the root causes of natural habitat loss and consequent extinctions, which are overpopulation and an economic system based on perpetual growth. The fallacy of sustainable development and the limitations of current conservation practice are addressed. Recognition that we cannot stop extinctions in the immediate future demands a new, supplementary approach to conservation based on advances in molecular technology.*

Keywords: Sumatra; Madagascar; conservation; sustainable development; land snails; cryo-banking.

Introduction

From a negligible figure just a few thousand years ago humans and their livestock now constitute over 95% of mammalian biomass (Bar-On et al., 2018). From an ecological perspective, there are simply too many of us. The biodiverse world that we were born into is disappearing and many branches of life will not be with us in the future. Much attention is focussed on the threats to a few iconic species but the extent of extinctions remains largely hidden, unknown in detail but indisputable in scale. We need to be aware of what we are losing. The earliest undisputed evidence of life on Earth dates from at least 3.5 billion years ago and there is evidence that life began much earlier. We, together with all complex multicellular organisms, belong to the eukaryotes and each individual is the end product of 2.7 billion years of eukaryote evolution. To appreciate the wonder of each group of animals and plants, we need to consider their history, and how they came to be where they are. The history of life is an interaction of biotic evolution with the complexities of the planet's geological history, continuous fluctuations in climate and vast spans of time, punctuated by frequent local and rare global cataclysmic events.

Despite the numerous perils facing marine environments, most extinctions in the current episode have been confined to terrestrial and non-marine aquatic environments. Many vertebrates are under intense threat, populations have crashed, some have become extinct, others are close to extinction (Ceballos et al., 2015). This justly generates much human anguish. However, over 99% of animals are invertebrates (Tetley et al., 1999). Invertebrate extinctions are massive, most notably in the biodiverse terrestrial faunas of tropical forest. Invertebrates form the foundation on which ecosystems and many life forms are totally reliant. If we are concerned about biodiversity loss then their story needs to be told and their fate needs to be a focus of our attention.

Different invertebrate groups can provide different perspectives. Numerous insects have become extinct without the losses being recorded (Hochkirch, 2016). Insect populations have crashed in many parts of the world, from Europe (Hallmann, et al., 2017) to the tropics (Lister and Garcia, 2018), along with their associated predators such as many reptiles, amphibians and birds. However, some of these results are controversial (Willig et al., 2019; Lister and Garcia, 2019) and although chemical controls are the main suspects, notably neonicotinoids, there is often no proven link to causes of declines in abundance. Despite overwhelming subjective evidence for massive drops in insect numbers (Vogel, 2017), we have a problem in that despite numerous recording schemes of insect species occurrence, there have been few long-term studies of insect species abundance.

Molluscs can provide a different perspective. They are a major invertebrate group in terms of both biodiversity and biomass (Bar-On et al., 2018), and land snails can be particularly informative about patterns of diversity and current extinction events (Lydeard et al., 2004). I am interested in and concerned about the whole of living diversity but land snails have several attributes that render them particularly informative about all scales of evolution and changes in the environment, such as climate and habitat changes through time. Good examples of this were made available when the channel tunnel was excavated, giving access to previously hidden fossil-rich deposits (Kerney et al., 1980; Preece and Bridgland, 1999), and examples of successive horizons are equally informative in tropical ecosystems such as in Jamaica (Goodfriend and Mitterer,1988, 1993; Paul and Donovan, 2005; Donovan et al., 2013).

Land snails are not what is termed a 'natural group'. In the distant past, several aquatic and only distantly related snails colonised the land independently (Little, 2009). Some such as the terrestrial Caenogastropoda are derived from winkle-like ancestors, they have separate sexes and seal the apertures of their shells with a plate that is attached to the top of their tails; they are numerous in parts of the tropics, less so in temperate regions. The other main groups included in the

Pulmonata have more developed lungs and are hermaphrodites, they occupy all habitat types in which land snails occur from deserts to marshland, from leaf litter to the heights of tree canopies.

Snails generally have relatively poor powers of dispersal but, given sufficient time, a few are passively dispersed over long distances, by hurricanes for example. There is also strong evidence of long-distance dispersal of snails by birds (Gittenberger et al., 2006; Leeuwen et al., 2012). In the short to medium term, most snails are confined to their location in ways that many other organisms are not. Unlike the majority of terrestrial arthropods, they cannot run or fly; the vulnerability of their delicate bodies is primarily offset by retracting and taking refuge within their shells. This limited motility makes them vulnerable to extinction when conditions change. However, where natural habitats are continuous, they can successfully change their distributions, including latitudinal and altitudinal changes, with the shifting of ecosystems in response to climate change. The shells may sometimes be delicate but many are robust and may survive long after the snail has died. In several lineages the shells are vestigial or lost altogether. There is a continuous transition between snails, semi-slugs and slugs but for convenience and to allow generalisations to be made, slugs are not considered here.

Whatever the season, a good measure of what snails are present in an extant habitat can be gained by collecting their shells. Thus, natural history museums around the world often hold extensive collections of shells that require no special procedures for their preservation and storage. Where well documented, these collections provide a partial record of where snail species were found in the past. Day to day routine identifications and classifications may be carried out solely by examination of snail shells. However, more sophisticated methods of morphological study of internal organs and molecular methods are essential for more critical studies. Such studies have shown that numerous cryptic species and even higher taxonomic categories can be recognised compared to identifications based solely on shell characters.

Extinctions on oceanic islands and on continents

The unique radiations of animal diversity that occurred on oceanic islands, most less than 10 myr old, took place in habitats that were free of the taxonomically diverse and highly evolved systems of predators and competitors that had developed on continents through tens and hundreds of millions of years. This contributed to island biotas' vulnerability to human introductions of continental species that had attuned to the harsh selective pressures from which the evolution of oceanic island species had been sheltered. The arrival of humankind on oceanic islands has progressively led to the widespread loss of oceanic island species, their unique habitats and ecosystems (Fordham and Brook, 2008). Recorded extinctions of land snails on oceanic islands exceed those of all other groups combined (Lydeard et al., 2004).

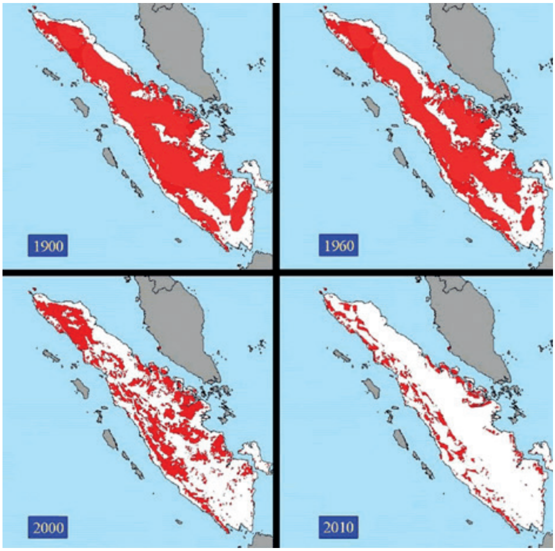
Losses on continental land masses through human activity also have a long history but they have generally been less visible. We are now losing continental species at an unprecedented rate, with complete and complex ecosystems that have evolved over many millions of years. This is a growing tragedy of the Anthropocene. Although these large-scale extinctions are now taking place on continental land masses, the circumscribed nature of continental islands (fragments of continental tectonic plates) allows them to be examined as discrete units and used as exemplars for what is going on in continents as a whole. To this end, aspects of the fauna of two of the world's largest and very different tropical islands, Madagascar and Sumatra, are considered here in the context of regional faunas with particular reference to their land snails.

Sumatra

Sumatra epitomises a manifestation of the sixth mass extinction and demonstrates the disaster that is rapidly unfolding in southeast Asia (Sodi et al., 2004; Hughes, 2017). What has happened in Sumatra has significantly influenced my thinking on extinction because nearly all of the lowland and much of the montane forest habitats, which previously blanketed the landscape, have been lost in my lifetime (figure 1). At 443,066 square kilometres, an area greater than twice the size of Great Britain, Sumatra is a large, geologically complex island about 3.3 times the area of Peninsula Malaysia. It was repeatedly connected to the continental land mass as an integral part of Sundaland, a southeast Asian global biodiversity hotspot, throughout glacial episodes. Thus, during the past 2.6 million years of ice ages, its biotic history and composition was as a part of continental southeast Asia (Woodruff, 2010).

Figure 1.

Forest loss on Sumatra due to logging and conversion to agriculture. The red depicts remaining forest cover.



Straddling the equator at an angle of about 45°, Sumatra is geologically a part of continental Eurasia and part volcanic in origin, its southern border lies along the subduction zone of Sundaland and the Indo-Australian plate and it is part of one of the most tectonically active areas in the world. Frequent volcanism, earthquakes and tsunami impact on the biota. Notably, the explosive eruption of Mount Toba 73,500 years ago must have had a massive impact on southeast Asia and peninsula India's biota through ash deposition (Bühring and Sarnthien, 2000; Jones, 2007). Nevertheless, a mixture of plains and complex mountain systems offered a diverse array of forest habitats in Sumatra providing it with some of the richest biodiversity on the planet. Despite enormous expenditure on conservation effort, lowland forest was close to being entirely lost at the end of the twentieth century (Whitten, et al., 2001), just a few diminishing patches remain. Iconic mammals such as the Sumatran tiger, rhinoceros, elephant and orangutan are all widely recognised as being critically endangered.

Benthem Jutting (1959) listed just 192 species of land snails from Sumatra and a few have been described since (Maassen, 1999, 2000; Páll-Gergely, 2017). However, we have little idea of how many species might have been present in Sumatra 60 years ago; it is likely to have been closer to 2,000 than 200. What is clear is that with most natural habitat destroyed in Sumatra, many of the endemic species will be extinct. The invertebrate diversity of Sumatra's lowland forests was never studied methodically and now never can be. This demonstrates what scientists mean when they speak of species going extinct before they have even been described. The loss of 98% of forests in large parts of Indonesia is projected by 2022 (Hughes, 2017, 2018). Sumatra stands out because the scale of destruction has been so rapid. It is not just forests that are disappearing. Limestone hills are habitat islands rich in biotic diversity with particularly high snail diversity and density. The more isolated a limestone hill, the greater the likelihood that it possesses high levels of biotic endemism and the greater the risk of its destruction for limestone extraction.

In Sumatra the main driver of habitat loss and consequent extinctions was explicitly and succinctly identified by Whitten et al. (2001), three pages of essential reading for anyone who wants to understand where conservation efforts in Sumatra stood at the turn of the century. What happened in Sumatra should and could have been avoided, and at least mitigated, but it wasn't. Despite massive conservation effort, all of the management plans, political accords and expenditure of unknown millions of US dollars, deforestation continued unabated. Big business and political corruption, both equally ruthless, rode over any conservation efforts. The whole purpose of the flourishing academic field of conservation was questioned by Whitten et al. (2001, p.1):

> In these same three decades we have also seen conservation biology rise as a respected and attractive discipline, with great successes in producing journals, books, and students. But if conservation biology is ineffective in helping to stop something as globally significant as the devastation of Indonesian forests, then what, please, is the point of it?

Sumatra has a human population of approximately 52 million, around 90.5 people per km^2; the human population of Indonesia as a whole has increased to 3.5 times its 1955 level. For comparison, consider Sri Lanka, which has a population of just over 20 million, 340 per km^2, about twice its 1955 level with 82% living in rural areas. Much forest has been lost in Sri Lanka but it has a number of relatively well-protected areas and has so far retained a rich biota including large mammals such as thriving populations of elephants and leopards. It appears that local human population pressure in Sumatra, with 6.75 times the area of Sri Lanka, might not have been the major driver of habitat loss and extinctions. It is in fact clear that the primary driving force of habitat loss and extinctions in Sumatra is external, consumption of its resources around the world, an insatiable demand for its products, notably palm oil and timber, facilitated by greed and corruption.

Madagascar

With an area of 587,041 km², Madagascar is a large continental fragment of Gondwana, one of the two great landmasses that separated from the single land mass of Pangaea with the opening of the Tethys Ocean about 175 million years ago. The southern continent of Gondwana was separated from the northern land mass of Laurasia for about 100 myr. During the subsequent breakup of Gondwana, Madagascar together with India, separated from Antarctica about 125 mya, having separated from Africa some 20 myr earlier. Around 88 mya, India separated from Madagascar. Madagascar moved slowly north to its current longitude whereas India was drawn north much more rapidly until it collided with Eurasia (Smith et al., 1994). India is still thrusting into Asia and continues to force up the Himalaya.

The world was a much warmer place throughout most of Madagascar's existence and large tracts of what is currently dry land were covered in shallow sea. The limestone deposited during these marine incursions provided a particularly rich habitat for limestone biotas including land snails. 88 myr of isolation have endowed Madagascar with a truly unique biota. Unlike Sumatra, Madagascar is an ancient land mass and geologically is relatively stable, although there is some tectonic activity and it possesses dormant volcanos (Pratt et al., 2016). The closest Indian coastline is now some 3,800km away but it was of course closer throughout much of the past 88 myr and there were periods when a series of islands, now largely submerged, provided potential stepping stones for biotic transfer. Mainland Africa, currently some 450km away at its closest point, has remained in relatively close proximity throughout.

Whereas the climate in Sumatra is hot and wet throughout the year, the climate in Madagascar is much more complex being dominated by the joint action of the moist southeast trade winds and the wet northwest monsoon. The east coast has a high annual rate of precipitation but on reaching the plateau prevailing winds have lost much of their humidity resulting in only light rain and mist, leaving the west in a rain shadow; areas of the southwest are semidesert. Madagascar's biota has exploited the diverse range of habitats that are strongly influenced by this climate. For agriculture, the climatic variations across Madagascar present challenges ranging from severe drought to deluge flooding.

A large proportion of Madagascar's biota is endemic but, during its 88 Ma of isolation, rare dispersal events across the seas introduced new biotic elements from further afield, some of which radiated into significant new components of Madagascar's biota. A classic example is the lemurs, now confined to Madagascar. Molecular phylogenetic and anatomical evidence suggests that the ancestor of the currently recognised 111 species and subspecies, 20% of the world's primate species, reached Madagascar from Africa at around 54 mya (Martin, 2000; Mittermeier et al., 2008). Following the loss of natural habitats (figure 2), some 95% of lemur species are on the threshold of extinction. The IUCN Species Survival Commission (SSC) raised over US$8 million to spearhead efforts to save them with a 3-year conservation plan in 2013 (IUNC, 2013). An IUCN updated assessment in 2018 (Bristol Zoo, 2018) showed that, despite some local successes, the threat of lemur extinction has increased.

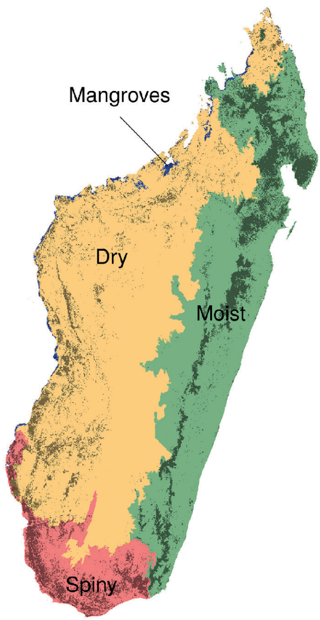


Figure 2.

Ecoregions and forest types in Madagascar. Madagascar can be divided into four climatic ecoregions with four forest types: the moist forest in the East (green), the dry forest in the West (orange), the spiny forest in the South (red), and the mangroves on the West coast (blue). The dark areas represent the remaining natural forest cover in 2014. Forest types are defined on the basis of their belonging to one of the four ecoregions. (Reproduced from Vieilledent et al., 2018).

Evidence strongly supports two Africa-to-Madagascar dispersal events for chameleons across the Mozambique Channel, one at about 65 mya, the second at about 47 mya (Tolley et al., 2013). These two rare events gave rise to the amazing diversifications of chameleons in Madagascar, about half of the world's chameleon species diversity. According to an assessment by the SSC, 52% are threatened, including 5 species that are critically threatened and 18% are near threatened (Hance, 2014).

As with Sumatra, by the middle of the twentieth century, some 200 species of land snails had been recorded from Madagascar. However, following intensive studies, notably by Emberton between 1990 and 2009, the total number reached about 1100 (Slapcinsky, 2014). Despite their commendable efforts, it is impossible for a handful of people to have described most of the land snails of the 587,041 km² of Madagascar. With no one dedicated to their study, there is unlikely to be the same pace in new species descriptions. Many will now be extinct but there may have been about 2,000 species in total.

Despite its 88Ma history as an isolated land mass, Madagascar's snail fauna has origins that extend across all directions of the Indian Ocean. The most distinctive components, the 115 described species of Acavidae, are considered to be Gondwanan relicts (Emberton, 1999). Their ancestors were distributed across Gondwana prior to its breakup and acavids are now found only on continental fragments of Gondwana: South America, Africa, Madagascar, the Seychelles, Sri Lanka and Australia. The mode of dispersal of acavids is to sit tight on continents for tens of millions of years and wait for plate tectonics to do the work for them. The acavids possess large, often brightly coloured shells and produce disproportionally large, bird-like eggs. With even their hatchlings being relatively large, their size seems likely to have contributed to the fact that they appear not to have spread across oceans by natural means.

The genera *Kalidos*, *Boucardicus* and *Tropidophora* have radiated into numerous Madagascan species. There is evidence that the ancestor of *Kalidos* made its way to Madagascar from southeast Asia, possibly via India. *Boucardicus* shows similarities with genera found in south and southeast Asia but, with similar looking fossils in 100 myr old Burmese amber, it is clear that these groups have been around for a very long time and their relationships need to be established by molecular methods A different distribution pattern is shown by *Tropidophora,* which also occurs on the opposite land area of Africa, on the Comoros and the Seychelles. Related genera are found around the Indian Ocean from Socotra, mainland Yemen and Oman, with a separate genus and two species occurring in the Western Ghats, India (Raheem et al., 2014).

They may be more ancient arrivals but the radiations into numerous species within single genera such as *Kalidos* and *Tropidophora* are suggestive of relatively recent arrivals of these genera into Madagascar, possibly during the Miocene (23 mya to 5.3 mya).

What the lemurs, chameleons and land snails have in common with much of Madagascar's and other tropical biotas is that most species have very restricted distribution ranges within the complex mosaic of naturally diverse habitats. The majority of Madagascar's land snails have been described on the basis of a few individuals from a single locality, some from partially weathered shells of species that may have already been extinct at the time of their description. Habitats cannot be transformed by human activity without the consequent wholesale loss of localised species. The composition and diversity of land snails conveys the long biotic history of Madagascar better than any vertebrate group and their Anthropocene extinction is already well underway.

There have been years of debate and a lack of consensus on the causes of tropical diversity but, whatever the mechanism, high diversity dominated by limited range distributions is widespread in the tropics and has been for millions of years (Brown, 2013). Despite the age of this biotic diversity of lineages in the wet tropics, they are now extremely vulnerable to habitat loss and transformation because of their often-restricted distributions and their being surrounded by a matrix of human transformed habitats.

With well-established recognition of its incredibly rich biodiversity and extreme levels of endemism, Madagascar has been a priority target of international research and conservation effort for decades (National Research Council, 1980; Myers, et al., 2000; Goodman and Benstead, 2005). Efforts reached a height during the implementation of a series of National Environment Action Plans between 1993 and 2008, when hundreds of millions of US$ were spent on over

500 environmentally-based projects. Eight Millennium Development Goals were established for a fifteen-year period from 2000, supported by the Madagascar Millennium Development Goals National Monitoring Survey (INSTAT, 2014) and the protected areas network was expanded threefold. Projects aimed at sustainable development and reducing poverty have failed, in fact none of the Millennium Development Goals were met nor was progress made towards them, and relentless deforestation continues unabated (Waeber et al., 2016; Vieilledent et al., 2018). The protected area network is widely ignored.

Madagascar is larger than Sumatra but has a smaller human population estimated at 20-27 million, approximately half that of Sumatra (population density of Madagascar some 46 per km^2; Sumatra 90.5 per km^2). It might be thought that human population levels would have less impact. However, Madagascar is in a sorry state (UNIC, 2019):

> The country's health and education systems are not really working, they are crumbling; In the last two years 77 % of the population have been living on less than 1.25 dollars a day.

More than 92% of Malagasy live on less than US$ 2 a day (World Bank, 2013). Madagascar's infant mortality rate is over 5% and three-quarters of the population live in rural areas. The estimated median age in 2017 was 18.7, compared with 40.1 for the UK, indicating that population growth is hardwired into the immediate future. Although the total fertility rate (TFR) has fallen from 7.3 in 1960 to 4.18 in 2016, Madagascar's TFR is still nearly double replacement level. Logging and mining controls are ineffective. Large numbers of people have little choice other than to take what they can from their environment, regardless of any conservation needs. Traditional slash-and burn agriculture is increasingly practiced in desperation and on a completely unsustainable scale, destroying natural habitats. They are not alone. As pointed out in the executive summary of the World Conservation Strategy (IUCN-UNEP-WWF, 1980, p.vi):

> ... hundreds of millions of rural people in developing countries, including 500 million malnourished and 800 million destitute, are compelled to destroy the resources necessary to free them from starvation and poverty.

Reponses to the biodiversity crisis

> "It is far better to grasp the Universe as it really is than to persist in delusion, however satisfying and reassuring." – Carl Sagan

The cases of Sumatra and Madagascar demonstrate both the scale and causes of biodiversity loss. In Sumatra conservation efforts have failed in the face of insatiable global demand for its resources along with greed and corruption, while in Madagascar endogenous factors, including poverty and population growth, have been the most significant causes of habitat destruction. Given the scale of biodiversity loss as exemplified by these islands, the following sections go on to consider some aspects of the global responses by governments, conservation agencies and academics.

Earth Optimism was launched in 2017 with a series of meetings including in Washington (Smithsonian Conservation Commons, 2017), in Cambridge (Cambridge Independent, 2017) and London (ZSL Institute of Zoology, 2017). The momentum of Earth Optimism continues and a Conservation Optimism summit was held at Oxford in 2019 (University of Oxford, 2019).

A number of justifications for Earth Optimism have been put forward. One suggestion is that such an approach is essential in order to engage with the public. Others suggest that people who are seeking careers in the field need to be encouraged by a sense of optimism and that it is needed to secure corporate and government funding. To quote from the ZSL Institute of Zoology (2017):

> Budding and perennial conservationists need to feel inspired and continue in the profession, not put off by pessimism. The public, businesses and government need to know that their actions can make a difference.

However, promoting optimism in this way exaggerates successes in relation to the size of the problem and ultimately is not only inappropriate but misleading. Importantly, it infantilises the public by assuming that they will only engage with optimistic information and runs the risk of undermining trust in scientific integrity. Perhaps the most worrying aspect of Earth Optimism is that in focussing on the celebration of those success stories the overriding issues of human overpopulation and overconsumption that are driving mass extinction are ignored.

The Convention on Biological Diversity (CBD) grew around the concept enshrined in Article 1 of the Convention (CBD, 1992, p.3):

> The objectives of this Convention, to be pursued in accordance with its relevant provisions, *are the conservation of biological diversity*, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies, and by appropriate funding.

With almost universal celebration and after years of preparation, the CBD was launched in Rio de Janeiro in 1992. Bureaucracies proliferated and numerous agencies were created so that many thousands are employed at great cost in developing both national and international plans and in attending massive international conferences. From a brief initial focus on conservation it soon became a behemoth of international agencies seeking to extract funding resources for development, programmes that had little if anything to do with biological conservation. It is an empire of vested interests that has failed to deliver conservation objectives. Extinctions continue unabated (Anon, 2016) and bio-nationalism has impeded international conservation efforts. The United Kingdom's flagship CBD programme, the Darwin Initiative, epitomises the change in direction that effectively constitutes a high-jacking of the CBD agenda from a biodiversity capacity building focus to a development agency based on poverty alleviation. Worthy as these objectives may be in their own right, they have not even slowed the current scale of biodiversity loss.

Brown (2015, p.1) provided an impeccable and succinct demolition of the notion of sustainable development:

> Unfortunately, "sustainable development," as advocated by most natural, social, and environmental scientists, is an oxymoron. Continual population growth and economic development on a finite Earth are biophysically impossible. They violate the laws of physics, especially thermodynamics, and the fundamental principles of biology. Population growth requires the increased consumption of food, water,

> and other essentials for human life. Economic development requires the increased use of energy and material resources to provide goods, services, and information technology.

Sustainable development goals can provide neither sustainability nor a pathway to halting the sixth mass extinction. However, governments, numerous agencies and commercial enterprises around the world, together with academics, fail to acknowledge their flawed nature. For example, the UN Sustainable Development Goal 15, life on land (UN, 2019), should be of key importance to biodiversity loss. Goal 15 seeks to sustainably manage forests, combat desertification, halt and reverse land degradation and halt biodiversity loss. However, there are no realistic mechanisms or new ideas put forward of how this could be achieved on a scale commensurate with the problem. Reference is made to the Lion's Share Fund, a worthy programme but one that can only have a tiny, if useful, impact on biodiversity loss.

A wide range of conservation activities are pursued by the IUCN including the formulation and development of international agreements such as the 1974 Convention on International Trade in Endangered Species, and the CBD. Together with partner organisations the IUCN is pursuing a pathway to conservation based on the concept of sustainable development. However, their Red Listing system (IUCN, 2019) is unique in aiming to provide hard data of extinction risk in support of conservation and, particularly for large vertebrates, has many merits. An example of an outstanding achievement with invertebrates is the IUCN Red List of European Terrestrial Snails (Neubert et al., 2019), which was developed from many years of recording schemes and input from numerous contributors. However, the situation for a single species, the world's largest cat, the tiger, is illustrative of the problematic nature of the IUCN's approach. Project tiger (National Tiger Conservation Authority, 2019) has been running for nearly 50 years, has cost millions of US$, involved thousands of people and supported numerous careers. Yet controversy surrounds the results of surveys and in obtaining accurate figures of tiger numbers (Karanth, 1995; Karanth et al., 2017; Mazoomdar, 2019). In contrast, only a handful of people have been dedicated to surveying land snails in the tropics, a totally inadequate number for assessing the status of numerous often tiny snails in the world's rainforests. For most species and areas, it is not remotely possible to obtain accurate information within a timeframe commensurate with the urgency imposed by the rate of habitat loss and extinctions. We remain in ignorance or, in Red List terminology, data deficient. The WWF sets out its agenda in the *Living Planet Report 2018: Aiming higher*. This would be a highly commendable document but for the fact that it ignores the major underlying causes of the problems it identifies: human overpopulation and the ecologically impossible concept of sustainable development. Together with overpopulation, economics is at the heart of our current unsustainable trajectory. Global economics is currently based on growth and benefits from population growth and increased wealth with consequent increases in consumption. Clearly, this is not to suggest that reduction in poverty is in itself undesirable but that it has inevitable, undesirable and unsustainable consequences. Much can be done to mitigate but not remove the impact of increased consumption, for example, by the reduction and ultimate elimination of the use of fossil fuels and by modifications to diets. However, the human ingenuity argument fails to recognise that improvements that science and technology have brought to human welfare have not been shared with the natural world. While economic growth is necessary to improve the welfare of the world's poor, endless economic growth to satisfy the wants of an ever-increasing global consumer class is simply unsustainable.

The desperately urgent need for a strategy aimed at establishing an inventory of what remains of living diversity has been recognised for some considerable time (Wheeler, 1995). It is utterly shameful that this has not happened. The Earth Biogenome Project (2019) is wildly overambitious to the extent of being utterly unrealistic in aiming to sequence, catalogue and characterize the genomes of all of Earth's eukaryotic biodiversity over a period of ten years. This to include what it estimates as the 80-90% of eukaryotes that have yet to be described. Over two centuries of just searching out living diversity has left us with a long way to go and locating the whole range of species is a long way off, even though that unknown number is rapidly declining. The Earth Biogenome Project (EBP) is described as a 'moonshot for biology' (EBP, 2019). It might have launched but it cannot reach its ten-year scheduled destination. Despite its extravagant claims as a means of contributing to the conservation of species (Lewin, et al. 2018), as it stands, it will not do so. Sequencing eukaryote diversity might provide employment for numerous scientists, if only for a decade; it can satisfy human curiosity and yield new means of exploiting natural resources but it will not contribute to preventing the loss of natural habitats or reduce human driven climate change. Their analogy with space exploration seeks to link the EBP with human achievements that are widely celebrated and have numerous indirect benefits. However, all such scientific endeavours should be judged by the proportionality of effort and cost in the context of priorities on our own planet and the destruction we are collectively inflicting on it. In the context of the sixth mass extinction, the disappearance of its subject matter, and unless balanced in new directions, the EPB objectives are a self-satisfying indulgence. This is analogous to a consortium of hospitals of global prestige around the world being obsessed with gaining academic stature while ignoring countless thousands of dying patients.

Curiosity driven research provides inspiration and motivation for learning about the universe and the EPB has the merit of recognising the scale of the issue and timeliness, if not the constraints. In addition, the EPB fails to accept the requirement for voucher collections that are needed to support the molecular sequencing. Unless intended as an abstract exercise, or an exclusively molecular based alternative to existing concepts, it is meaningless to sequence samples without being able to relate them to physical entities. Voucher specimens are the preserved samples linked to the genomes to be sequenced. Some species might be sufficiently well known for their identity to be accepted but such are insignificant compared to the vast majority of described but poorly understood species and for undescribed species. Traditionally, voucher samples were whole preserved specimens and there is still a place for these but detailed images could in many instances be a practical option in combination with tissue sampling. In addition to traditional methods of preservation and frozen tissue collections, it is possible to prepare specimens in an ultimate state of preservation by preserving viable cells, cell lines, without sacrificing or harming the animal. Most importantly such preservation can underwrite all traditional conservation efforts. If this were included in the EBP protocols then it would completely transform the value of the programme. This is the obvious direction in which resources and research efforts should be directed. It is early days and there are numerous difficulties in extending the practice to a wide range of species but cryogenically stored viable sperm and egg cells are already being used as a measure to conserve species close to extinction (Hermes et al., 2018) and viable somatic cells can potentially be cloned. Thus, it is not only possible to conserve and utilise genetic diversity of threatened species but preservation of viable cells offers the potential to restore species if they should become extinct (Naggs, 2017), together with associated organisms such as their gut biota. Viable cells of extinct species are already being stored. The Hawaiian tree snail *Achatinella apexfulva,* supposedly the first recorded extinction of 2019, was given extensive media coverage including by the National Geographic (Wilcox, 2019) and the Natural History Museum (Pavid, 2019). Living cells of *Achatinella apexfulva* are cryogenically stored in the San Diego Zoo Institute for Conservation Research's (2019) Frozen Zoo. As with Kew's Millennium Seed Bank, this material could potentially be cryogenically stored for hundreds of years and should be the routine mode of preservation. Who can say what future capabilities might be but, if we do not act now, whatever current and future potential value they might have will be lost forever and options for their use will not exist.

One hurdle to surmount is that access to specimens has become much more difficult and complicated. The way forward is to establish and nurture long-term relationships, particularly with biodiverse countries. The pilot project that I ran in 2013 demonstrated the value of collaboration and that viable cell preparation could be routinely added to existing field practice (Naggs, 2017). The sixth mass extinction should position natural history in the forefront of scientific endeavour to record and conserve living diversity in an urgent structured, focussed and relevant way.

The Intergovernmental Panel on Climate Change (IPCC) is the United Nations body invested with the task of evaluating the science related to climate change. Scientific evidence is not determined by consensus but the overwhelming assessment of scientific information is clear and cannot be ignored, humankind is causing global warming. Where the IPCC has failed is in recognising that by our very existence and ever-growing numbers, we cannot avoid global warming. Indeed, there is clear evidence that the rise in CO_2 and CH_4 began some 7,000 years ago with human driven deforestation and the development of agriculture and livestock tending (Ruddiman, 2014, and references therein). Furthermore, Ruddiman presents the case that without anthropogenic influence, we would already have entered a new ice age. We undoubtedly need to take steps to mitigate global warming but, even when we deal with eliminating fossil fuel, as we must, the transformed landscapes and biomass of humans and their livestock will continue to deliver elevated CO_2 and CH_4 above natural levels.

Climate change is integral to earth history and happens regardless of human activity, sometimes very rapidly. It is instructive to recognise that throughout much of earth's history CO_2 levels have been much higher and global temperatures have been much higher than they are now and natural events could overwhelm any anthropogenic changes. We should be prepared for the inevitability of climate change in one direction or another. Living diversity has accommodated to climate change throughout its existence. What is unique about the current situation is that natural forest landscapes have been transformed into a mosaic of modified (largely agricultural) habitats and fragmented natural forest, the forest remaining as isolated and shrinking patches. Combined with climate change, the barriers to dispersal will precipitate a new catastrophic wave of extinctions and there is an urgent need to provide habitat corridors and to be prepared to intervene with the seeding of new habitats that develop in response to climate change.

Taking stock

The history of life on earth shows it to be a dynamic mix and match of blending and separating of biotas through time. In addition to the many other human impacts on the natural world is an acceleration of this mixing to a global scale and breakdown of geographical isolation. In the mixing of biotas there are a few winners and numerous losers. Increased mixing leads to a reduction in local endemism and thus a reduction in biodiversity.

Sumatra and Madagascar demonstrate that both local and global human population pressures produce the same outcome, habitat loss and extinction. Socioeconomic factors and human numbers present an unsolvable conundrum. There is a widespread belief that human ingenuity can solve such problems. Proponents of this view correctly point out that living standards throughout much of the world have improved dramatically through the application of science and technology. The same cannot be said of natural environments that have suffered as a consequence. We are already a long way down the road of destroying the natural world. Habitat fragmentation combined with climate change will precipitate a surge of extinctions in the near future. Conservation is thriving as an academic discipline and can point to success stories but overall it is a failure. Such an assessment is often dismissed as a doom and gloom scenario but there are many opportunities to act in positive ways. There are too few habitats approaching pristine condition for them to be the sole focus of conservation effort and some transformed habitats retain significant subsets of biological diversity and need to be integrated into conservation practice. Again, snails show the way in demonstrating that some forest fragments and transformed habitats can still support a significant subset of forest species (Raheem et al., 2008, 2009; Triantis et al., 2008), although such transformed habitats are being rapidly lost to more intensive modes of agriculture.

We have to accept that we cannot halt large scale extinctions and act accordingly. A new drive for a zoological species inventory, that also conserves biodiversity and secures options for the future, is essential in the context of massive species loss. For conservation in the here and now, new and direct emergency action is needed to protect natural habitats. One overriding need is for a simple and straightforward mechanism for providing significant funding for poor but biodiversity rich countries to protect natural habitats. Used for the benefit of their human populations, this is possibly the only way to arrest immediate biodiversity loss where it is driven by poverty. This is happening in a small way but it needs to be on a huge scale, something appropriate for private agencies and governments to engage with through the United Nations.

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