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Perspective

Managing Natural Extinctions

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Simple Summary

While the current goal of conserving the environment today is to prevent species going extinct, what can be overlooked is the fact that extinction is a process that has always accompanied life on Earth, including prior to human evolution. Despite the importance of continued efforts to save species from extinctions, there is a need to differentiate extinctions caused by humans from extinctions that would have occurred in our absence and are thus natural. In this perspective, we propose there is a dilemma in halting extinctions altogether if this also prevents natural extinctions that are a key component of life on Earth. If possible, managers need to determine if natural extinctions are still occurring and if so, whether they should be allowed.

Abstract

The Earth is facing an extinction crisis caused by anthropogenic activities, with a primary goal of today's conservation management being the protection of species from being lost to the Anthropocene. What is missing from the debate surrounding extinction, and how humanity grapples with this issue, is an acknowledgement that it is a natural phenomenon that has always accompanied biological life, including prior to human evolution. Despite the importance of continued efforts to save species from extinctions, there is a need to differentiate extinctions caused by humans (anthropogenic extinctions) from extinctions that would have occurred in our absence (natural extinctions). We propose that there is a dilemma in halting extinctions altogether and in perpetuity if this also prevents non-anthropogenic extinctions that are a key component of life on Earth, particularly when considering much longer timescales than the current extinction crisis necessitates. From this perspective, we argue that non-anthropogenic extinctions should be allowed if they can be distinguished from anthropogenic extinctions. This perspective is intended for managers to consider the ways in which they actively manipulate ecosystems moving forward in the pursuit of conservation and how extinction needs to be considered on a case-by-case basis to fulfil this process of management.

Keywords: Anthropocene; extinction rate; mass extinction event; speciation; species decline

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1. Introduction

The Earth is facing an extinction crisis, with the rate of species loss 100–1000 times greater than what is documented as 'natural' [1,2]. This has been brought about by the synergistic effects of several anthropogenic activities including habitat degradation, species introduction, exploitation, and climate change [3–7]. Yet, extinction is a phenomenon that has always accompanied biological life, with periods of low (background extinction)

and high (mass extinction events) rates of species loss seen across the fossil record [8–10]. Indeed, the vast majority of extinctions have occurred prior to human evolution, resulting from climatic and environmental changes [11], including stochastic events [12], that cannot be attributed to anthropogenic pressures.

The goal of current conservation management is to prevent species extinctions using a range of strategies, including habitat remediation, captive breeding, translocations, and cryopreservation of gametes [13–15]. However, what must be determined for each species at risk of extinction is whether the cause is partially or fully related to human activities. This is because the impact of humans has not been the advent of extinction as a process but the creation of anthropogenic extinctions and an increase in the speed at which some species would otherwise have gone extinct in the absence of human-related causes. Despite the importance of continued efforts to save species from extinctions that are caused by humans, we propose that there is a dilemma in halting extinctions altogether and in perpetuity if this also prevents non-anthropogenic extinctions that are a key component of life on Earth, particularly when considering much longer timescales than the current extinction crisis necessitates. From this perspective, we argue that non-anthropogenic extinctions should be allowed if they can be distinguished from anthropogenic extinctions. While this paper explores philosophical viewpoints, it is not intended to be an exhaustive philosophical debate around the process of extinction itself and the values we place on nature. Instead, it is intended for managers to consider the ways in which they actively manipulate ecosystems moving forward in the pursuit of conservation, the complexity of decision-making in biodiversity conservation across different timescales, and how extinction needs to be considered on a case-by-case basis to fulfil this process of management.

2. What Defines a Species and Their Endpoint?

An exploration of the roles and impacts of extinctions on wildlife first relies on delineations of what a species is, which is based on changing human interpretations and has differed over time based on the use of different attributes (morphology and genetics) and concepts (biological species concept, evolutionary species concept) [16,17]. Irrespective of the criteria used, classifying organisms into species types is an effective way for humans to record fixed points in the evolution of a common ancestor that has undergone continuous change and diverged to form a branching family tree of many separate populations of interbreeding individuals [17,18]. If we are to categorise organisms into species types, then we can assume that all species have a beginning/birth (speciation) [19], yet clear taxonomic boundaries are arbitrary and thus difficult to detect and define, as the transition points between species over geological time periods represent a continuum of intermediate forms. This is particularly apparent at the genetic level, where speciation is simply the process of different gene cohorts being carried forward by different populations that split from a common ancestor. Likewise, the extinction of a species is difficult to define as it represents the decline of the species to zero, which can occur if the species is impacted by some sort of disturbance and dies out (i.e., a true endpoint) or if the species has transitioned into a new species. Despite the complexity of determining what defines a species and their endpoint, current classification systems are used for the conservation management of wildlife and should thus also be used when exploring extinctions in general.

3. Are Human-Driven Extinctions Unnatural or Natural?

3.1. Our Interactions Within Ecosystems

Extinctions have either occurred prior to or after the evolution of humans. It is only since our presence on Earth that extinctions can be broadly defined as those that have been caused by human activities to some extent (anthropogenic extinctions) versus those that

have occurred and do occur in the absence of human involvement (non-anthropogenic extinctions). What must be considered is the appropriateness of considering anthropogenic extinctions as unnatural and non-anthropogenic extinctions as natural, which is based upon considerations of humans as either a native species and natural component of ecological systems (i.e., coevolution) or separate and outside of nature or even an introduced species. Given that a primary driver of current wildlife management is to prevent extinctions that are being caused by human activities, it could be argued that current anthropogenic extinctions are indeed considered unnatural; otherwise, they would be allowed and considered widely among conservationists as natural. This question of whether extinctions are natural or not is separate from the ethical debate of whether unnatural extinctions are 'bad' and natural extinction thus 'not bad', which is explored later. What remains relatively more difficult to define is whether human pressures across all stages of humanity are considered unnatural and thus whether all anthropogenic extinctions should be similarly classed as unnatural.

3.2. Extinction Thresholds in Time

A nuanced approach may be to exclude extinctions with human involvement prior to a particular period in history as being unnatural. For example, the extinction of species before and at the beginning of the Holocene could be defined as natural, even if humans were a potential or likely contributing factor, dependent on how conservationists today view our species' actions at that point in time and whether we deem those humans as foreign to the ecological assemblages that were present [20]. This would subsequently exclude extinctions that have occurred in more recent times but still prior to the industrial revolution that humans have played a role in, such as the extinction of the moas (flightless birds) after the first colonisation of New Zealand only 900 years ago [21]. We are not suggesting that a threshold should be set, rather the need to consider our interactions with and influence on natural systems and whether we deem ourselves a natural component or an unnatural threat. We could also go further back in time and explore the role pre-sapien hominins played in earlier extinctions and whether a threshold is instead set between us and our relatives [22], but this is beyond the scope of the current study which is primarily confined to our species alone.

Take, for example, the Pleistocene megafauna, which suffered dramatic population declines and extinctions in a period of warming after the last glacial maximum, in the late Pleistocene and early Holocene (late Quaternary) [23]. There is ongoing debate as to the main driver of this event, including humans or natural climate change or the intersection of both [24,25]; however, more recent analyses suggest humans were likely the predominant driver [26,27]. Whether we view these extinctions as natural or anthropogenic influences the ways ecological systems, which these species were once a part of, are managed today. For example, rewilding initiatives have considered or applied megafauna replacements, which are deemed to have a positive effect on ecosystem functioning by restoring species interactions that were lost [28]. The application of such conservation strategies today would suggest that all human led extinctions, including those in the distant past, are unnatural. Indeed, megafauna restoration should only be considered if their extinction was attributed to us, as it would be an overreach and ecologically damaging to revive species that went extinct naturally without human influence.

It is possible that the initial decline of some megafauna and earlier extinctions in the Pilo-Pleistocene did not have significant human involvement but were instead driven by natural environmental change [29]. For example, the decline and extinction of gomphotheres (related to elephants) in the Americas occurred in the late Pleistocene after humans had arrived but may have been caused by climatic and vegetational changes, with only some populations likely experiencing hunting pressures but after they were already in

natural decline [30]. Thus, it becomes apparent that some megafauna likely went extinct without human involvement (primarily natural), while others were already in decline but later impacted by humans (partially anthropogenic), and others which were primarily driven to extinction by humans (primarily anthropogenic). Additionally, the demise of at least some ancient plants during the same period as the megafauna (in the late Quaternary), may not be attributed to human activities, such as the spruce *Picea critchfieldii* [31]; although it is plausible that megafauna extinctions or human fire practices may have been influencing factors [32]. These examples stress three critical factors that must be considered in this discussion: (i) the initial cause of a species decline may be natural but subsequent human-related pressures may exacerbate the rate of this decline and be implicated in the extinction; (ii) extinctions during the same time period may have different causes, with some representing natural extinctions and others anthropogenic; and (iii) the impact of humans on species decline may differ between populations, which means some population level extinctions could be entirely natural while others are not.

4. Preventing Extinctions in the Anthropocene

It is important for us to consider the reasons why conservation managers try to prevent extinctions from occurring. Most extinctions attributed to humans have not been intentional, instead being a negative byproduct of human activities [33]. Exceptions include the hunting of predators of livestock (e.g., [34]) and pathogens that cause human diseases (e.g., [35]), which have been deliberately eradicated. Beyond the debate as to whether anthropogenic extinctions are considered unnatural or natural, they have been considered morally wrong [36]. Each extinction event can be considered negative or wrong based on their causes, or their implications for the environment, or the values we place on particular species or all life on Earth [37,38], which are drivers for conservation activities today that underpin the philosophy of conservation science and provide justification for anthropogenic extinctions as being both unnatural and wrong.

Species may be prioritised for human-intervention if they offer value by playing a critical role in maintaining the functioning of ecological systems [39]. This is apparent with the loss of keystone species that can result in the dramatic shift in ecosystem states, including a deterioration in system health or complete collapse [40,41]. For example, the local extinction of wolves from Yellowstone National Park led to an increase in prey populations and the subsequent overexploitation of vegetation, with the reintroduction of the species leading to system recovery [42]. Species may also be protected for their cultural or religious value, or for human-centric, selfish reasons due to the ecosystem services they provide us [43]. Finally, species may be protected from extinction as they have innate, intrinsic value that is not related to their role or function in the environment or their importance for humans [36,38]. If we did not assign some type of value to species, then anthropogenic extinctions would not be considered ethically or pragmatically wrong, and species preservation would not be a priority.

It is apparent that anthropogenic extinctions are judged as being 'negative', 'bad' or 'wrong' [36,44]. Thus, it should be equally justifiable to define natural extinctions as 'neutral', 'necessary', or 'not bad' for the same reasons, given the role of extinction in ecosystem function and evolution and the right of all species processes to be undisturbed by humans [36]. Of course, we may still view natural extinctions as 'sad' and mourn the loss of any species regardless of the cause for their demise, which may prevent us from seeing natural extinctions as 'good'. Yet, preventing natural extinctions to relieve our emotional guilt would only benefit ourselves and not the ecological systems we are trying to protect.

Soulé [36] explores the right of species to exist free from anthropogenic extinction, and we believe that this sentiment should be extended to all species processes that should be protected from human interference. If species should be allowed to persist without the threat of an unnatural extinction, then there must be some consideration of their right to succumb to natural extinction unobstructed by human intervention. Part of the issue may be the way in which conservationists and society at large view extinction during the Anthropocene as it is a process that is immediately linked to human causes, especially if we do not make a clear distinction between natural and anthropogenic extinctions and which is morally wrong (e.g., [44]).

5. Extinctions Are a Part of Biotic Change

Ecosystems are complex and constantly undergoing changes, including adapting to perturbations, and sometimes even shifting states entirely [45]. If the primary goal of preventing extinctions is to preserve the functioning of an ecological system, we must consider whether it is to preserve the system within a current, certain, or ideal state (e.g., pristine and before human modification) in perpetuity or to preserve the interactions within the system to allow it to undergo changes naturally without human interference. If the latter is prioritised, then preventing natural extinctions may keep systems and species within a rigid state with no capacity for change.

5.1. Evolutionary Transitions

In addition to extinctions that are caused by species declines, extinctions also occur as part of the evolutionary process, as it marks a species' transition into newer forms based on current delineations of the terms 'species' and 'speciation'. Extinction is thus inherently linked to the process of evolution, not only as a driver of speciation, but as a part of speciation [46]. A dilemma may arise in the future if the current genetic makeup and diversity of a species is conserved when it is going naturally extinct given its transition into a new species type.

5.2. Niche Availability

Extinctions are a part of the process of change observed in ecosystems and play a role in driving the evolutionary process as they make available niches that allow for the rise in new species to fill them [47,48]. This reasoning is in line with contemporary ecological hypotheses regarding the "flux of nature", which recognises the transience or absence of equilibria states in ecosystems [49]. Natural extinctions are a contributor to the flux in nature, as niches are opened and closed by organisms with different morphotypes. Preventing natural extinction thereby interferes with and, dependent on our view on human disturbance, impedes the evolutionary trajectory of systems by keeping niches full and preventing natural changes from occurring.

The opportunities for species diversification following extinction are apparent after mass extinction events when large numbers of species die out, leaving niches unfilled that survivors can fill, leading to diversifications [50–52]. For example, the Cretaceous-Paleogene (KPg) mass extinction that wiped out non-avian dinosaurs allowed for the rapid adaptive radiation of mammals as their replacements [52,53]. These large events led to the removal of a large proportion of Earth's species and the diversification of survivors [46]. This is not to argue that all species alive contribute equally to niche exclusion or that extinction alone drives speciation, but that the decline of species into rarity, which may take thousands if not hundreds of thousands of years, or even abrupt extinctions, which may occur with stochastic events, offers opportunities for other species to fill the niches that are left behind in their absence.

6. The Dilemma in Identifying Natural Extinctions Today

Global species richness estimates vary between studies, ranging from as low as 7.4 million to as high as 24.51 million [54], with most species still undescribed. In the absence of human activities, an expected 15,000–49,000 species should have still become extinct from natural causes over the past 2000 years (7.5–24.5 per year), assuming a natural extinction rate of one species per million each year [19,55,56]. Yet, there is little to no evidence in the literature of any natural extinctions in the past few centuries [36], and perhaps even since human evolution [48]. This could suggest that all modern extinctions have been completely the result of humans and should thus be referred to as anthropogenic or that natural extinctions are still occurring but not detected or even detectable.

6.1. The Natural–Unnatural Continuum

It is possible we have entered an era of life on Earth where natural extinctions cannot be identified or no longer exist, as all ecological systems have been exposed to anthropogenic disturbances that have irrevocably changed the evolutionary processes and trajectories of the planet's biota. With human activities exerting such strong environmental pressures on species, even those in remote areas, it may also be difficult to obtain sufficient data to determine when population declines commenced and whether they were from primarily or completely natural causes. Given the interconnectedness of Earth's ecological systems, even species in virtually untouched areas may still be affected by disturbances elsewhere (e.g., human-induced climate change; [57]). As evidenced by the extinctions of the late Quaternary, whereby the causes remain contestable, the fact that no clear-cut natural extinctions have been detected since human evolution raises questions about how we define extinctions in the modern era, and possibly the need to redefine what is considered natural.

If all species have now been impacted by human disturbances, then it would be more appropriate to consider extinctions along a continuum from natural to anthropogenic and determine how much human pressures are contributing to or driving declines. Using this framework, an extinction could still be defined as natural, despite being influenced by human disturbance, if the cause was primarily the result of natural circumstances and the effect of humans on the timing of the extinction was considered sufficiently small. Alternatively, we could predict extinction risk from a reference point in time (i.e., temporal baseline), analogous to how carbon emissions targets are based on pre-industrial levels, and define extinctions as natural if they do not significantly deviate from projections. If we cannot define natural extinctions in the modern era, then we may be condemned to prevent all future extinctions in perpetuity, which is of course logistically unfeasible and an ecological dilemma as we cannot keep systems within a stagnant state forever.

Nevertheless, some living species have a high probability of dying out without intervention due to traits inherent to the species (e.g., small population size, limited dispersal ability, narrow niche) [58]. Additionally, natural causes of extinction can arise at any point in the future. These may constitute stochastic events, such as an asteroid strike, tsunami, or volcano, as well as more gradual changes within a system, such as the emergence of novel biological pressures from species that have naturally colonised a new area and the emergence of a new pathogen, as well as climatic changes [29,31]. The dilemma is determining whether such species are succumbing to natural extinctions with some degree of certainty, the extent to which natural causes of extinction have been exacerbated by human influence, and what declines are considered natural despite human influence.

6.2. When to Interfere

Many species have experienced range contractions and severe population declines in the past, only to recover on their own. The cheetah is a clear example, as it went

through a major population bottleneck one-hundred thousand years ago but still persists, albeit with genetic consequences [59]. Assuming the decline of cheetahs in the past was natural without anthropogenic causes but occurred today, would conservation managers be inclined to intrude and manage the species without realising the species would survive the bottleneck on their own? If we can determine that a species is undergoing a natural decline, then perhaps we must not interfere with natural changes in their population dynamics, even if it leads to their natural extinction.

6.3. Case Study

The Wollemi pine (*Wollemia nobilis*) is a 'living fossil' species that was thought to be extinct, but a single population of living trees was discovered in the 1990s in a canyon in the Greater Blue Mountains, Australia [60]. Since the time of the discovery, less than 100 individuals remained, and the species is currently considered critically endangered [61,62]. Its small geographic range and population size, coupled with low genetic diversity [63,64], means it is at risk from disease, disturbance, and catastrophic events. The species has thus been provided significant conservation funding, including the cultivation of cuttings, a translocation programme, and the creation of a seed bank [60,61,65,66]. Additionally, commercial cultivation has made the species available from nurseries to grow at home anywhere around the world as part of a domestication programme [67]. These management actions have effectively increased the chance of the species persisting by increasing the number of living trees and distributing them over a wide area.

The decline of the pine was likely brought about by natural climate change associated with the continental drift of the Australian continent northwards, which caused conditions to become dry and rainforests to convert to woodlands except for in deep ravines that allowed moist conditions to persist [68,69]. It is plausible that changes in natural fire dynamics following the arrival of the first humans may have also contributed to range contractions [70,71]; although human fire more likely led to changes in drought-adapted species away from tropical forests and not those with little evolutionary history of fire exposure [72]. It is difficult to discern the contribution of indigenous modifications to fire frequency on the Australian landscape from its desiccation caused by continental drift on the decline of this species. Yet, its confine to moist crevasses would suggest it was not impacted by human-fire changes that would have occurred in dry systems.

Yet, in more modern times, human-induced threatening processes such as climate change have fuelled unnatural weather events that could wipe the pine out, made apparent by the Black Summer fires of 2019–20 [73]. This would make it difficult to discern whether the extinction of the pine from a stochastic event such as a fire was natural or induced by anthropogenic climate change, but that would only relate to the final moment of the species' existence and not the initial cause for the decline. With intensive conservation management implemented over the past three decades, the pine will effectively never go extinct. Its current protection against extinction may be considered inappropriate if its original decline is considered natural.

The decline of some ancient plants likely mirrors the range contraction and dwindling population size of the pine brought about by changes in climate. While humans have the capacity to prevent the extinction of species today, we did not have that capacity at the beginning of the Holocene when humans and these species coexisted. If these ancient species and the pine were to swap places, they could have hypothetically been saved and the pine unknowingly lost. While there are plans to revive some ancient species through a process referred to as de-extinction [74], there are unanswered questions as to whether this should occur [75] and whether extinct species should be revived if their demise was not

the direct result or only partially attributed to human interference or occurred far back in history [76].

7. Restoring Natural Extinction Cycles

A long-term goal of conservation management should involve allowing extinctions deemed natural to occur unimpeded, as allowing species to persist indefinitely impedes the evolutionary trajectory of their systems. This view is in line with arguments against de-extinction of animals, given that the reintroduction of extinct animals back into ecosystems after extended periods of absence may alter the current niche-space of species that are now present [77]. We propose that an extinction process is allowed for any species that is deemed a candidate for natural extinction and thus ineligible for conservation (Figure 1), including any management actions that would keep them extant in perpetuity, thereby matching the predicted change in these systems that would have occurred in the absence of human influence.

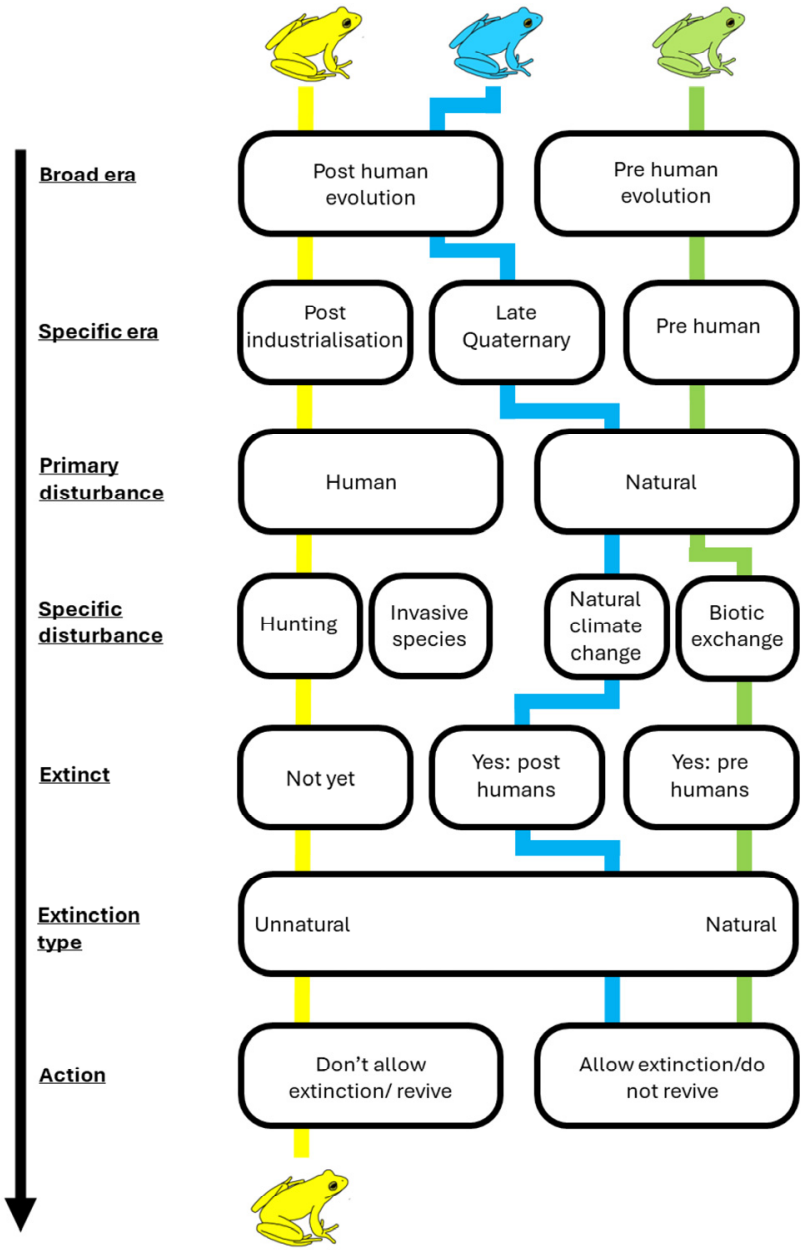


Figure 1. Decision-making framework for determining extinction type and management intervention. The diagram illustrates the pathways of three hypothetical species as they pass through sequential

levels of evaluation, based on temporal context (era) and threat drivers, to assist with classifying whether they have, are, or will experience natural versus anthropogenic extinction. Only species identified as undergoing anthropogenic extinction (e.g., yellow frog) proceed through all levels and exit the framework to receive conservation assistance (i.e., action) and continue on to complete the process again as an iterative cycle, while those experiencing natural extinction (e.g., blue and green frogs) are filtered out and do not cycle through the process again.

7.1. Identifying Natural Extinctions and Implementation

The allowance of natural extinctions would require clear criteria on when a species is perceived to have reached its endpoint. Distinguishing between natural and anthropogenic extinctions thus requires an ability to identify and subsequently tease apart the contribution of natural versus human-related factors that have played a role in a species' decline and whether they were implicated in the initial decline or simply the last few moments of a species' extinguishment. What must be determined for species still present today is whether they are undergoing natural declines and when natural extinction may eventuate versus declines that have been sufficiently influenced by human pressures, and which may result in anthropogenic extinction. This will require a combination of analytical approaches that establish natural species distribution, habitat suitability, population size, and population viability, and whether anthropogenic pressures can be directly linked to changes in these attributes and increased extinction risk or timing beyond what is considered acceptable.

Species distribution and habitat suitability: Historical occurrence data (e.g., fossil records and historical observations) can be used to reconstruct the 'natural' distribution of a species (while accounting for natural limiting factors such as dispersal barriers and competitive exclusion) prior to exposure to human-related threats (e.g., introduction of invasive predators) or emerging pressures (e.g., climate change) that have subsequently influenced habitat suitability and resulted in the realised distribution observed today [78]. Comparisons of historic and current distributions would establish a benchmark for whether a species' extent has already been impacted by humans. The historic distribution could then be projected into the future, accounting for natural changes in climate (e.g., continental drift), and assess whether a natural decline due to a contraction in suitable habitat was to occur, followed by projections of the realised distribution accounting for current or emerging human-related threats. Comparisons of future extents under these different scenarios could provide insight into the contribution of humans in the decline of a species, the period in which extinction may occur, and whether the extinction would be defined as natural or anthropogenic.

Population viability analysis: PVA is used to simulate the expected extinction probability and timing for a species based on key population and environmental parameters [79,80]. Simulations could be performed for scenarios before and after exposure to each known or predicted human threat as inputs [81]. This comparison would make it possible to assess how each threat truncates the expected time to extinction, whether it increases the risk of extinction within a specific time frame, and whether there is a threshold below which exposure to the threat does not significantly change that extinction profile of a species.

Sensitivity analysis and inference modelling: We could calculate the contribution of each threat (natural and human) on the observed decline of a species using modelling (e.g., generalised linear modelling) and conduct simulations to explore non-linear interactions among threats [82]. This could be used to determine whether the decline has been and remains natural, and the time point at which any human-related threats have exacerbated the decline.

7.2. Implementation

If it is determined that a species is at risk of anthropogenic extinction, then typical management actions should be activated (Figure 1). In contrast, if a species is at risk of

natural extinction, then a decision must be made as to whether this is allowed or prevented. If allowed, then it would be expected that conservation efforts for the species may be pulled back. Yet, a concerted effort is required to sequence the genome and store gametes of the species to maintain an extinction library, which requires proven cryopreservation, seed banks, and captive husbandry protocols [83]. This is an insurance policy in cases where there is a shift in paradigm regarding the allowance of some species extinctions. Additionally, ecological monitoring should be performed to determine the aftermath of the extinction on the system that will be impacted.

7.3. Dealing with Changes Already Felt in the Anthropocene

What must also be considered is the effect humans have already had on species adaptation and speciation from (i) the opening of niches due to anthropogenic extinctions, (ii) changing conditions such as the introduction of exotic species, and (iii) novel environments such as cities [84–86]. In the presence of continued anthropogenic pressures, we must seek to promote the adaptation of extant species to current Anthropocene landscapes. It is apparent that disentangling natural and anthropogenic extinction is a complicated process, but this difficulty does not reduce the importance of exploring such work.

8. Future Extinctions

Even if it is not possible to disentangle natural extinctions from those that are anthropogenic today, there may be scenarios in the distant future where extinctions, in general, will need to be considered in the management of changing ecosystems. This is nowhere more apparent than during the merging of previously isolated landmasses through geological processes such as continental drift. For example, the Australian continent is on a collision course with Asia [87], and when this occurs species communities that have not shared an evolutionary history will be exposed to one another. As these communities begin to interact via these biotic exchanges, competition, predation, and disease transmission will inevitably cause some species to be outcompeted, decline, and go extinct as the merging biota reach a new equilibrium [88].

A similar situation occurred relatively recently when the North and South American landmasses became connected with the closing of the isthmus of Panama 3–5 million years ago. In what is referred to as the Great American biotic interchange, the migration of placental mammals both north and south of the crossing caused natural species extinctions until a new equilibrium was reached [88–90]. The issue with applying today's conservation goals into the distant future is that it does not account for natural changes in species composition over long periods of time. Using the philosophical standards of conservation biology today, we would be compelled to manage and protect all species from extinction if a biotic interchange occurred, including those that would not have a chance of persisting in the wild on their own.

9. Conclusions

The most important role of conservation management today is protecting species from anthropogenic extinction. What is missing from the debate surrounding extinction is an acknowledgement that it is a natural phenomenon that has always accompanied biological life, including prior to human evolution. Indeed, it is one that all species inevitably complete as they die out or transition, much like death at the individual level. We believe that the value of natural extinction should not be forgotten in the debate on how ecological systems are conserved, as this may be critical over longer time scales than the current extinction crisis. If possible, managers need to determine if natural extinctions are still occurring and if so, whether they should be allowed. Additionally, in the future we must consider the

practicalities of allowing natural extinctions and the criterion that is used to allow these events to occur. This perspective is relevant to contemporary conservation decision-making as we will need to make a decision at some point in our future about what extinctions are considered acceptable, in terms of their 'naturalness', in a world that has been forever changed by the actions of our own species.

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