Conservation and Evolution: together, can these tools keep species from vanishing?

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The Sixth Mass Extinction

Scientists agree that today's extinction rate is hundreds, or perhaps thousands, of times higher than the natural baseline rate. Five other times in Earth's history have extinction rates skyrocketed to the point of being encapsulated in a mass extinction event. We find ourselves in the midst of the sixth mass extinction episode which promises to wipe out living things across the globe.

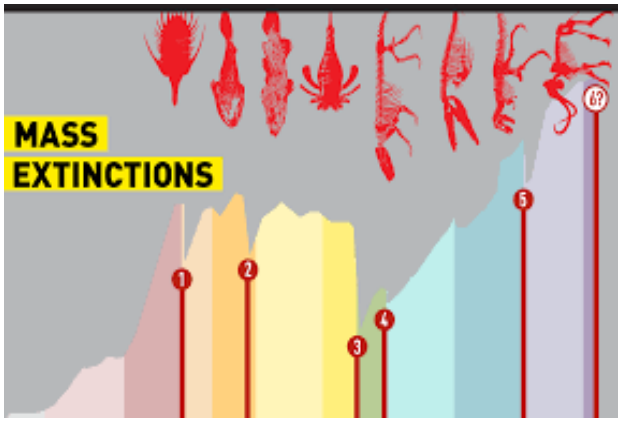
Today's extinction event traces back 10,000 years ago, at the end of the last ice age. Many North American animals including the mammoth went extinct due to changing environmental conditions, but evidence also supports that overhunting by humans played a role in removing these species from the face of the Earth.

Beginning in the 1800s, industrialization increased the rate of extinction and is continuing to have this effect on the natural world. Climate change, pollution and habitat degradation are among the many anthropogenic forces driving species to the brink.

Unsurprisingly, at the eye of the biodiversity loss storm, we find humans. With the very real threat that our continued overuse of resources and impact on climate will not only decrease the chance of many species' survival but also that of our own, scientists and policymakers scramble to preserve what is left of Earth's biodiversity (*Extinction Over Time| Smithsonian National Museum of Natural History*, n.d.).

Conservation biology is the science of managing ecosystems to prevent the extinction of species. Due to finite resources, not everything can or will be saved. Conservation efforts target species and habitats based on a number of factors ranging from economic to ethical.

It is clear that human activities have had dramatic effects on the life forms seen on Earth today, and our actions have led to the need for conservation efforts to mitigate and in best cases, reduce the damage done. It is also evident that human activities shape the evolution of species as is the case in widespread hunting and fishing which direct the selection of smaller body size and cryptic behavioral tendencies in animals. Likewise, pesticide use has led to the evolution of pesticide resistance in many crops. In fact, archeological records indicate that human habitat modification and intensive harvesting practices have affected the evolution of nonhuman species since before the beginning of the historical record, perhaps dating back to 50,000 years BP or even earlier (Sullivan et al., 2017).



But how does increasing human involvement in selecting which species are protected and preserved lead to evolutionary effects down the line? Are we correcting our mistakes or making things much worse? How does it make sense to solve the current extinction crisis if human intervention is both the cause and the solution? Is the trajectory of life on Earth in our control? Very little research addresses the ways in which conservation management actions influence the evolution of species (Shefferson et al., 2018).

Conservation biology as a field would be better equipped to handle the demands of today's mass extinction event armed with the underlying biological theory: evolution. The understanding of the relationship between conservation and evolution is a helpful connection to ground today's protection efforts. Utilizing a species' evolutionary history in developing conservation mechanisms is one benefit of this insight as is understanding the inverse realtionship of conservation altering the course of evolution. If evolution via natural selection is the underlying reason for biodiversity on Earth, why not harness the power of this biological fact in our push to keep species here?

A History of Conservation Ethics

The advent of conservationism came about through a shift in thought from the preservation of untouched landscapes devoid of human influence to a more pragmatic acceptance of human presence in the natural world and ways to conserve biodiversity in light of this reality. In the 1930s and 1940s, ecologists began to exert influence on the field of conservation leading to a wider conceptualization of diversity of ecosystems alongside species. These transitions took many decades and occurred during the same time period that Charles Darwin's theories on evolution via natural selection were continuing to rise to prominence. Darwin's work and the intellectual synthesis surrounding his theories paved the way for the understanding of the importance of evolutionary processes in the emergence and extinction of species (Franco, 2013).

Some of the foundational conservation biologists were also evolutionary biologists, beginning with Ed Wilson, Peter Raven, Michael Soule and Darwin himself. Today, evolutionary biology has limited reach on conservation management. For instance, very few evolutionary biologists participate in national delegations to the Convention on Biological Diversity (CBD) or contributed to the Millennium Ecosystem Assessment (MEA), platforms of conservation policy debate dominated by ecologists along with environmental economists. While evolutionary concepts which would be helpful in this discourse are absent, ecologists bring ecological frameworks such as ecosystem services to the forefront of discussions (Hendry et al., 2010). Society and biodiversity at large, not to mention the discipline of evolutionary biology, would benefit from the inclusion of evolutionary mechanisms in conservation policy and rhetoric.

Broadly, the focal points of ethical debates surrounding conservation have been outlining reasons to maintain the existence of a threatened species at the expense of another due to limited resources. However, there is general consensus that humans have an obligation to conserve species threatened as a result of human actives. Recently, the goals of environmental policy in the face of climate change have challenged the conservation community to come to terms with the importance and potential futility of dedicating resources to conserve species which will require more and more input as environmental conditions worsen (Hendry et al., 2010). In light of this uncomfortable and pessimistic view, conservationists remain dedicated to the moral responsibility of humans to protect species from the fate we created.

Why We Conserve

While many argue for the conservation of a species for its own sake, in reality, conservation targets species that provide instrumental value to humans, primarily economically. International policy seeks to strengthen the bridge between the natural world and human development. These links include ecosystem services essential to human well-being including water purification and pollination behaviors that contribute to food security (Bottrill et al., 2014). Ecological and evolutionary perspectives outline the value of biodiversity as a measure of ecosystem resiliency to threat and services provided to humans. Presently, many scientists, scholars and citizens recognize that species have direct and indirect effects on human livelihood and ought to be conserved for the benefit they confer on our species.

Recent studies reveal that the reason behind humanity's desire to conserve and protect nonhuman species is deeply rooted in our species' evolution and past.

Spotlighted Scientist: Dr. Hare investigates the evolution of altruism in humans and the impact of this trait on conservation today.

Charles Darwin, in his famous work *Descent of Man* which revolutionized humanity's conception of our own evolution as a species, states that humans are social animals. We, as a species, are "impelled partly by a wish to aid" and possess the power of expression which leads us to "become a guide to the aid required and bestowed." He also states that sympathy is an instinctual emotion in our species (Darwin, n.d.).

Dr. Darragh Hare is a postdoctoral fellow in the Department of Natural Resources at Cornell University, a research visitor in the Wildlife Conservation Research Unit at Oxford University, and an adjunct assistant professor of evolutionary anthropology at the University of New Mexico. His interdisciplinary research echoes that of Darwin's initial postulates and reveals that morality is a set of adaptations favored by natural selection that promotes mutually beneficial cooperation. In the most simplistic terms, cooperators receive more favorable survival and fitness outcomes than do noncooperators. Humans have a history of cooperation with other species, from our coevolution with gut microbiota that increase human health, to the cultivation of plants and animals for our benefit. (Hare et al., n.d.)

Dr. Hare identifies this fundamental truth of human evolution and uses this to contextualize human conservation behaviors.

Dr. Hare and his team ask whether altruism, a form of cooperation where another's fitness is improved at the expense of some fitness cost to oneself, can be adaptive when directed towards members of other species. Just as cooperation between humans has evolved to maximize our species' fitness, so too could conservation tendencies have evolved to promote cooperation between humans and members of different species.

Dr. Hare and his team developed a concept termed the adaptive conservation rule (ACR) which finds that it is adaptive for an individual to take an action that affects a recipient's success when the ecological relatedness between the recipient species and

the individual, when multiplied by the recipient's resulting success, exceeds the expense of the initial cost of taking the action. It is not assumed that an individual or group will inherently calculate predicted costs and benefits of engaging in an act such as conservation management, however it is found that selection will favor traits that promote doing something when the conditions of ACR are satisfied.

Dr. Hare's model of ACR is akin to that of Hamilton's rule which explains why individuals act altruistically towards members of their own species. This evolutionary concept states that it is advantageous for an individual to pay a cost in providing a benefit to a recipient as long as the success of the recipient multiplied by the genetic relatedness of the two individuals is greater than the cost. ACR finds that fitness consequences of doing something for another species will be selected for if the results of this act produce more advantages than that of doing nothing. It utilizes the magnifying factor of ecological relatedness rather than genetic relatedness to predict when human's will take action to conserve a species (Hare et al., n.d.).

This guiding principle illuminates which species organizations and societies choose to dedicate resources towards saving as determined by perceived ecological relatedness. The perceived benefit to humanity of taking conservation action varies with local social and cultural practices. Those who live near species and are more impacted by their presence may prioritize conservation of these taxa over those geographically removed. Integrating the context of human evolution into the discussion of conservation policy allows us to better understand why conservation ethics exist and vary across human populations. Understanding the importance of local traditions as well as moral and evolutionary justifications for conservation behaviors may promote more universalized approaches.

Another study conducted by Dr. Hare and a team of researchers draws on humanity's evolved trait of cooperation in proposing how we can best unlock our evolutionary potential to design more systematic and beneficial conservation initiatives by working together. Cooperative conservation involves targeting the instinctual human desire to protect future generations with initiatives that promote kinship with the natural world (Curry et al., 2020).

Dr. Hare on the Evolution of Self-Interest

Dr. Hare and I met over spotty zoom internet connection and things got deep. We bonded over our desire for humanity to appreciate the intrinsic value of species, rather than expecting some sort of return on investments in conservation initiatives. "I got into my line of research because I was frustrated and annoyed at humans putting ourselves in the center of environmental and conservation ethics. There were lots of we shoulds and we shouldn'ts surrounding prioritizing certain conservation efforts and it made me uncomfortable. We should be thinking about nonhuman interests too."

Dr. Hare, I completely agree. But our lacking ability to perceive an inherent value in other life forms can be explained by- you guessed it- evolution.

"Self-interest is a trait favored by evolution. Humans have adapted to look after ourselves and our children." Dr. Hare's work is all about reconciling humanity's predisposition to be self-interested with how to effectively improve the chance of survival for many species. As he states, it's all about viewing species as "not just things that live in the woods, but our cousins. Humans have evolved to prioritize the survival of their families."

The biological mechanism behind this is that closely related individuals share many genetic similarities. If I can ensure that my relatives live, some of my genetic material is preserved in the population. It is this evolutionary drive that makes campaigns focusing on future generations so effective.

"Conserve a wetland not for its intrinsic value, but because a wetland purifies the water that your children and grandchildren will drink. Sometimes the language we use in conservation efforts can put people off; people think the language of economics with respect to conservation is distasteful. Appealing to our species self-interest and family interest targets our evolved psychology."

As for focusing conservation solely on the intrinsic value of species, Dr. Hare doesn't think this approach is necessary or even preferable. "Nonhuman and human interest aren't always at odds, they can be in sync. Intertwined fitness can explain cooperative behaviors. Doing right by them does right by us." It's hard for humans to recognize our positionality in the ethics of conservation. "There's no way I am going to argue there is an intrinsic value for smallpox or coronavirus simply because these things are not good for humans."

We ended our conversation on a not so hopeful note, with a harsh reality check. Conservation efforts today sometimes see one side of the equation and can be overly optimistic according to Dr. Hare, and for what it's worth, I agree.

"It's not like conservation is a modern thing. It wasn't invented by John Muir. The anthropological record shows that conservation has been with our species for a long time." Efforts to conserve species are not unprecedented, what is completely unprecedented are the social and environmental changes we see today which are "much more rapid and much more global" than ever before. While conservation strategies focus on increasing genetic diversity, this is a one sided approach. A crucial ingredient is missing. Time.

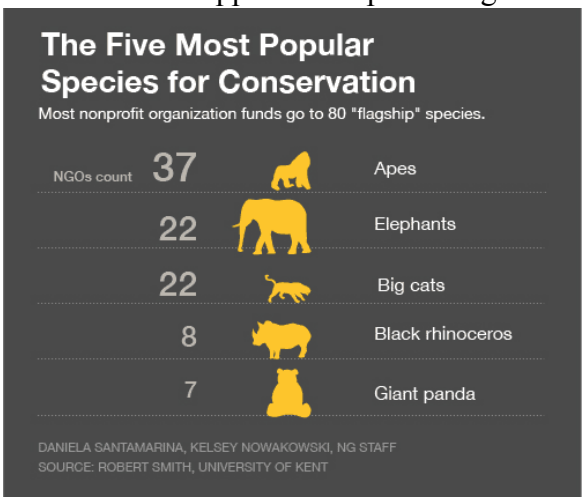
"Adaptation doesn't just emerge from genetic diversity. You need time, lots of time, for selection to act on variance" which results in advantageous traits. Basically, we need to give evolution time to do its thing if we have any hope of species coping with changing environments. And with rapid climate change and habitat destruction, time is something we just don't have. Are conservation efforts a band-aid approach, offering temporary solutions while the driving force of extinction, anthropogenic activities, remain unchecked? Is it ethical to keep species around just to subject them to increasingly hostile living conditions as the result of escalating climate change? "Well that," says Dr. Hare, "is an excellent question."

With over 20,000 species near extinction, how do we decide who is conserved?

In particular cases, teams of scientists and economists may devise algorithms and other mathematical models to determine how many individuals of a species it is feasible to save with a certain amount of money and resources. Oftentimes, conservationists select species based on numerous factors including economic value and public care including emotional or national motivations. The harsh trends reveal that the species we

take action to keep alive reflect our bias for certain groups of wildlife. This emphasis on conserving animals tied in sentiment and tourism dollars detracts resources and attention from plants and animals that are keystones in their ecosystems. One such example, ants, are essential in our environment. Their many roles include distribution of seeds, aerating soil and eating insects. When we choose to dedicate resources towards pandas, tigers or other awe-inspiring creatures that capture the public's hearts over conserving ants and their function on our planet, it seems that the most compelling motivator is cuteness factor. Indeed, it is our society's obsession with so called "celebrity species" that outshine the thousands of organisms in need (*20,000 Species Are Near Extinction*, 2013). Is the future of species gracing the Earth one of megafauna and loss of less charismatic critters?

One conservation management approach that is gaining traction is referred to as the ecosystem approach. This practice involves management strategies surrounding regions rich in biodiversity as opposed to dedicating efforts towards a single species. New research supports that protecting areas



for the benefit of one highly societally valued species will indirectly serve those species who inhabit the same area but are less emotionally charged (*20,000 Species Are Near Extinction*, 2013).

It is hard to believe that direct intervention into ecosystems will not have implications on evolution and research shows that conservation efforts due in fact alter the evolutionary trajectories of target and surrounding species where management strategies are set in place.

Tigers are consistently rated among the most popular animal in surveys conducted in the West. This endangered species may have more money spent on it than any other. In 2010, the cost of managing tiger reserves was at least $82 million as reported by the *Economist*.

Elephants are another celebrity species and target of conservation efforts even though there are still a half a million left on Earth. Many other species are much closer to the brink of extinction.

- Many lesser known species of fish and frogs are in more dire straits, with just

Conservation Affects Evolution

Modern conservation strategies seek to understand the ecological effects as well as the environmental sustainability of protection techniques. While evolutionary considerations are being incorporated slowly into management ideas, consequences of conservation actions on evolution remain largely uninvestigated prior and after implementation of these mechanisms. New research reveals the evolutionary effects of commonplace conservation strategies.

One common management strategy of invasive species control may in fact favor the evolution of resistance and increasing tolerance to control methods. The goal of this management strategy would be to restore a habitat to pre-invasion conditions.

Common types of conservation strategies and consequence. (a)Protection of the Mendenhall Glacier in the Tongass National Forest, Alaska has also resulted in some tourist development, including the creation of walking paths. (b)Grazing maintains meadow communities in central Europe. (c) Prescribed fires are common mechanisms used to maintain many ecosystems that evolved with fire regimes such as this pine flatwoods in Lake Placid, Florida. (d) Management for biodiversity commonly involved mechanical removal. Here, a chainsaw is used to reduce the canopy height of overgrown oaks in the fire-suppressed scrub of the Archbold Biological Station in Florida.

selection. Individuals with the ability to resist

Individuals who evade control methods due to a fitness advantage survive to reproduce,

conferring this genetic resistance to the next generation and increasing the strength of the remaining population. Additionally, removal of invasive species may provide novel adaptive landscapes for native species that had previously evolved in the presence of the invasive species. This is a classic example of evolution occurring which results in a discrepancy between targeted outcomes and the reality of management strategies ill-equipped to predict a species' response (Shefferson et al., 2018).

Another example of a well-intentioned conservation strategy leading to unforeseen, unwanted evolutionary costs is bioremediation which seeks to remove toxic chemicals from an ecosystem. This strategy may have unpredicted ramifications for the ecology of a region by increasing predation and herbivory on native plants with less toxins. Evolutionary mechanisms at play may select for loss of tolerance to toxins in natives, reducing resistance if and when toxins are reintroduced into the environment and beginning the cycle of adaptation to a threat anew (Shefferson et al., 2018).

Ecological and evolutionary responses to human intervention are complex and difficult to predict. It follows that efforts to remediate initial human intervention into landscapes through conservation management can have unwanted ecological and evolutionary effects. These examples cement the fact that conservation biologists should utilize an evolutionary lens in predicting management affects to prevent unwanted consequences of protection strategies on target and surrounding species.

Harnessing the Power of Evolution to Improve Conservation Strategies

Conservation practices can result in species evolution but how can evolution be utilized as a tool in the design of conservation management strategies to better protect biodiversity? The explosion of technology and emphasis on genetic information in identifying and mapping distributions of endangered species is remarkable yet distracts researchers from exploring how the basic and underlying process of evolution can help craft better conservation strategies (Latta, 2008). In a few cases, evolutionary perspectives have been utilized in management techniques and the success of these instances is further evidence of the importance of incorporating such a perspective. One example is the conservation plan regarding the Florida panther, an apex predator with important ecological functions.

> Conservation genetics in the broad sense can be seen as an attempt to manage human influence on the evolutionary process so as to minimize the harmful effects of human activities, and to maintain as much as possible the adaptive potential of natural populations (both large and small). I am going to suggest that as complicated as this challenge is, we have the advantage of applying one of the most elegant and powerful unifying theories in all of science-evolution by natural selection.
>
> Dr. Robert Latta

Inbreeding and resulting diminished genetic diversity were targeted as a major threat to this population and the corresponding strategy involved managing genetic diversity. Concurrently, scientists recognized the importance of maintaining genetic combinations which render the

Florida panther well adapted to the local environment. Individuals from a subspecies, the Texas panther, were brought in to alleviate the negative effects of inbreeding in the small population of Florida panthers. However, this subspecies has adapted to a set of different ecological parameters than the Florida panther. A challenge for this evolutionary conservation plan was to avoid the loss of local adaptation Florida panthers had developed overtime. Armed with knowledge of evolution and population genetics, a mathematical model was developed to determine the proportion of Texas panthers to be introduced into the population that would increase genetic variance but not at the expense of local adaptations and genes that morphologically distinguish these two subspecies. A plan was proposed and acted upon based on this model with great success (Latta, 2008).

Evolutionary biologists urge conservationists to empower their management plans with the unifying theory that applies to all species: evolution. The role of domestication of plants and animals through artificial selection illustrates that humans have exerted influence over the process of evolution without extensive research into genetics. Our lofty goals of trying to preserve adaptive potential in small, slowly breeding populations of endangered species and reducing this potential in rapidly populating species of invasive groups are more complex than selecting for beneficial traits in domesticated crops. While the goals of agricultural pursuits may be more straightforward than the web of interactions that are involved in a conservation plan, our understanding of evolution is more advanced and enhanced by the field of genetics (Latta, 2008).

Conservation Controversy: A Conversation with Dr. Robert Latta

Carl Linnaeus developed a system of classification of the natural world where the unit of species came to prominence as a fixed entity. Today, it is becoming understood that species exist, like other terms of classification, due to human invention. Oftentimes, there is just as much genetic diversity within a species as there can be expected between species (Olivieri et al., 2016). Despite the relatively arbitrary divisions that exist between species at times, the use of hybridization or cross breeding of individuals from two distinct species is a conservation strategy meeting mixed reviews in the scientific community. Hybridization is referred to as genetic rescue or restoration as the introduction of individuals from another species can increase diversity in a population by reducing the proportion of deleterious genes in a species that come about through inbreeding. Hybridization increases the speed of adaptation and expedites evolution, demonstrating resilience in light of rapid environmental change.

However, there has been push back in the conservation community surrounding this strategy as some see a fusion of two

species as a net loss in biodiversity. Dr. Robert Latta is a professor at Dalhousie University and his work focuses on evolution, conservation and the field of genetics. Latta is a proponent of hybridization in conservation plans, advocating for his position with the fact that hybridization is oftentimes used as a last resort when a local population is "in pretty dire risk of extinction without the influx in new genes." Without incorporating novel genetic material into the population, there would have been "a loss of diversity anyway" according to Latta, as extinction would be inevitable. In discussing the controversy surrounding hybridization, Latta states, "I tend to think that this concern is almost a value judgement more than a scientific question. I think what conservation genetics can answer as a scientific question, is to predict what the consequences of a particular hybridization scenario are likely to be. Which ones are considered beneficial or harmful are likely to depend on the context." Latta does concede that hybridization events are not always beneficial to an ecosystem. "When invasive species are introduced from multiple source populations, there is the chance that hybridization among them will make the invader more successful. So, in this case, hybridization accelerates the adaptation of the populations, but that outcome is seen as a threat because the better-adapted invader may well displace a lot of native biodiversity." How humans intentionally facilitate hybridization between species in conservation initiatives is considered on a case by case basis. However, hybridization between species is rapidly increasing as an unintended consequence of human activities decreasing geographic barriers that once reproductively isolated distinct populations (Latta et al., 2008). The full impact of these events on evolution is yet to be seen.

Evolution Sees a Future, So Can We

The field of conservation biology would see greater victories if research and policy can successfully shift from a single-minded focus on saving species, the products of evolution, to saving the underlying process of evolution itself. Evolutionary conservation biology has the promise and capacity to bridge the divide separating humanity and the natural world to better understand the impact of human activities and ethics on the course of ecosystem evolution during the age of the Anthropocene. The incorporation of evolution into the field of conservation biology is not in conflict, but in concert with current policy initiatives. Bringing evolution to the forefront of conservation debates will only strengthen our ability as a species to save those that are threatened as a direct consequence of our actions. Evolutionary biology offers a unifying and solidifying perspective and sense of direction to disjointed conservation efforts.

Only good will come to the field of conservation biology through establishing closer connections between individual actions and population dynamics, investigating the advantages of local adaptation in response to rapid environmental change, designing controlled experiments to better predict selection patterns as a result of conservation strategies in the wild, and emphasizing the genetic processes that can limit or accelerate the speed of a population's response to threats. Understanding the ecological and evolutionary mechanisms involved in speciation, invasion events, and population diversification will only enhance

our ability to keep the natural world's variance alive and well.

Ignoring the broader implications of evolution and the persisting and magnifying threat of climate change will strip conservation efforts of any lasting impact. Developing long term, sustainable policies and strategies that avoid negative evolutionary consequences and instead strengthen the ability of targeted species to adapt and cope with continued pressures is a necessary goal ahead for conservationists (Ferrière et al., 2004). Evolutionary biology is a forward looking field focusing on the promise of biodiversity's future, if necessary steps are taken today.

In the age of the Anthropocene, it is hard to picture a fragment of Earth where the landscape remains untouched and species live unencumbered by human involvement. With this sentiment in mind, it is equally hard to imagine a species whose evolutionary trajectory is unaltered by some human variable. We have the tools to study how human activities including conservation efforts are impacting evolution and likewise we have the capacity to utilize the brilliance and simplicity of evolutionary theory to enhance our ability to save species on the brink of disappearance. Evolution is a resilient and ever present phenomenon. It is also a resource to conservation efforts that begs to be utilized. And the species inhabiting Earth today can't wait any longer.

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