Estimating Extinction

The Science Behind Our Best Estimates of Mass Extinction

With an estimated 9 million species on Earth today, the task of monitoring and assessing the status of the World's biodiversity is no small one. Yet if we have any hope of putting a halt to the astonishing loss of species occurring worldwide, we must try to understand what species are threatened and by which human activities.

"Reducing rates of extinction represents one of the **greatest ecological challenges** of our time"

Dr Jonathan Davies,
McGill University

It is estimated that there are **8.7** ± 1.3 **million species on Earth**.

(That means our best guess is that there are between 7.4 and 10 million species, we can't really be any more certain than that)

There is no argument that the World's biodiversity is under massive threat from human activities. There is no argument that we are in the midst of one of the most extensive and rapid mass extinction events in the history of life. But it isn't easy to quantify the extent of this threat or the magnitude of our losses.

We aren't even sure how many species there are on Earth, so how can we possibly begin to try and keep track of them all?

One system that has become popular with conservationists is the use of indicators and indexes. Indicators are usually single species or ecosystems, whose health is monitored and taken to be indicative of larger-scale trends. More recently, scientists have begun aggregating data about the conservation status of species into indexes, such as the Living Planet Index and the IUCN RedList. These indices require huge teams of academics to comb through the literature and assemble an overall assessment of the global status of a particular animal. Based on this, species are characterised according to their status; the IUCN

RedList considers the conservation status of the species (endangered, critically endangered, vulnerable, etc.) while the LPI considers the current population trend relative to a historic baseline, almost like a stock market for biodiversity. In many cases, the science simply isn't strong enough and species must be classified as 'data-deficient'.

Recent data from these indicators suggests that we are facing massive population declines in many of our vertebrate populations, and perhaps even more worrying, there are a huge number of species about which we still know next to nothing.

Sorting and Filing

Conservation scientists have also looked for other ways to categorise species and aggregate lists. The Edge of Existence project lists species that are both critically endangered and locally endemic. For example, there are four species of the wonderfully enigmatic echidna on the Edge list. These egg-laying mammals related to the Platypus, are found only in Australia. The Eastern Long-beaked Echidna (*Zaglossus bartoni*) is critically endangered.

Ultimately, the goal is to identify which species are of greatest conservation concern, and which human activities are most harmful. However, another aim of conservation science is to predict what might happen in the future.

One issue for indices like the IUCN Redlist, which categorises species into risk categories, is how we define the criteria. At present, species are classified as endangered if they have a small or declining population, or a declining geographic range. But a few recent studies have suggested that different criteria should be developed for different groups of organisms. For example, a paper published in PLoS Biology this year showed that young (in evolutionary terms) plant species, tended to be more likely to go extinct, simply because they were young – new species need time to grow and spread their populations, and during this time they are very vulnerable to extinction. The authors point out, therefore, that existing criteria which define species of conservation priority as being those with a small population and limited geographic range, would have conservationists focusing on newly

> "We need to rapidly increase our understanding of where species are on the planet....If you don't know what you have, it is hard to conserve it."
>
> Prof Stephen Hubbell,
> UCLA

evolved vulnerable plant species that may be doomed anyway. Further, another study suggested that the Red List criteria need to be changed for invertebrates because the type of data required for classification is difficult to collect for many invertebrates. However, invertebrate coverage in the Red List is improving, with 15,000 new invertebrate assessments published recently. The problem for invertebrates may not be so much that the data is difficult to collect, but that relatively few people are willing to collect it (or provide the funding to do so).

Projecting the Future

Several methods have been developed to predict what might happen to biodiversity in the future. Often, scientists will use current and historic trends to predict future ones. A common approach is to use the species-area model, which uses real data on how the abundance of a species relates to the size of available habitat to predict how abundance will change in the future. Although these models have taught us a lot about the damage of habitat destruction and fragmentation, they rarely consider how different species respond differently. Furthermore, one recent study suggests that this assumption is statistically flawed, and methods that use it may be overestimating the rate of species loss by as much as 160%! The problem is that although the species-area relationship works forwards - in the real world populations seem to adhere to it, extrapolating backwards is not so straight forward.

The Importance of Family

Traditionally, many large-scale analyses have grouped living things according to their taxonomy – that is, their position in the evolutionary tree. Birds were grouped with birds, reptiles with other reptiles, and so on. However, increasingly conservationists are considering the traits of these species as well. How a species responds to changing climate, habitat loss, pollution or hunting can depend more on the characteristics of that species than whether it is a bird or an insect. For example, the ability of a species to relocate to new habitats, known as dispersal ability, can have a big influence on how it copes with habitat loss. Generation time and body size can be important in determining whether a species can bounce back from hunting pressure.

Researchers have investigated a number of biological traits and found them to be strongly predictive of short-term extinction risk. Body size, generation time, social behaviour and diet can all influence a species' chances of survival under future climate change and habitat loss. Demographic variables, such as range size (indicative of how versatile a species is) and population size, are also key indicators of extinction risk.

Another study showed that simple metabolic-scaling models are able to successfully predict extinction risk in laboratory populations of a single-celled organism called *Loxocephallus*. Using known relationships between metabolism and temperature in combination with data on population dynamics under present conditions, the authors were able to accurately predict future extinction at different temperatures.

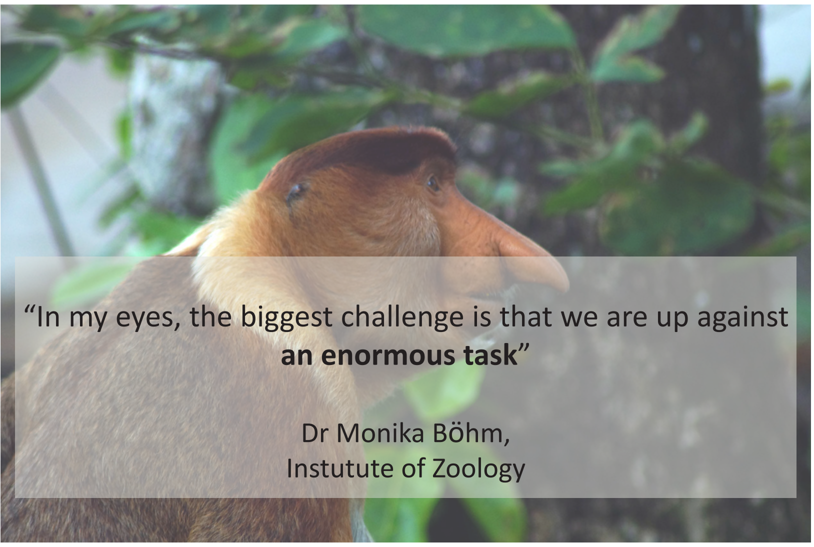
Another common approach uses species distribution models to map the habitat requirements of a particular species and compare these to climate and land-use projections for the future, in order to identify areas of suitable habitat as they move geographically. Scientists can then estimate whether a particular species will be able to track the changing environment fast enough, or whether human intervention in the form of a translocation might be necessary to preserve the species. One recent study did just this for populations of the Hihi, an endangered bird endemic to New Zealand. Researchers at the Institute of Zoology found that Hihi populations are affected by the climate irrespective of it's influence on food availability – even with a supplemented food supply, survival was influenced by changing temperature and increasing climatic variability. Models revealed that suitable Hihi habitat is likely to move south across New Zealand, and translocation may be necessary to protect populations on the North Island.

Local Patterns and Global Projections

Finally, one project aims to take a comprehensive statistical approach to predicting species responses to changes in land-use, such as the conversion of rainforest into plantations, or of secondary habitat into an urban environment. "There are thousands upon thousands of published papers that each give a bit of the overall picture", remarks Professor Andy Purvis from the PREDICTS project. "Researchers have surveyed the diversity at each of multiple sites that differ in the level of pressure they face, so it's possible to see how the diversity they surveyed responded to the pressures they looked at in that part of the world. To get a global picture, you need to put these pieces together." The PREDICTS project aims to do just that – they've collated data from over 500 different studies, including 34,000 species.

"*In PREDICTS, we've … put all the data into a common framework, and then used statistical modelling to ask, what's the average effect of, for instance, conversion to plantation forest? And how does it depend on the intensity of management of the plantation, the number of people who live nearby, and so on*?" – Prof Andy Purvis

Combining statistical analyses of current trends with global projections for future change, the PREDICTS project is able to estimate global consequences of certain futures for site-level biodiversity. Their results have so far indicated several logical results, for example human-dominated habitats tend to harbour fewer species than more natural, pristine habitats, but also a few surprises. This project is just beginning, however, and the team is constantly adding to their huge database ,as well as developing and performing innovative new statistics to draw out more insights.



The Current Status of Biodiversity

So, there's a lot of project working on this, but there are also a lot of problems. What do we actually know already? Well, this year's new Living Planet Report tells us that things are pretty bad. According to the LPR, of the 10,000 representative populations of mammals, birds, reptiles, amphibians and fish that monitoring data has been collected for, populations have declined by 52% since 1970. The picture is much worse for tropical species than temperate ones, with a loss of 56% for the 1600 species monitored in tropical climates and a shocking 83% loss for Latin American species. The causes? Habitat loss and degradation, species exploitation and climate change.

It is important to remember that the LPI data is based upon a *representative* but limited set of species, and understudied species, of which there are many, are not included in this. So, the situation could in fact be a lot better, or a lot worse, that the statistics suggest. It's easy to imagine that the LPI is optimistic, if say we tend to be more likely to study endangered species. Equally, however, it's easy to imagine there are many species with very small, vulnerable populations that we don't know about simply because they are small. Ultimately, the LPI is one of the best estimates we have of current biodiversity loss, and it doesn't look good.

Recent extinctions that we know about have included the golden toad, Baiji and Yangtze River dolphins, Hawaiian crow and the West African black rhino, to name just a few. According to the IUCN RedList, 13% of birds and 21% of mammals are currently threatened with extinction. These losses are not evenly distributed however, and species with specialist habitat and food requirements are the worst affected. Initial results from the PREDICTS project show that birds are particularly poor at surviving in urban environments – only 10% of forest specialist are found in here.

Birds and Mammals

For both birds and mammals, the species that do especially well in urban environments (think foxes, pigeons, rats) often have much larger populations there than they do in the natural environment. These species are the lucky

ones, though – being willing to eat anything and live anywhere, or just by chance finding that human habitats mimic their natural habitat.

We know less about reptiles and amphibians, although the picture we do have is considerably bleaker. A recent study of 1500 species of reptile, that's just over 15% of all known reptile species, found that **one in five** are threatened with extinction. Around 18% of Reptiles are classified as threatened in the IUCN RedList, and reptiles are the most threatened group in freshwater habitats. Another important challenge in understanding extinction risk in reptiles in particular is their vulnerability to climate change. Furthermore, many species of amphibian are now experiencing shocking declines due to *Chytridiomycosis*. Chytrid, for short, is an infectious fungal disease, which in some amphibian species is a mild annoyance, while in others it has decimated entire populations. In part, chytrid is being spread by the surprisingly large global trade in exotic pets.

Interest in studying reptiles and amphibians is increasing, however, according to Dr Böhm, "*there is still much work needed to streamline reptile conservation needs into conservation decision making*".

Creepy Crawlies

Unfortunately, invertebrates tend to be one of the most understudied groups. Currently 28% of known invertebrates are data deficient in the Red List, but it is estimated there may be as many as 5 million species of invertebrate that we haven't even discovered yet. Shake a single tree in the Amazonian rainforest and you will be inundated with new species of insect and arachnid. The task of trying to classify them all, let alone monitor their populations, is daunting, and funding for this type of research is not always easy to come by.

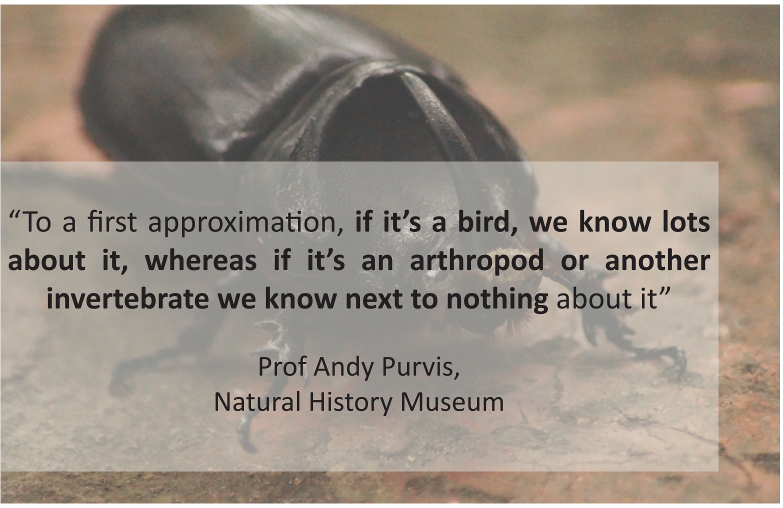
Appreciation for invertebrate conservation might not be so forthcoming from the public, and admittedly snails, crabs, spiders and octopuses, may not be as fluffy and cute as the charismatic mega fauna (Giant Pandas, Lions, Tigers etc.), but as Dr Böhm points out, some of them are still spectacularly beautiful, and many others are fascinating for their behaviour or evolution. "For their looks" says Böhm, her favourite "has to be a species of sea slug or cone snail – they are amazingly beautiful to look at". Finally some, like North American freshwater mussels, are great just because we've given them silly names – "What's not to like about species such as the purple warty back, snuffbox, pocketbook, spectaclecase, longsolid, elktoe or, in fact, the giant floater?" asks Böhm, and I cannot fault her logic.

> "If we want to understand which functions are in peril in which ecosystems, we need a much better understanding of how **invertebrates and plants** respond to human pressures."
>
> Prof Andy Purvis
> Natural History Museum

Our understanding is not only skewed with respect to taxa, it is also skewed in terms of the types of environment (terrestrial, freshwater, marine), the biome (rainforest, savannah, desert) and the climate (tropical, temperate). We know the most about the species found in Europe and North America, where species richness is relatively low, and recent declines are more modest (in no small part due to the fact that we wiped out a great deal of our wildlife centuries ago), while more inhospitable habitats such as deserts and tundra are relatively understudied.

Tropical ecosystems may be the best studied, and the LPR shows much greater declines in tropical ecosystems than temperate ones. Freshwater species tend to be more at risk from extinction than terrestrial or marine species, and are under threat from habitat degradation due to agriculture, urbanisation and logging. The LPI shows a decline of 76% for freshwater species, compared to 39% for terrestrial and marine species.

Our understanding of the current status of biodiversity, how it responds to human activities, and what is likely to happen in the future, is highly skewed towards certain species and taxonomic groups. Purvis explains that one of our biggest problems is the lack of overlap between our areas of knowledge and the species of ecological and economic importance. While we know an awful lot about birds and vertebrates and a few other charismatic groups such as butterflies, the most important species for ecosystem functions tend to be invertebrates and plants – species we know relatively little about.



These 'data deficient' species are so called because so little science has been done on their biology or the threats they face, that we simply don't know what's happening to them. Funding can be limited for less charismatic species, such as insects, arachnids, gastropods and cephalopods, and those species that are inaccessible or difficult to study. This can often be the case for marine cephalopods (octopus, squid, cuttlefish etc.), where an entire species is known only from a few specimens, dragged up in the nets of trawlers. Furthermore, our rigid definition of species and individuals can get in the way of classifications – when it comes to fungi, for instance, it can be hard to decide what makes up an individual, let alone whether it is endangered!

In birds, the best-studied group, less than 1% of known species are data deficient. However, in mammals this figure rises to 15%. In reptiles, marine and freshwater turtles and tortoises, along with crocodiles, receive a lot of scientific attention, while others are severely understudied – a worrying 25% of all reptiles are currently classed as data deficient in the IUCN RedList. The picture is even worse for invertebrates, where 25% of species are considered threatened but a further 30% are data deficient!

Around the world, scientists are working hard to try and identify, classify and monitor biodiversity before it is too late. It is an enormous task, however, and funding and time are both extremely limited. Political and social factors are almost always complicating variables that create a chasm between conservation theory and practice. Yet, we must be able to define what species are endangered and which are of greatest conservation priority before we can even begin to enter into the process of implementing policy. A recent survey of 55 datasets concluded that although our efforts to protect the natural world are increasing, so too are the pressures faced by biodiversity, and at present we are not on track to meet the Convention on Biological Diversity Aichi targets by 2020.

Curious Meerkat

Want to Know More?

Living Planet Report
PREDICTS Project
IUCN Red List
How Many Species?
Defaunation in the Anthropocene

Tittensor (2014)
Bohm *et al* (2013)
Chauvenet *et al* (2013)
Collen *et al* (2013)
Collen & Bohm (2013)
Forden et al (2013)
He & Hubbell (2011)
Davies *et al* (2011)

Images by Claire Asher

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