Evolution Lost

Status and Trends of the World's Vertebrates

Jonathan E. M. Baillie, Janine Griffiths, Samuel T. Turvey, Jonathan Loh and Ben Collen

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SSC Species Survival Commission
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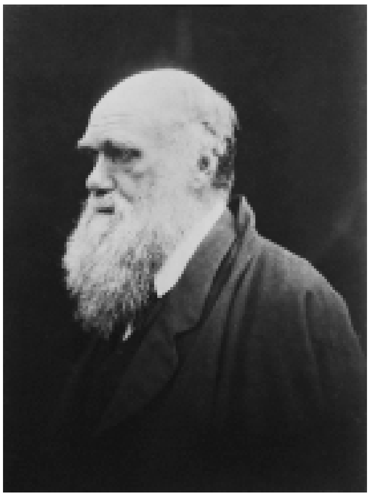
Evolution Lost

Status and Trends of the World's Vertebrates

We dedicate this book to

Charles Robert Darwin,

Fellow of the Zoological Society of London, 1831



"There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and wonderful have been, and are being, evolved."

Charles Darwin. *On the Origin of Species,* 1859.

"Extinction rates are now fast outpacing speciation rates, resulting in the loss of entire groups of species that have evolved on this planet for millions of years."

Paul H. Harvey CBE FRS, Head of the Department of Zoology, University of Oxford Secretary and Fellow of the Zoological Society of London.

Evolution Lost:
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Editors

Jonathan E. M. Baillie

Janine Griffiths

Samuel T. Turvey

Jonathan Loh

and Ben Collen

Section editors: Ariadne Angulo, Jonathan E. M. Baillie, Monika Böhm, Luigi Boitani, Thomas M. Brooks, Stuart H. M. Butchart, Ben Collen, Neil Cox, William R. T. Darwall, Peter Paul van Dijk, Matthew Gollock, Janine Griffiths, Craig Hilton-Taylor, Mike Hoffmann, Rachel Jones, Heather Koldewey, Gordon McGregor Reid, Louise McRae, Nadia Richman, Carlo Rondinini, Michael Samways, Andy Symes and Brian Zimmerman.

Foreword by Georgina M. Mace
Preface by Simon N. Stuart

2010

Foreword

In this International Year of Biodiversity we have been celebrating the diversity of life, considering our success in conserving and managing it, and making commitments for future actions that will safeguard it for future generations. These are two interlinked steps – we need to see the diversity of life in order to celebrate it, and we need to know more about the status, trends and causes of degradation in order to plan for the future. This publication makes an invaluable contribution to the available information, focusing on vertebrate species and bringing together a wealth of recent information that helps us to understand what we risk losing.

Conserving biodiversity is a shared responsibility and matters to everyone, though not always in the same way. To many people, nature is valued simply for the pleasure and inspiration it brings, and no further justification for conservation is required. But there are also many other, functional reasons that we should be concerned about the loss of biodiversity. Wild species and habitats bring many material benefits to people, providing resources and buffering us against environmental change. While we do not fully understand this role of biodiversity, there is no doubt that its loss will impact human well-being in many potentially very serious ways.

Species are a natural unit for biodiversity assessment, and the vertebrates include many of the most charismatic and distinctive species. Extinction is more than the loss of a species. With the extinction of any species, we also lose unique features that evolved during the millions of years that the species lived on Earth. The evolution lost will represent some intricate and detailed adaptations which, quite simply, cannot be replaced. This book provides information on the evolution we risk losing if we do not take care of the vertebrates. Thinking about evolution lost must encourage us to make greater efforts to preserve the species with which we share our world.

Georgina M. Mace CBE FRS

Imperial College London
Fellow of the Zoological Society of London

Preface

With the publication of *Evolution Lost*, for the first time the world has a detailed understanding of the conservation status of vertebrates: fish, amphibians, reptiles, birds and mammals. This information is pulled together at the level of species and populations. The species-level data are based on the IUCN Red List of Threatened Species. The population-level data are drawn from the WWF Living Planet Index.

The story that emerges is not a happy one. Among vertebrates, amphibians, freshwater fish and large mammals are in particularly serious decline. In our careless, wasteful and excessive use of the earth's bounty, our species has pushed most others to the side. We have paid so little attention to our impact on our fellow species that, in most cases, we have driven them to decline or extinction without even being aware of it. We are also losing whole swathes of irreplaceable evolutionary history, and certain ancient evolutionary lineages, such as coelacanths and sturgeon, are struggling for survival.

This book would not have been possible were it not for the voluntary contributions of thousands of scientists from every country in the world. It is they who collect the raw data that is ultimately compiled into the IUCN Red List and the WWF Living Planet Index. They comprise a global network, the 8,000-strong Species Survival Commission of the International Union for Conservation of Nature (IUCN). Without their collective and largely unpaid endeavours, the world would be in the dark on the overall conservation status of nature.

This book is a wake up call. Will we continue to live in 'business as usual' mode? Or will we make room for other species? The measures we need to take include direct and much more extensive conservation action to save critical species and habitats. However, we also need to take more painful measures that will affect our own lifestyles, such as massively reducing carbon emissions, removing perverse agricultural subsidies and curtailing the use of nitrogen- and phosphorus-based fertilisers. If society is unwilling to pay these costs, then many of the species with which we share this planet will go the way of the dodo. It is our choice. Do we have the courage to take the difficult decisions?

Simon N. Stuart

Chair, Species Survival Commission, International Union for Conservation of Nature
Visiting Professor, Department of Biology and Biochemistry, University of Bath
Honorary Conservation Fellow of the Zoological Society of London

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We give gracious thanks to the global network of thousands of scientists who have contributed in the collection of data for the IUCN Red List and WWF Living Planet Index, making this book and our understanding on the trends and status of vertebrates possible.

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Fish

IUCN/WI Freshwater Fish Specialist Group
Groupers and Wrasses Specialist Group
Hawkfishes and Sandperches Red List Authority
Salmonid Specialist Group
The GMSA Team
Sciaenid Red List Authority
Seabreams, Snappers and Grunts Red List Authority
Shark (sharks and rays) Specialist Group
Sturgeon Specialist Group
Syngnathiformes and Gasterosteiformes Red List Authority Group
Tuna and Billfish Specialist Group
Coral Reef Fishes Specialist Group

Amphibians and reptiles

Amphibian Specialist Group
Crocodile Specialist Group
Iguana Specialist Group
Marine Turtle Specialist Group
North American Reptile Red List Authority
Sea Snake Specialist Group
Tortoise and Freshwater Turtle Specialist Group

Mammals

African Elephant Specialist Group
African Rhino Specialist Group
Afrotheria (including aardvark, hyrax, golden-mole, tenrec and elephant-shrew or sengis) Specialist Group
Anteater, Sloth and Armadillo Specialist Group
Antelope Specialist Group
Asian Elephant Specialist Group
Asian Rhino Specialist Group
Asian Wild Cattle Specialist Group
Australasian Marsupial & Monotreme Specialist Group
Bat Specialist Group
Bear Specialist Group
Bison Specialist Group
Canid (fox, jackal and wild dog) Specialist Group
Caprinae (wild sheep and goat) Specialist Group
Cats (wild cat) Specialist Group
Cetacean (dolphin, porpoise and whale) Specialist Group
Deer Specialist Group
Equid (horse, ass and zebra) Specialist Group
Hippo Specialist Group
Hyaena Specialist Group
Lagomorph (rabbit, pika and hare) Specialist Group
New World Marsupial Specialist Group
Non-volant Small Mammal Red List Authority Specialist Group
Otter Specialist Group
Peccary Specialist Group
Pinniped (seal and walrus) Specialist Group
Polar Bear Specialist Group
Primate Specialist Group
Sirenian (dugong and manatee) Specialist Group
Small Carnivore Specialist Group
South American Camelid (guanaco and vicuña) Specialist Group
Tapir Specialist Group
Wild Pig Specialist Group
Wolf Specialist Group

Birds

Bird Red List Authority
Cormorant Specialist Group
Crane Specialist Group
Diver/Loon Specialist Group
Duck Specialist Group
Flamingo Specialist Group
Galliforme Specialist Group
Goose Specialist Group
Grebe Specialist Group
Heron Specialist Group
Pelican Specialist Group
Stork, Ibis and Spoonbill Specialist Group
Swan Specialist Group
Threatened Waterfowl Specialist Group
Woodcock and Snipe Specialist Group

Invertebrates

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Freshwater Crab and Crayfish Specialist Group
Grasshopper Specialist Group
Marine Invertebrate Red List Authority
Members of the International Association of Astacology
Mollusc Specialist Group (snail, slug, squid, clam, scallop, etc)
Terrestrial and Freshwater Invertebrate Red List Authority

Disciplinary groups

Conservation Breeding Specialist Group
Invasive Species Specialist Group
Re-introduction Specialist Group
Sustainable Use Specialist Group
Wildlife Health Specialist Group

Task forces and working groups

Large Carnivore Initiative for Europe Working Group
Species Conservation Planning Task Force

Red List Index – sampled approach

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www.iucnredlist.org/partners/contributors
www.birdlife.org
www.zsl.org/indicators

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WWF Netherlands

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www.edgeofexistence.org

ZSL Library:

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Disclaimer - This book has been supported by a broad range of organisations, but does not necessarily represent the view of those organisations.

Please accept our apologies for any accidental omissions.

Plate 1. *Cicinnurus regius*. Bowdler Sharpe: Monograph of the Paradiseidae. 1891-98.

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Vital Statistics

Vertebrates

Number of species:	62,839
Proportion threatened:	19%
Estimated number of threatened species:	11,939
Estimated population trend:	30% reduction since 1970
Main threats:	agriculture, logging, development, exploitation and invasive species
Most threatened groups:	amphibians followed by mammals and reptiles
Number of documented historic extinctions:	323

Plate 2. *Paradisaea minor*. Bowdler Sharpe: Monograph of the Paradiseidae. 1891-98.

Vital Statistics

Fish

Number of species:	31,600
Proportion threatened:	15%
Estimated population trend:	freshwater fish: 65% reduction since 1970; marine fish: 20% reduction since 1970
Main threats:	fisheries, pollution, development, habitat loss, dams and water management, and invasive species
Most threatened groups:	coelacanths, seahorses, lampreys, killifishes, livebearers, cichlids, rainbowfish, coregonids, galaxiids, tunas, sharks, rays and chimaeras
Number of documented historic extinctions:	58
Recent extinctions:	a fish endemic to Israel (*Acanthobrama hulensis*) *c.*1975; cachorrito de la Trinidad (*Cyprinodon inmemoriam*) 1990s; gokce baligi (*Alburnus akili*) *c.*1998
Countries with most threatened species:	Mexico, Lao PDR, Thailand, USA, China and India

Plate 3. *Holocanthus ciliaris*. Catesby:
The natural history of Carolina, Florida and the Bahama Islands. 1731-43.

Vital Statistics

Amphibians

Number of species:	6,638
Proportion threatened:	41%
Estimated population trend:	80% reduction of the restricted number of monitored populations since 1970
Main threats:	agriculture, biological resource use, and residential and commercial development
Most threatened groups:	salamanders, genus Leiopelma (frogs endemic to New Zealand and including Archey's frog, the number one EDGE amphibian), Rhinoderma frogs (genus including Chile Darwin's frog and Darwin's frog) and Seychelles frogs
Number of documented historic extinctions:	37
Recent extinctions:	a frog endemic to Costa Rica (*Craugastor escoces*), Holdridge's toad (*Incilius holdridgei*) and two species of Sri Lankan shrub frog (*Pseudophilautus maia* and *Pseudophilautus pardus*) were all assessed as extinct in 2008 - the latter two species declared extinct shortly after their formal description
Countries with most threatened species:	Colombia, Mexico, Ecuador, Peru and China

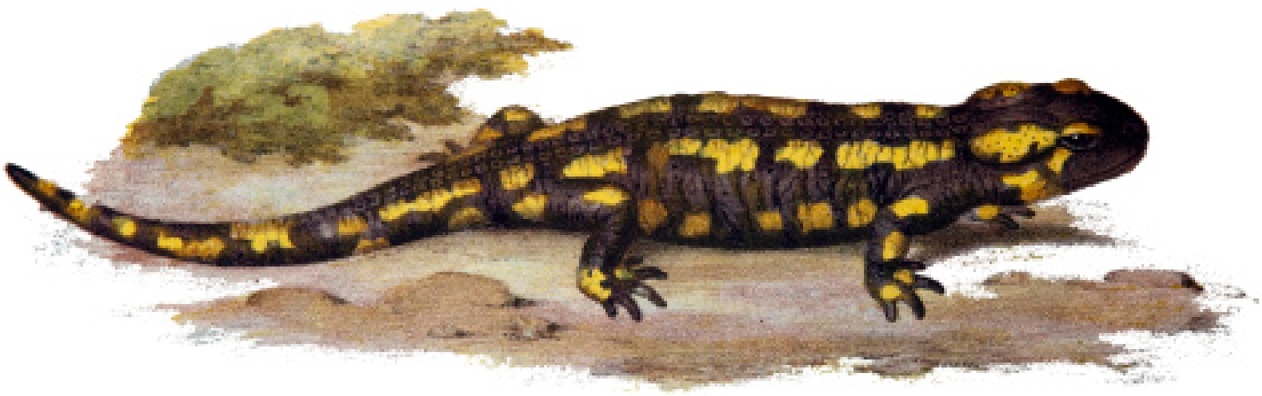


Plate 4. *Salamandra salamandra*. Fitzinger: Bilder-Atlas zur wissenschaftlich-populären Naturgeschichte der Amphibien in ihren sämmtlichen Hauptformen. 1864.

Vital Statistics

Reptiles

Number of species:	9,084
Proportion threatened:	22%
Estimated population trend:	7% reduction of the restricted number of monitored populations since 1970
Main threats:	agriculture, logging and commercial development
Most threatened groups:	turtles, tuatara and crocodiles
Number of documented historic extinctions:	20
Recent extinctions:	Eastwood's longtailed seps (*Tetradactylus eastwoodae*) collected once *c.* 1912-1913; Round Island burrowing boa (*Bolyeria multocarinata*) *c.* 1975
Countries with most threatened species:	Madagascar, Colombia, Ecuador, Mexico, Australia and Brazil

Plate 5. *Pantherophis obsoletus*. Catesby:
The natural history of Carolina, Florida and the Bahama Islands. 1731-43.

Vital Statistics

Mammals

Number of species:	5,490
Proportion threatened:	25%
Estimated population trend:	25% reduction in terrestrial mammals since 1970
Main threats:	logging, agriculture, hunting and trapping, and commercial development
Most threatened groups:	apes, river dolphins, solenodons, rhinos, manatees, dugongs and hutias
Number of documented historic extinctions:	76
Recent extinctions:	crescent nailtail wallaby (*Onychogalea lunata*) *c*. 1950s; the Caribbean monk seal (*Monachus tropicalis*) 1952; blue-grey mouse (*Pseudomys glaucus*) 1956; Guam flying fox (*Pteropus tokudae*) 1968
Countries with most threatened species:	Indonesia, Mexico, Brazil, Vietnam and Papua New Guinea

Plate 6. *Tachyglossus aculeatus*. Gould: The mammals of Australia. 1863.

Vital Statistics

Birds

Number of species:	10,027
Proportion threatened:	13%
Estimated population trend:	8% decline since 1970
Main threats:	agricultural expansion and intensification, logging and invasive alien species
Most threatened groups:	albatrosses, cranes, parrots, pheasants, bustards and pigeons
Number of documented historic extinctions:	132
Recent extinctions:	Spix's macaw (*Cyanopsitta spixii*) 2000; Hawaiian crow (*Corvus hawaiiensis*) 2002; po'ouli (*Melamprosops phaeosoma*) 2004
Countries with most threatened species:	Brazil, Indonesia, Peru, Colombia and China

Plate 7. *Aulacorhynchus prasinus*. Gould: A monograph of the Ramphastidae. 1834.

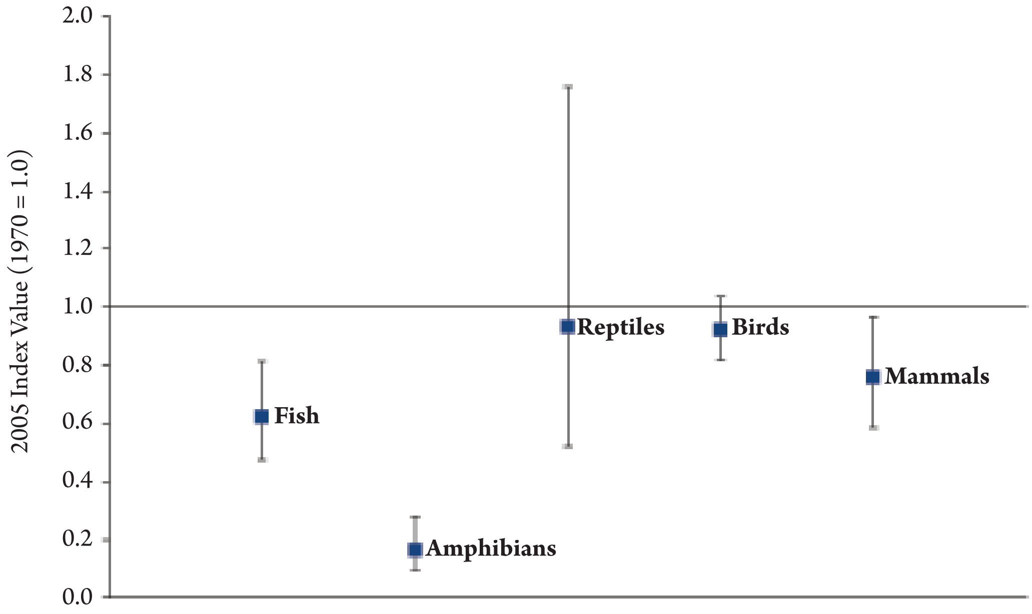
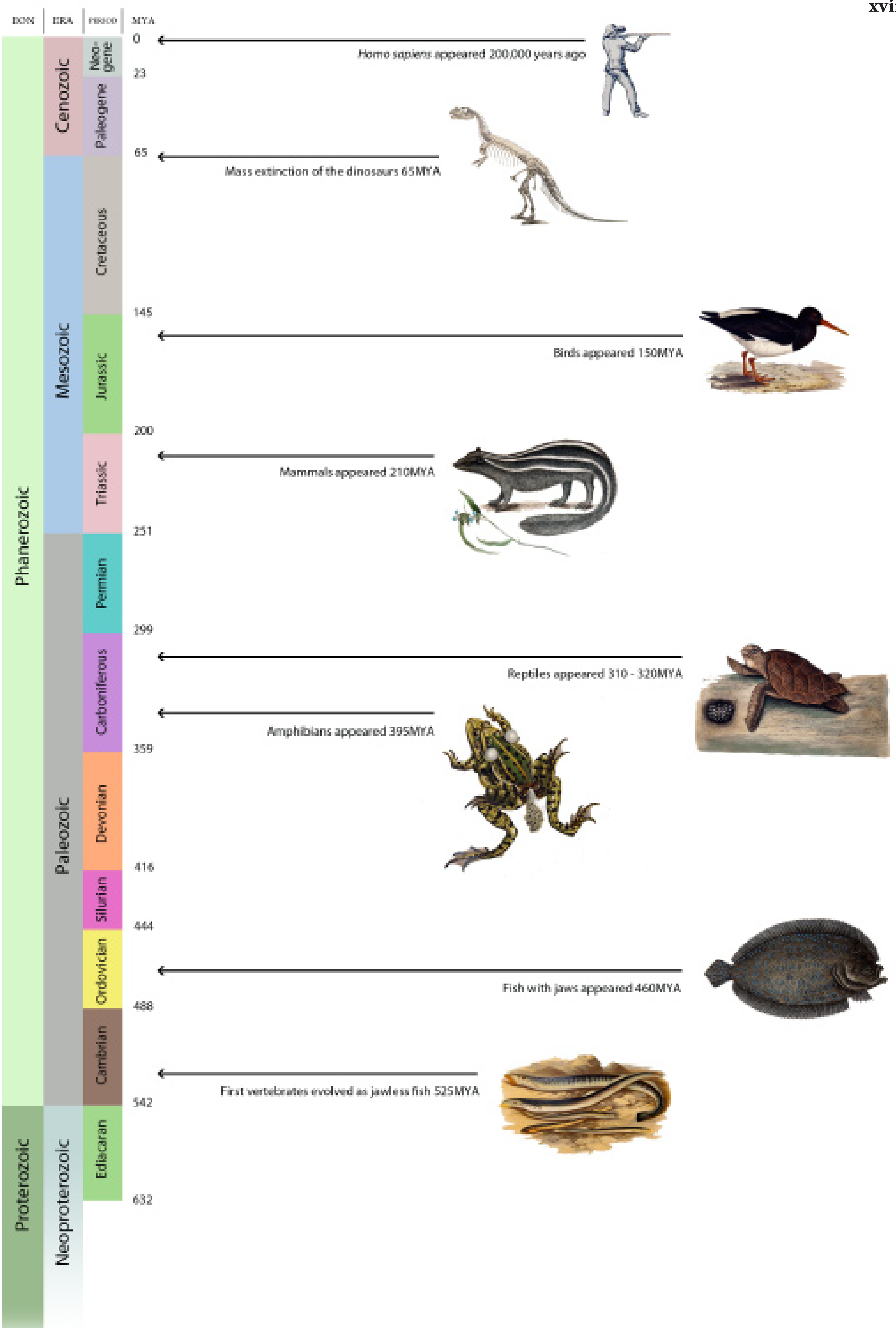


Figure 1: Population trends in fish, amphibians, reptiles, birds and mammals since 1970. These data are derived from the Living Planet Index which is used to monitor 7,953 populations of 2,544 species of mammals, birds, reptiles, amphibians and fishes from around the globe. The change in the size of these populations relative to 1970 (1970=1.0) is plotted over time. A stable Living Planet value would indicate that there is no overall change in average species abundance. Squares are index value in 2005, bars are 95% confidence limits.

Plate 8. *Grus leucogeranus*.
Gould: The Birds of Europe. 1837.



This timeline is adapted from Richard Dawkins (2004) "The Ancestor's Tale". MYA = Million years ago

Vertebrata

Plate 9. *Iguana iguana*. Fitzinger: Bilder-Atlas zur wissenschaftlich-populären Naturgeschichte der Amphibien in ihren sämmtlichen Hauptformen. 1864.

Vertebrata

Evolutionary History of Vertebrates

Editors: Mike Hoffmann, Nadia Richman, Louise McRae, Craig Hilton-Taylor and Monika Böhm

Vertebrates (Vertebrata) are animals defined by possession of a skull and a stiff segmented vertebral column. They are a diverse group numbering more than 60,000 species, ranging in size from the blue whale (at 160 tonnes, the largest species to have ever lived) to the diminutive female Paedocypris fish (measuring just 8 mm in length). The earliest known vertebrates are recorded from the Early Cambrian period around 525 million years ago, close to the first appearance of complex animal life in the fossil record [1]. The vertebrate fossil record is relatively good in comparison with that of many other animal groups due to the high preservation potential of bone, and the fact that vertebrates have a long and complex evolutionary history. The first major vertebrate evolutionary radiations occurred during the Late Ordovician and Silurian periods, when the jawless fishes (including lampreys and hagfishes) and then gnathostomes (fish possessing biting jaws) began to diversify in marine and freshwater environments [2]. Vertebrates continued to evolve in the seas throughout the Phanerozoic eon, and aquatic environments still contain the highest levels of vertebrate diversity.

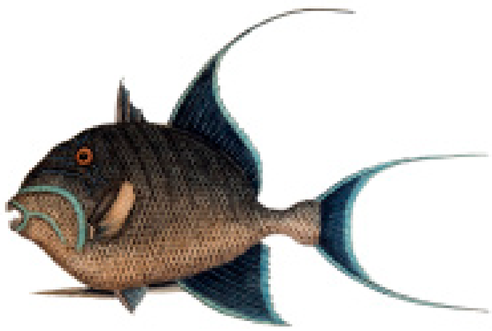


Plate 10. *Balistes vetula*. Catesby: The natural history of Carolina, Florida and the Bahama Islands. 1731-43.

Tetrapods (vertebrates with four legs) evolved almost 400 million years ago during the Devonian period from lobe-finned fish; their descendants were therefore able to colonise terrestrial environments. These early tetrapod groups and their modern-day amphibian descendants, the frogs, salamanders and caecilians, were still dependent upon water for reproduction.

Plate 11. *Necturus maculosus*. Fitzinger: Bilder-Atlas zur wissenschaftlich-populären Naturgeschichte der Amphibien in ihren sämmtlichen Hauptformen. 1864.

However, during the Carboniferous period, the development of terrestrially-adapted eggs protected by water-holding, permeable membranes (amniotic eggs) allowed further transition into dry environments. These early amniotic-egg laying vertebrates diverged into two distinct lineages, the sauropsids (represented today by reptiles and birds) and synapsids (represented today by mammals), which became a key component of ecosystems throughout the Late Palaeozoic, Mesozoic and Cenozoic eras [3]. Both of these lineages experienced evolutionary innovations including flight and the secondary re-colonisation of the seas. The terrestrial vertebrates experienced their most significant diversification at the end of the Cretaceous period 65 million years ago, when the dominant dinosaur fauna became extinct as a result of the collision of a large asteroid with Earth, and terrestrial large animal niches instead became filled largely by mammals during the Early Cenozoic era [4-5].

Biogeography of Vertebrates

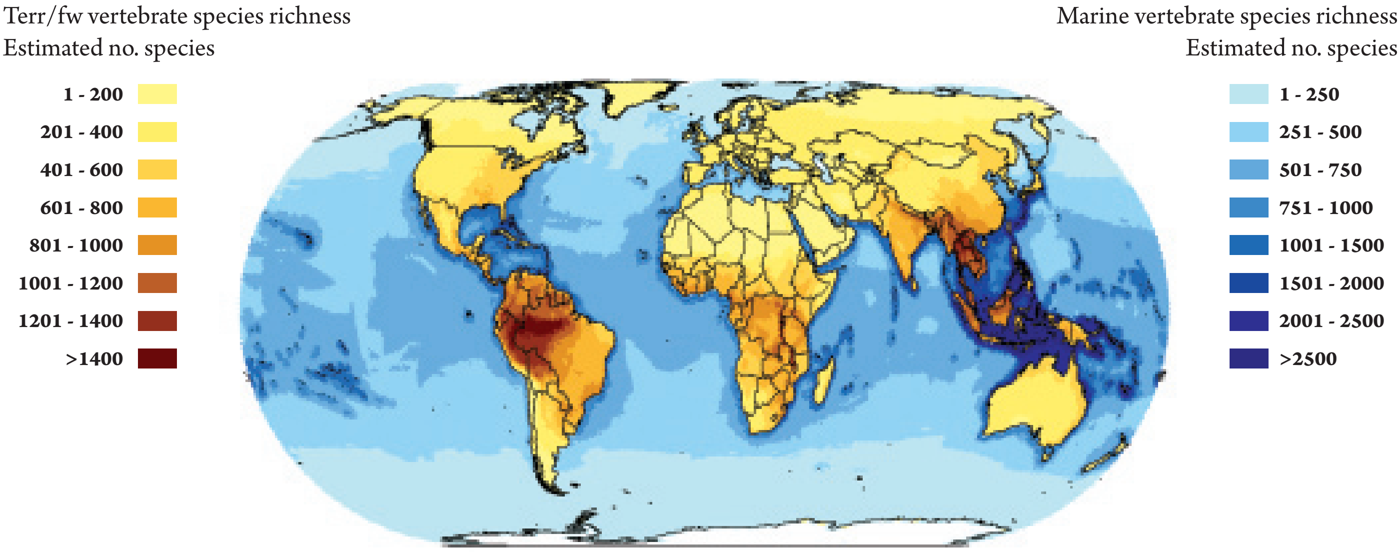


Figure 2: Global species richness of vertebrates, based on an assessment of 24,437 vertebrate species. Amphibians, birds and mammals are comprehensive assessments of all species in the group. For fish and reptiles, which are sampled assessments of 1,500 species, each cell richness total is scaled to the proportion of species it would represent in the true total. 'Terr' idicates terrestrial species and 'fw' indicates freshwater species.

The legacy of these many millions of years of evolution is the species that inhabit the Earth today. The diversity of vertebrate species is lowest at the poles and generally increases towards the equator (figure 2 [6]).

The highest species richness of terrestrial vertebrates is found in tropical regions in a broad band along the equator. Marine vertebrate biodiversity is highest in coastal regions, especially around southeast Asia and Oceania. Both on land and in aquatic environments, patterns may under-represent true diversity in regions where survey work has been less intense or (as in the case of the oceans) is more difficult.

Plate 12. *Prionailurus bengalensis*.
Elliot: A monograph of the Felidae. 1883.

The IUCN Red List explained

The IUCN Red List is the most widely accepted standard for assessing species' risk of extinction [7-9]. Species are assessed according to five quantitative criteria to evaluate symptoms of risk, using information on population decline, range size and population size [10-11] and classified in one of eight Red List categories: Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC) and Data Deficient (DD). Throughout this report, the term 'threatened' is used to refer to species listed as Critically Endangered, Endangered and Vulnerable. A species is categorised as Data Deficient when there is insufficient information available to make a reliable assessment. Least Concern species are considered to be at a low risk of extinction at the time of assessment. In this report we explicitly account for the uncertainty of Data Deficient category listings. The status of species classified as Data Deficient is uncertain, as the true category of risk of the species is unclear. Many of these species could actually be highly threatened. Consequently, we report a range of values for each vertebrate class, ranging from considering all Data Deficient species as threatened (resulting in an upper estimate) to all Data Deficient species as Least Concern (resulting in a lower estimate).

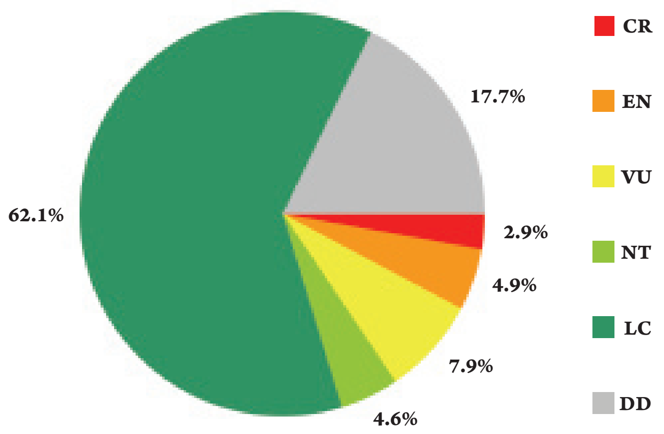


Figure 3: IUCN Red List assessment of vertebrates. (25,535 species, including weighted assessments of reptiles and bony fish).

An innovative approach

Although the status of the world's mammals [12], birds [13], amphibians [14] and cartilaginous fishes (sharks, skates and rays, and chimaeras) has been comprehensively documented, knowledge of the status of the world's reptiles and bony fishes is incomplete [15]. Both are speciose groups: at just over 9,000 species [16], reptile diversity is on a par with birds, while bony fishes number nearly 30,000 species [17]. Efforts are currently underway to complete a comprehensive assessment of both groups, but in the meantime we can employ a sampled approach to gain some understanding of the conservation status of these groups relative to other vertebrate groups [15, 18]. The sampled approach involves conducting Red List assessments on 1,500 randomly selected species from each taxonomic group to provide representative information on extinction risk. In this report we detail status information for vertebrates based on comprehensive assessments of mammals, birds, amphibians and cartilaginous fishes, and representative assessments of reptiles and bony fishes. The reptile and bony fishes have been weighted to give a proportion of threat that is then representative of the global number of described species in the particular group.

Status of vertebrates

Nearly one-fifth (19%) of the world's vertebrates are currently estimated to be threatened with extinction. As noted above, this estimate assumes that Data Deficient species are threatened in the same proportion as data sufficient species. A more conservative estimate would be to treat all Data Deficient species as being not threatened, which provides a lower bound of 16% of vertebrates threatened with extinction (figure 3). On the other hand, assuming that all Data Deficient species are threatened generates an upper bound of 33%.

Amphibians have the highest proportion of threatened species among the vertebrate groups, but also the highest proportion of Data Deficient species and the lowest proportion of Least Concern species (figure 4). The high degree of threat in amphibians relative to other groups owes much to the recent emergence of the disease caused by a pathogenic chytrid fungus, which has had a devastating impact on amphibian populations and communities [19-20]. Birds have the highest proportion of Least Concern species, reflecting their comparative high mobility resulting in a lower risk of extinction, and they also have the fewest Data Deficient species of any of the vertebrate classes, illustrating the rich knowledge and interest we have in birds and their easily observed presence in an ecosystem.

Just as species are not evenly distributed across the face of the planet, neither are the threats to species. Geographic patterns of threatened species (figure 5) reveal that threatened vertebrates are concentrated in southeast Asia, which is subject to exceptionally high levels of both forest loss and hunting. Other peaks of threatened species richness are evident in the Afromontane regions of Africa and in Central and South America, particularly in the tropical Andean regions. Threatened marine species are concentrated mainly in coastal regions, particularly around the coasts of southeast Asia, the Mediterranean, southern Africa, Australia, the Caribbean and the Gulf of Mexico (figure 4).

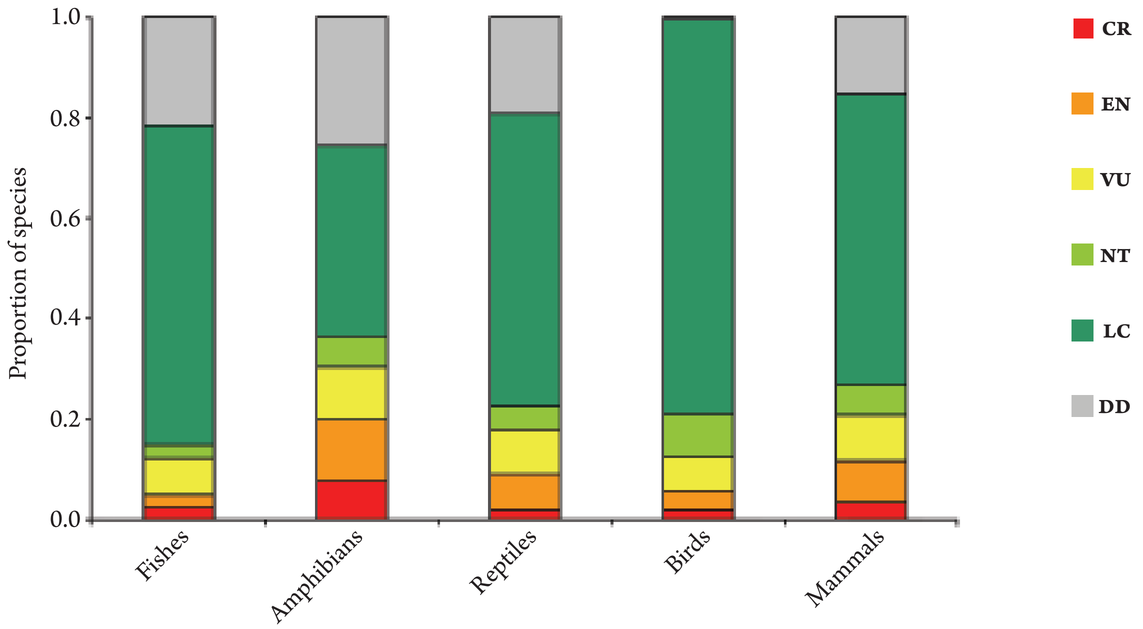


Figure 4: Proportion of vertebrate species by IUCN Red List Categories.

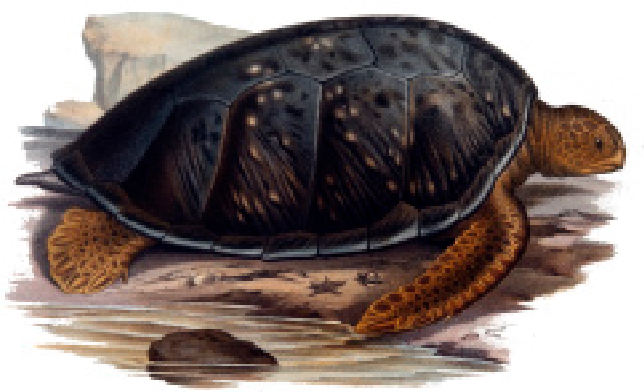


Plate 13. *Chelonia mydas*. Fitzinger: Bilder-Atlas zur wissenschaftlich-populären Naturgeschichte der Amphibien in ihren sämmtlichen Hauptformen. 1864.

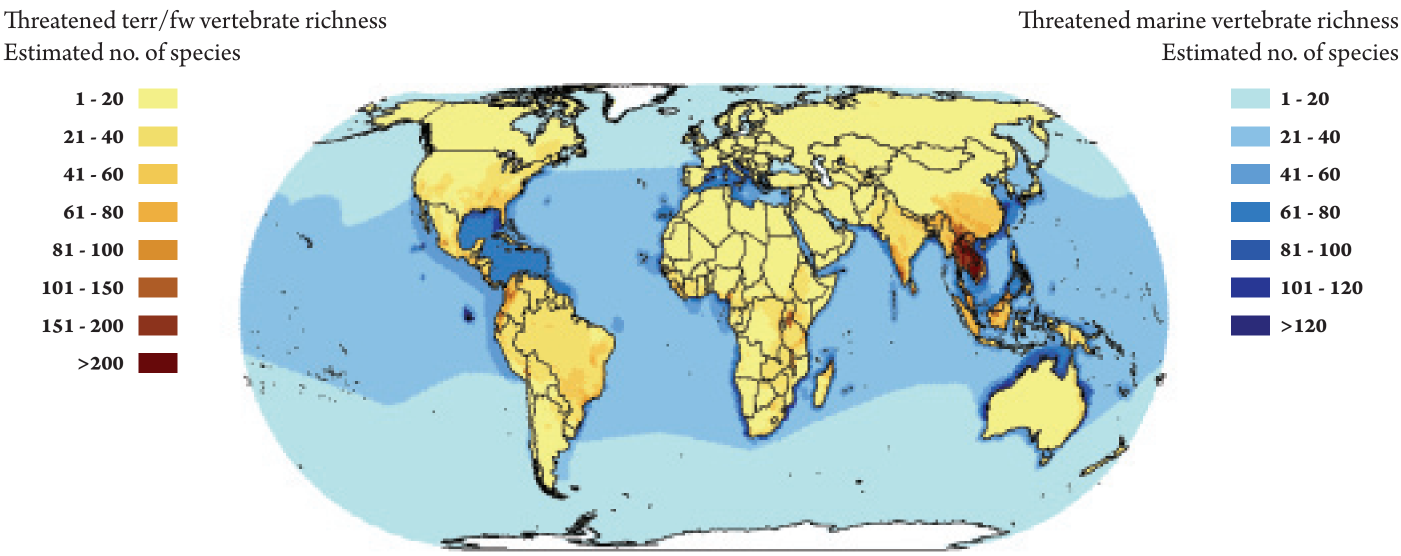


Figure 5: Global species richness of threatened vertebrates, based on an assessment of 4,585 vertebrate species. 'Terr' idicates terrestrial species and 'fw' indicates freshwater species.

Trends in vertebrate species populations

The Living Planet Index (LPI) reflects changes in the health of the planet's biodiversity by tracking trends in nearly 8,000 populations of 2,544 vertebrate species [21-23]. Much as a stock market index tracks the value of a set of shares traded on a stock exchange, the LPI is used to track trends in vertebrate species populations in the wild. The annual rate of change for each species population is calculated and the average rate of change for all species is calculated each year from 1970, when data collection began, to 2005, the latest date for which sufficient data are available. The LPI for vertebrates indicates a decline of 30% in vertebrate population abundance over the last 35 years (figure 6). This loss of vertebrate abundance mirrors the high extinction risk faced by the group as a whole. The LPI trend data for specific vertebrate groups is presented in this document for the first time and in some cases the sample size is relatively small, resulting in lower certainty of the estimated population trend. The population data also tend to be biased toward temperate ecosystems, which are in general under much less threat than the tropics. The individual vertebrate indices should therefore be considered as preliminary and in most cases conservative. Accuracy will improve as additional data are collected for each group and increased monitoring is carried out in the tropics.

Threats to vertebrates

It is now well established that over the past 50 years there have been more substantial changes to habitats globally than at any other time in human history [24] and that the major drivers of change have varied and continue to vary in both nature and intensity over time and space [25].
Overwhelmingly, habitat loss is the greatest threat to all vertebrate groups, driven mainly by expanding agriculture and logging as well as extensive alterations to freshwater systems (figure 7). However, the introduction of non-native invasive species and overharvesting for food or medicines are also considerable threats for many vertebrate species, while pollution remains particularly problematic to both marine (particularly coastal marine fish) and freshwater vertebrate groups (especially amphibians). Increasingly, climate change in combination with other threats is of considerable concern, causing ecosystem imbalance, habitat loss, population decline and changing species distributions.

Plate 14. *Equus zebra*. Waterhouse Hawkins: Gleanings from the menagerie and aviary at Knowsley Hall. 1850.

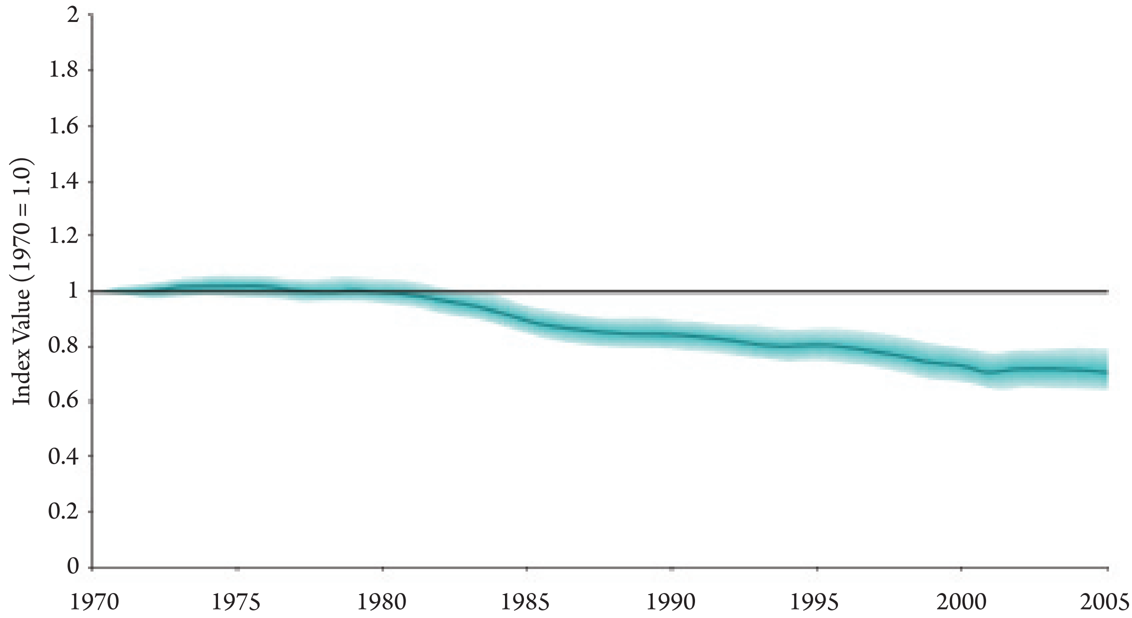


Figure 6: The Living Planet Index for vertebrates (7,953 populations of 2,544 species). Index value shown in bold line, shaded area shows 95% confidence limits.

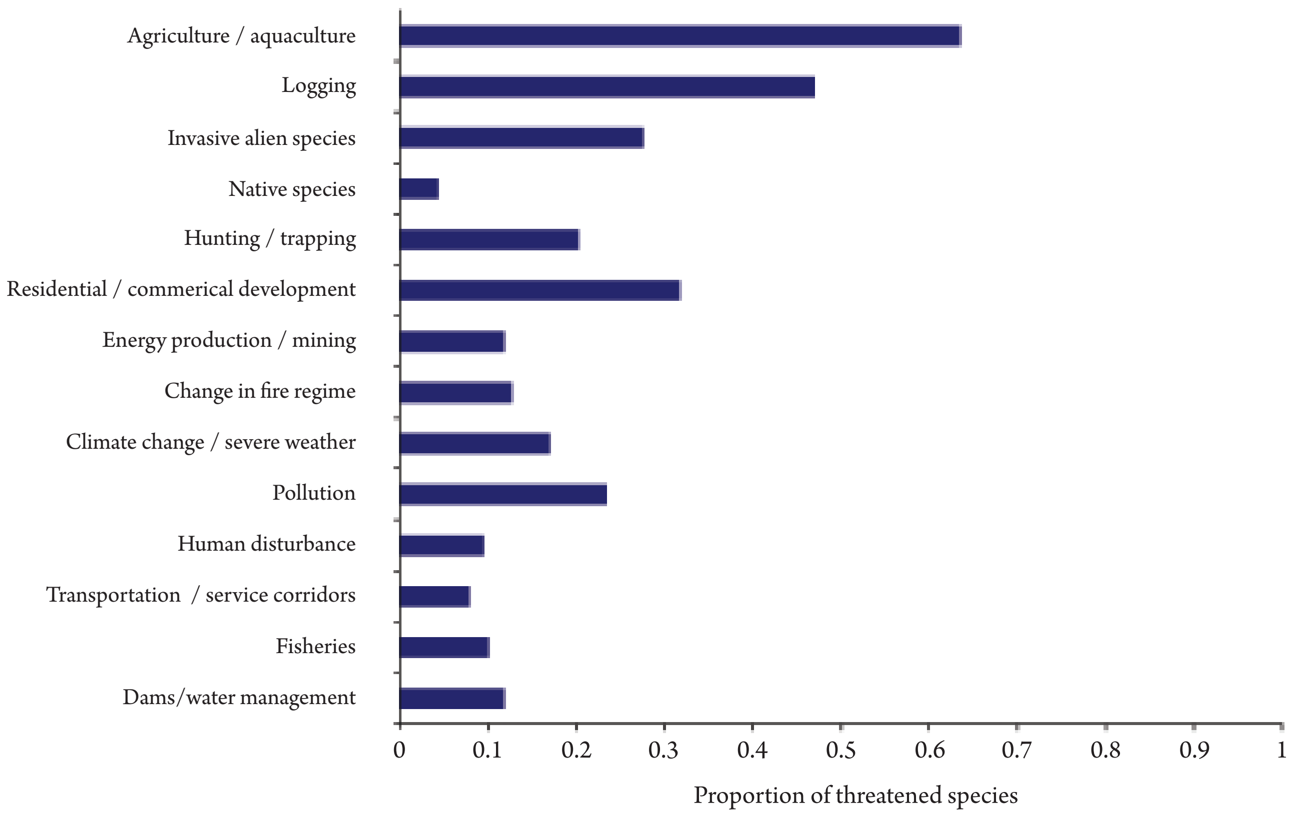


Figure 7: Global threats to vertebrates. Horizontal axis shows the proportion of threatened (CR, EN, VU) species affected by each of the threatening processes on the vertical axis. Note - these numbers may add up to more than 1 because species are often affected by multiple threats.

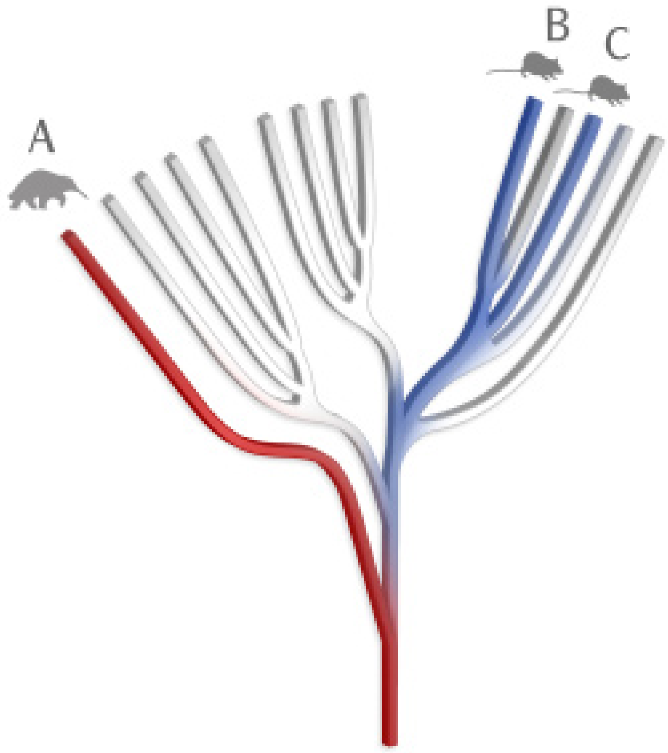


Figure 8: Evolutionary Distinctiveness shown with a hypothetical phylogeny.

In the phylogeny above, species A would have a higher ED score than either species B or C - it represents a branch rather than a twig on the tree of life. If species A were to go extinct, there would be no similar species left on the planet and a disproportionate amount of unique evolutionary history would be lost forever.

Evolutionarily Distinct and Globally Endangered (EDGE) species

Evolutionarily Distinct and Globally Endangered (EDGE) species are threatened species that have few or no close relatives on the tree of life [26]. The evolutionary distinctiveness of a species is calculated using a phylogeny, or evolutionary tree, which measures the patterns of relatedness between species. As shown in the hypothetical example in figure 8, species A would score more highly in evolutionary distinctiveness, as it represents an entire branch in the evolutionary tree, whereas species B and C are more closely related and may represent the same family or genus. If species A were to become extinct, there would be no extant representatives remaining of that entire lineage.

EDGE species have few close relatives and are often distinct in appearance and behaviour [27-28]. An example of an EDGE amphibian is the Chinese giant salamander (*Andrias davidianus*). This amphibian grows up to 1.8 metres in length and belongs to a family (Cryptobranchidae) containing three extant species that diverged from other amphibians around 170 million years ago. This salamander has recently undergone huge population declines due to overharvesting for food and loss of habitat [29].

The EDGE programme at ZSL has identified that 70% of the world's top 100 EDGE mammals and 85% of the top 100 EDGE amphibians are currently receiving little or no conservation attention. The EDGE of Existence programme aims to give priority to these species, which are currently overlooked due to limited conservation resources.

Pisces

Plate 15. Presented in the original publication as Orbis laevis variegatus.
Catesby: The natural history of Carolina, Florida and the Bahama Islands. 1731-43.

Pisces

Evolutionary History of Fish

Editors: Heather Koldewey, Brian Zimmerman, Rachel Jones, Matthew Gollock, William R. T. Darwall and Gordon McGregor Reid

Fish-like chordates lacking jaws or fins first appear in the fossil record in the Early Cambrian period around 525 million years ago. These early eel-like animals were relatively similar to hagfish, the most primitive living vertebrate-like animals. Hagfish are sometimes excluded from Vertebrata because although they have heads with a brain, sense organs and skull, they lack vertebrae (they are instead placed in Craniata [30]). Appearing during the Early Palaeozoic era, heavily armoured primitive jawless fish, using their gills solely for respiration rather than feeding, were the earliest true fish. The development of jaws from gill arches led to the appearance of the gnathostomes, or jawed fish, during the Late Ordovician period, and by the Devonian period (416-359 million years ago) they had evolved into a wide diversity of species, including giant predators such as the 10-metre long placoderm *Dunkleosteus* [2].

Plate 16. *Muraena*. Catesby: The natural history of Carolina, Florida and the Bahama Islands. 1731-43.

In addition to the primitive hagfish and lampreys, living fish represent two distinct groups: the cartilaginous fish, containing all sharks, rays and chimaeras; and the bony fish, containing the ray-finned fish (ranging from the world's smallest vertebrate, *Paedocypris progenetica*, to the giant Mekong catfish, *Pangasius gigas*) and the lobe-finned fish.

In terms of species and individuals, fishes far outnumber all other vertebrate classes (amphibians, reptiles, birds and mammals), with over 31,600 described species of fish known today, almost all of which are ray-finned fishes [17].

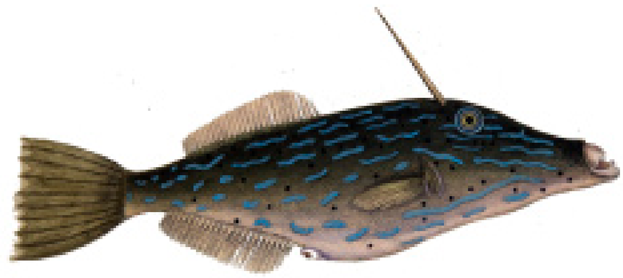


Plate 17. *Aluterus scriptus*. Catesby: The natural history of Carolina, Florida and the Bahama Islands. 1731-43.

Fish are a group of vertebrates from which all terrestrial tetrapods have evolved and so represent an evolutionary 'grade' rather than a unique clade. They are typically cold-blooded, use gills to obtain oxygen while underwater, have bodies covered in scales and lay eggs to reproduce. However, there are exceptions: some species show warm-blooded characteristics (for example, the great white shark *Carcharodon carcharias*), others possess lungs and are able to obtain oxygen from air (for example, lungfish *Lepidosiren*, *Neoceratodus* and *Protopterus*), many lack scales (for example, seahorses *Hippocampus*), and there are many species that give birth to live young (for example, the guppy *Poecilia reticulata*). Reproductive capacity ranges from laying single eggs in some sharks to 28 million eggs in the ocean sunfish *Mola mola* [31].

Biogeography of Fish

The oceans occupy over 70% of Earth's surface area and over 90% of the biosphere's volume. In spite of the 10-year effort (2000-2010) by more than 80 nations to assess and explain the diversity, distribution and abundance of life in the oceans through the Census of Marine Life [32], the proportion of undiscovered species may still be close to 70–80% of all marine species [33].

In terms of area, freshwater ecosystems occupy only 0.8% of Earth's surface, but they are estimated to harbour nearly 6% of all described species, 25% of global vertebrate diversity and approximately 40% of global fish diversity [34]. In addition, many new fish species are being described every year: in South America alone, about 465 new freshwater fish species have been described in the last five years, a figure that corresponds to a new species every four days [34].

Of the fish species that have been described to date, 41% of the world's fish are obligate freshwater species, 58% are obligate marine species and the remainder are anadromous or catadromous species that can tolerate both systems.

Fish are usually considered in terms of fisheries and food rather than as wildlife. It is only in the last 15 years that scientists have begun to assess the conservation status of fish in the same way as terrestrial vertebrates [35]. A global threat assessment of fish has not yet been completed, and in the interim, the Sampled Red List approach has been used for both marine and freshwater fish to provide an indication of the threat status of fishes. The sample can be considered sufficient to provide a global indication of the status of species and the major threats. However, it may not accurately represent global distribution patterns or levels of threat at the regional scale and may under-represent some of the medium to low species richness areas. This considered, the Indo-west Pacific, central Indo-Pacific, South China and Coral seas are the centre of diversity of marine fish species (figure 9). Southeast Asia, eastern Africa's Great Lakes, South American Amazonia and the forests of central Africa hold a high proportion of freshwater fish species.

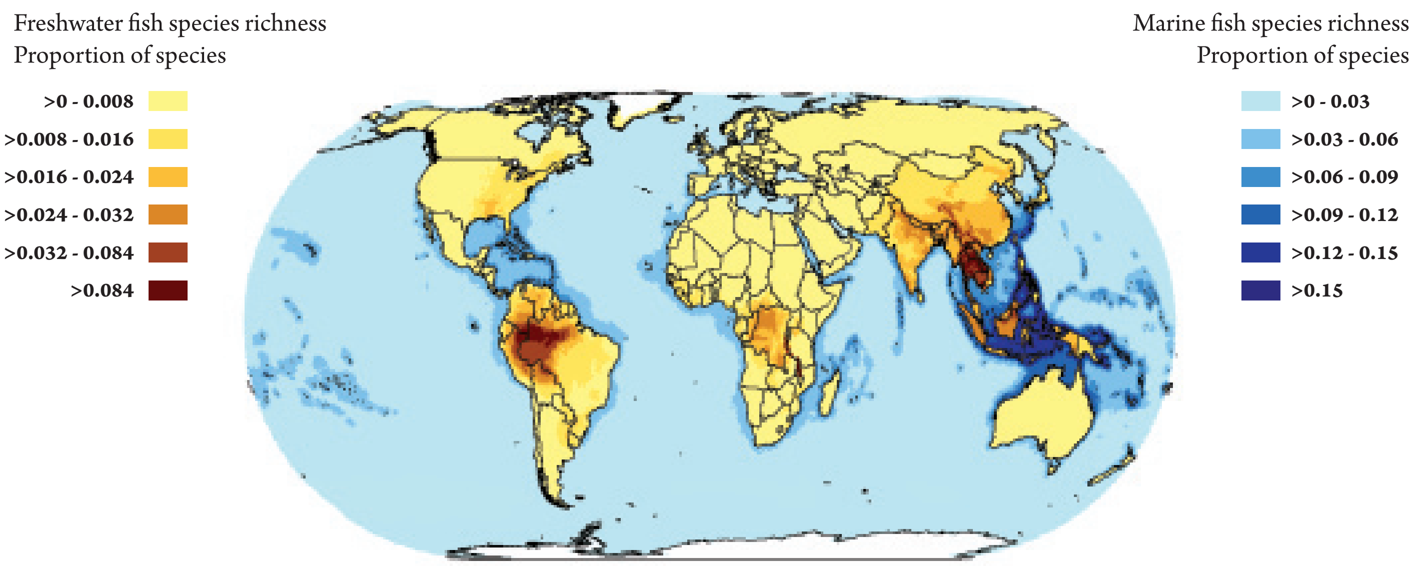


Figure 9: Global species richness of fish, based on an assessment of 1,500 fish species.

Status of fish

Based on the 2010 IUCN Sampled Red List assessment of the world's freshwater and marine fish, 15% of the world's fish species are currently threatened with extinction.

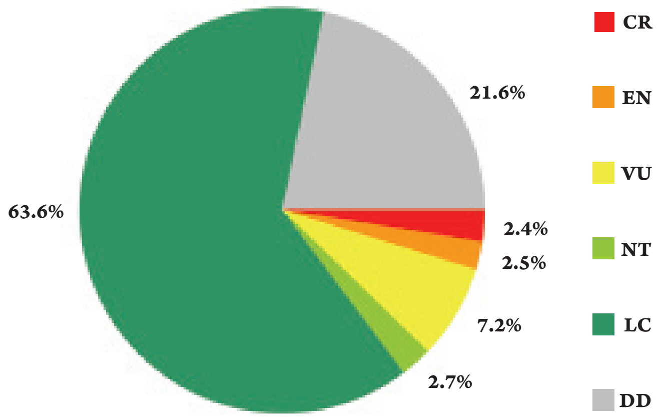


Figure 10: IUCN Red List assessment of fish (1,500 species). Note – this total contains data from a comprehensive assessment of sharks and rays (1,044 species) which are weighted in the appropriate proportion to the ratio of bony fish to cartilaginous fish in the whole sample of 1,500 species, therefore giving a true representation of the status of fish.

This estimate assumes that Data Deficient species are threatened in the same proportion as data sufficient species. Estimates range from 12% if all Data Deficient species are not threatened to 34% if all Data Deficient species are threatened. The IUCN Red List pie chart in figure 10 shows 12% of fish species are threatened, which is the lowest estimate. Many commercially exploited fish are classed as threatened, including southern bluefin tuna (*Thunnus maccoyii*) and beluga sturgeon (*Huso huso*), both of which are Critically Endangered due to overfishing almost to the point of extinction. Almost 22% of fish species are listed as Data Deficient, indicating that we know less about non-terrestrial vertebrate species.

The highest species richness of threatened marine fish species is found in the Indo-west Pacific, central Indo-Pacific, South China, Coral, Caribbean and Mediterranean seas (figure 11). The highest species richness of threatened freshwater fish species is found in southeast Asia.

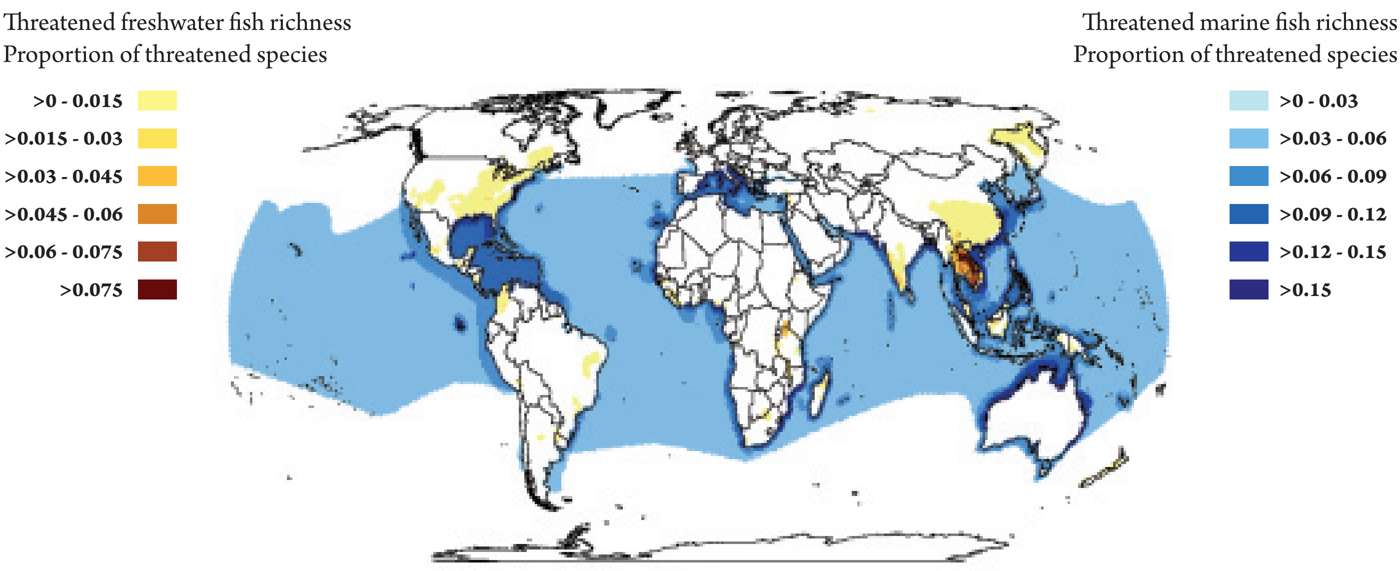


Figure 11: Global species richness of threatened fish, based on an assessment of 172 fish species.

Trends in fish populations

The Living Planet Index for freshwater fish tracks 876 populations of 242 species, a relatively small proportion of all freshwater fish. The available data indicate that a rapid and steady decline in population abundance has occurred since 1970, approaching an average 65% reduction in the populations of freshwater fish species by 2003 (figure 12). The available marine data (tracking 761 populations of 386 species) indicate that a gradual decrease in the number of marine fish populations has occurred, with a 20% reduction in global populations of marine fish species (figure 13).

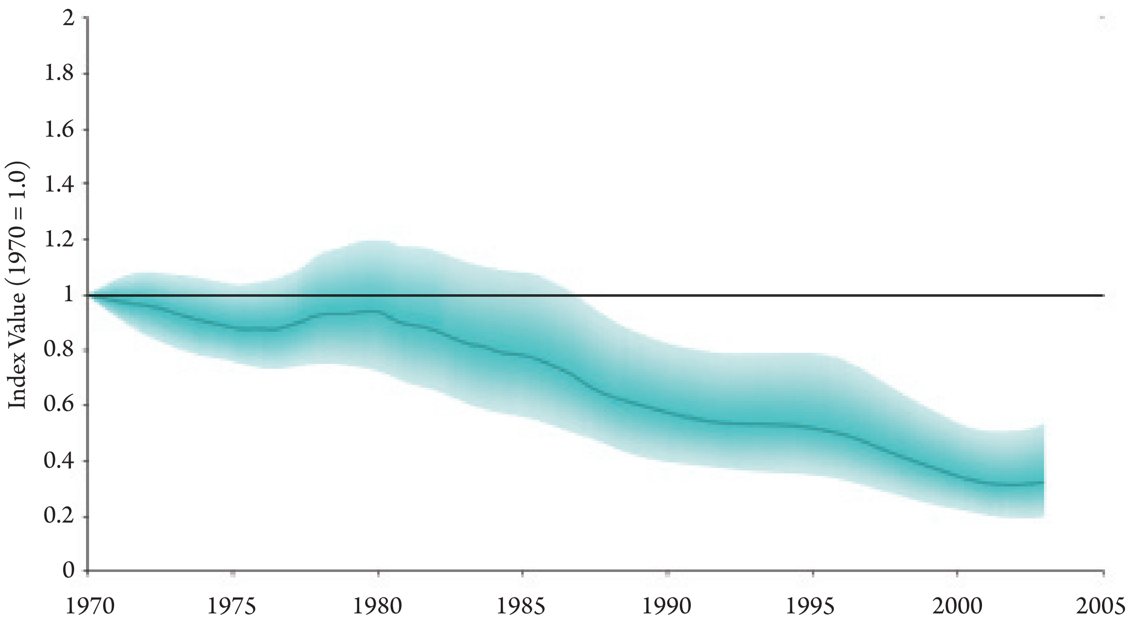


Figure 12: Living Planet Index for freshwater fish (876 populations of 242 species). Index value shown in bold line, shaded area shows 95% confidence limits.

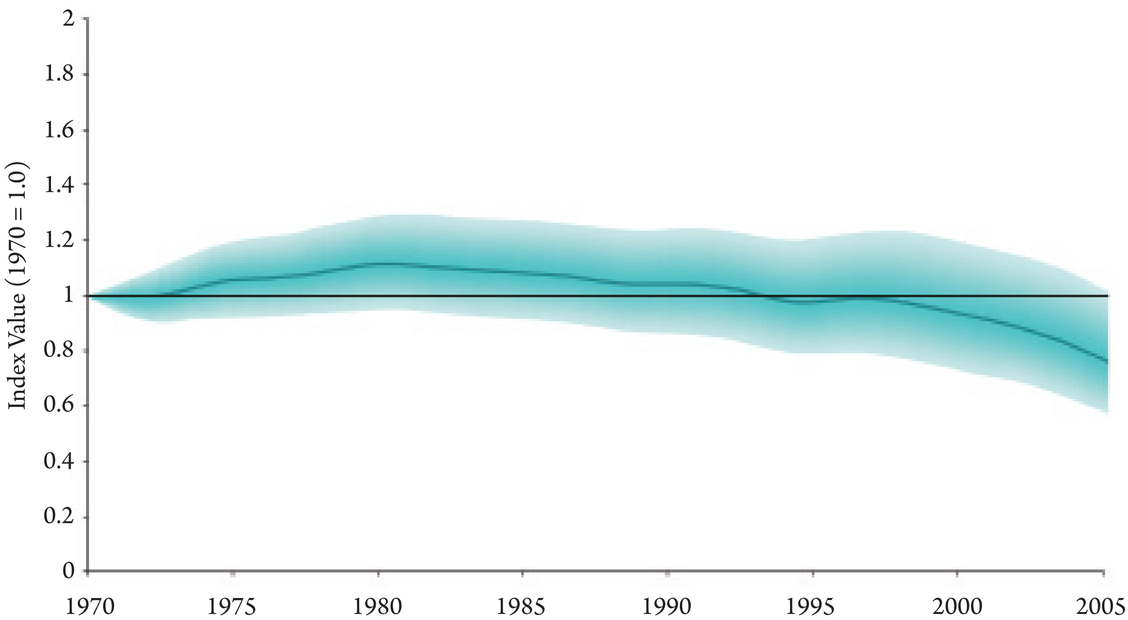


Figure 13: Living Planet Index for marine fish (761 populations of 386 species). Index value shown in bold line, shaded area shows 95% confidence limits.

Threats to fish

Aquatic habitats are routinely treated as limitless sources for human consumption and sinks for waste, which has resulted in the decline and loss of fish species. Exploitation of fish and other marine groups (such as invertebrates) is the main threat to biodiversity loss in the marine environment (figure 14), resulting in species population declines and extinctions, habitat degradation and ecosystem changes [36-38]. Over 80% of the world's fisheries are either fully or overexploited [39].

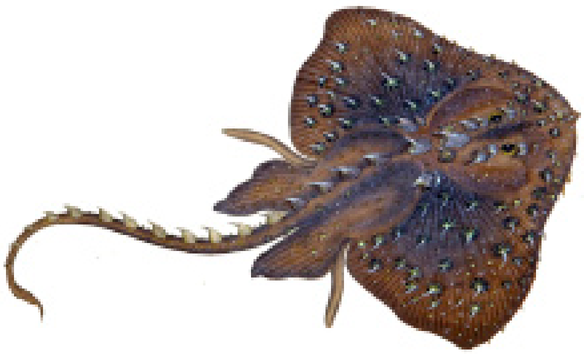


Plate 18. *Amblyraja radiata*. Donovan: The natural history of British fishes. 1808.

Freshwater ecosystems face increasing pressure from dams, water abstraction, pollution, invasive species and overharvesting [34, 40-41]. While overexploitation is still a significant threat to freshwater fish, pollution has the greatest negative impact (figure 15). Freshwater fish have also been particularly negatively affected by habitat alteration caused by damming and water management activities such as abstraction for agriculture. The introduction of invasive alien species is increasing both within and between countries to the detriment of native species. Climate change has already demonstrably negatively affected aquatic ecosystems and provides a significant threat for many fish species in the future [42-43].

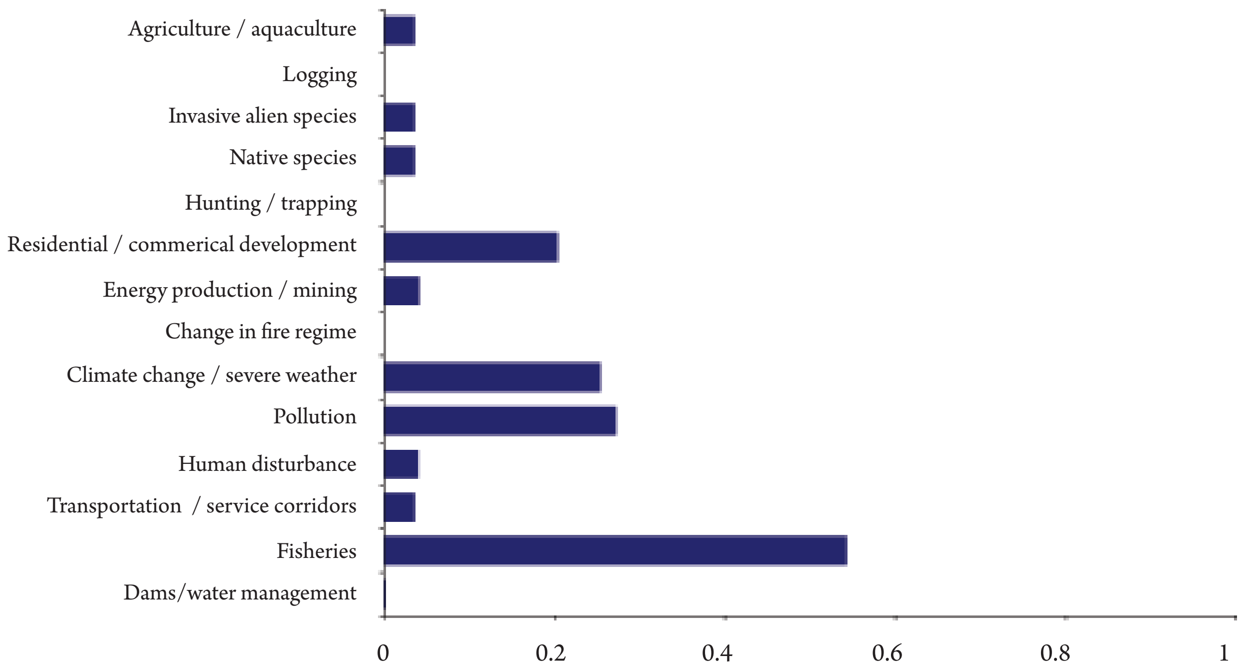


Figure 14: Global threats to marine fish species. Horizontal axis shows the proportion of threatened (CR, EN, VU) species affected by each of the threatening processes on the vertical axis. Note - these numbers may add to more than 1 because species are often affected by multiple threats.

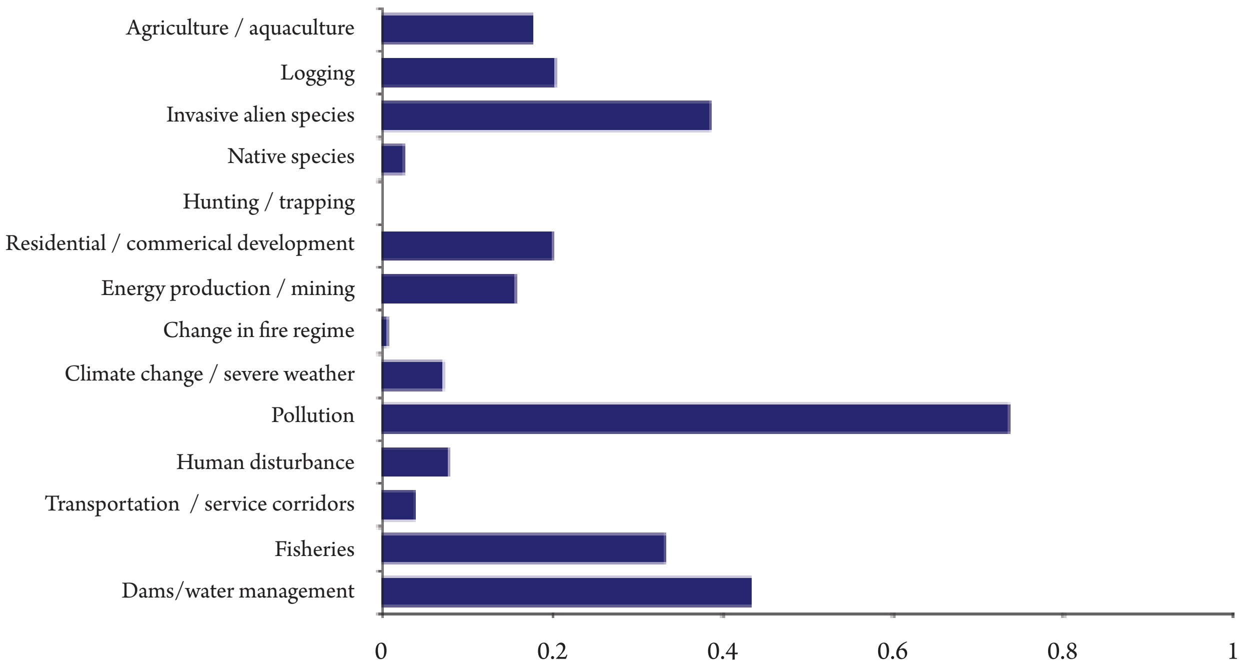


Figure 15: Global threats to freshwater fish species. Horizontal axis shows the proportion of threatened (CR, EN, VU) species affected by each of the threatening processes on the vertical axis. Note - these numbers may add up to more than 1 because species are often affected by multiple threats.

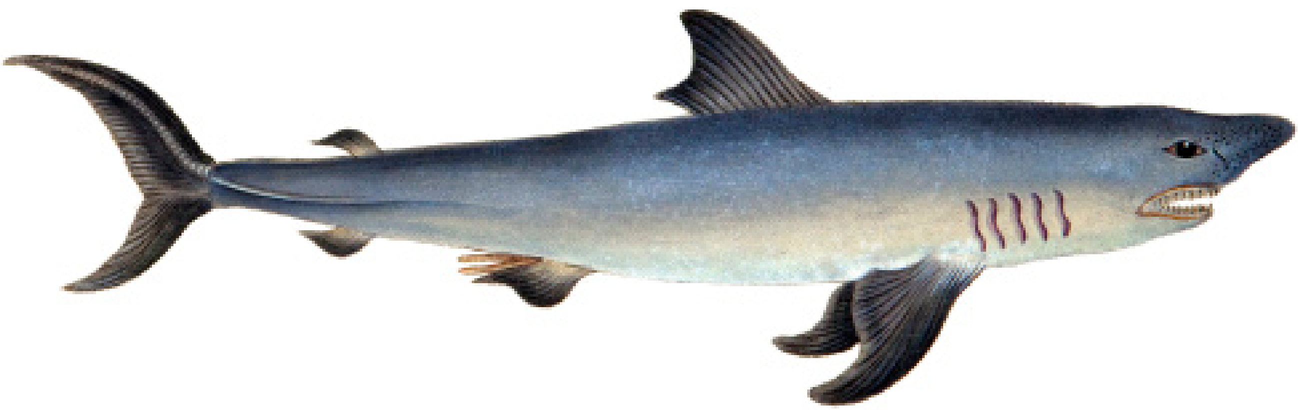


Plate 19. *Lamna nasus*. Donovan: The natural history of British fishes. 1808.

Phylogenetic supertrees are not yet available to assess the patterns of relatedness across different groups of fish and so the EDGE approach cannot yet be formally employed.

However, there are several contenders for EDGE fish species. Probably the best examples are the two species of coelacanth, the famous 'living fossil' fish. As the only surviving members of the order Coelacanthiformes, the two coelacanth species represent over 400 million years of evolutionary history. Coelacanths are relatively common in the Devonian-Cretaceous fossil record, but the group was thought to have become extinct 80 million years ago [44]. However, in 1938 a fishing vessel captured a coelacanth off the coast of South Africa, much to the surprise and excitement of the scientific community; it was described as the new species *Latimeria chalumnae* [44]. Since then an increasing number of coelacanths have been recorded in the Indian Ocean around Madagascar and Mozambique. In 1998, a second extant species of coelacanth, *Latimeria menadoensis*, was discovered in Sulawesi, Indonesia [45].

Today's extant coelacanths live in small populations at depths of around 200 metres, often in caves [44]. *Latimeria* are estimated to live between 12-20 years and give birth to live young which develop internally from eggs the size of tennis balls – the largest recorded of all fishes. They are threatened by bycatch from deep-sea trawls for oilfish (*Ruvettus pretiosus*) [44]. As a result, combined with the intrinsic vulnerability conferred by their slow life history, *Latimeria chalumnae* is classified as Critically Endangered by IUCN while *L. menadoensis* is Vulnerable [46].

The Chinese paddlefish (*Psephurus gladius*) is endemic to the Yangtze River and is one of two extant paddlefish species left in this ancient family of primitive chondrostean ray-finned fishes. An unusual characteristic of paddlefish is their reliance on sensory pores on their paddle-like snouts for detecting electrical fields emitted by prey [47-48].

The Chinese paddlefish is probably the largest freshwater fish in the world, but over the course of the 20th century the length of paddlefish caught has declined significantly, a strong indicator of overfishing and stock depletion. The Chinese paddlefish is classified as Critically Endangered due to habitat loss, overfishing for food and caviar, and dam construction [46]. Unfortunately, the Chinese paddlefish may well already be extinct, with a recently completed three-year survey of the Yangtze finding no specimens [49].

Plate 20. View: Ceylon. Daniell: The island of Ceylon. 1808.

The Critically Endangered daggernose shark (*Isogomphodon oxyrhynchus*) is a poorly known species in the same family as the great white shark, which has a very long, flattened snout with a pointed tip. The fish gets its name from the Greek oxys ("sharp" or "pointed") and rhynchos ("nose") and was first recognised in 1839, although it does have an extinct relative *I. acuarius*, which is known from 45 million year-old fossils [50]. It is believed to live in muddy, shallow waters off the northern coast of South America and is often caught in artisanal gill nets [51]. Its long nose and small eyes are thought to be an adaptation to living in these turbid waters, where it relies on electroreception rather than sight.

Evolution lost

According to the IUCN Red List of Threatened Species, 58 fish species have gone Extinct and nine Extinct in the Wild since 1500 AD [46]. Most fish extinctions have been driven by human-caused habitat alteration, introduction of non-native species, overfishing and pollution [40].

The extinction of any species involves the loss of evolutionary history, although a comprehensive analysis of the extent of this loss in fish has not yet been undertaken. One example of an evolutionarily distinct species that has already been lost is the Ukrainian migratory lamprey (*Eudontomyzon sp. nov.* 'migratory'), which became extinct in the late 19th century. Although the reasons for its extinction remain enigmatic, it was a known target of fisheries [46]. Lampreys are related to the earliest chordates and therefore represent an ancient lineage of evolutionary history.

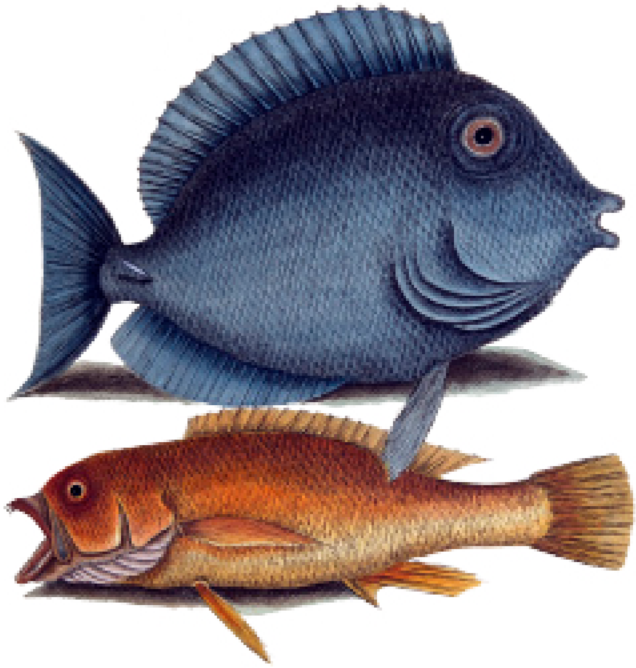


Plate 21. Presented in the original publication as *Turdus rhomboidalis & Turdus cauda convexa*. Catesby: The natural history of Carolina, Florida and the Bahama Islands. 1731-43.

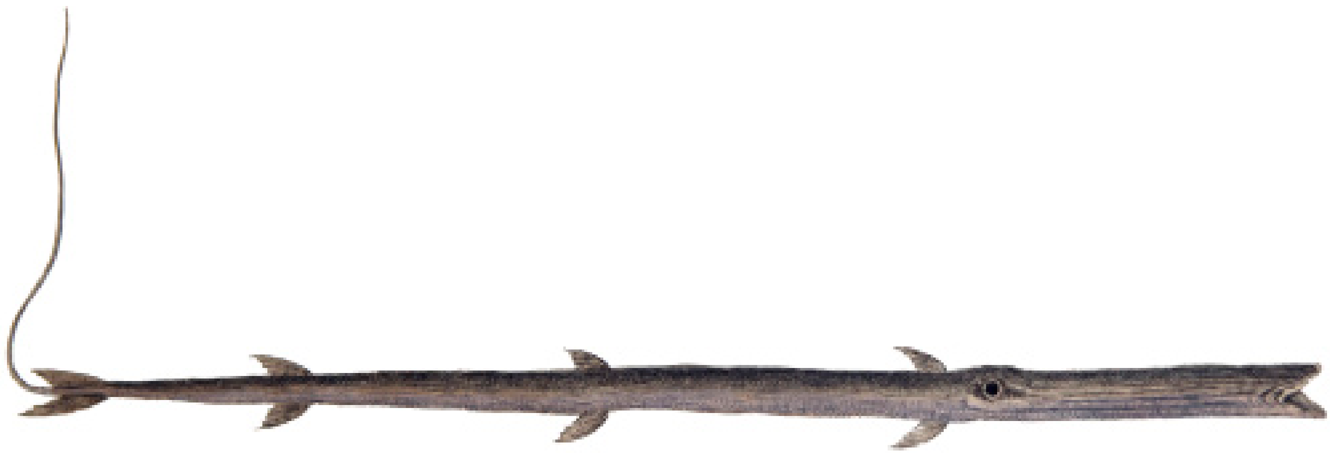


Plate 22. *Fistularia tabacaria*. Catesby: The natural history of Carolina, Florida and the Bahama Islands. 1731-43.

Evolution Lost case study

Any species can become extinct and this is true for fish, in spite of the long-held opinion that populations of the most common species were inexhaustible. Here two contrasting examples are discussed that highlight the complexity of fish extinctions.

Pupfish are a group of small killifish belonging to the family Cyprinodontidae of ray-finned fish, which are especially noted for being found in extreme and isolated environments. Four species of pupfish used to live in a series of four small springs in close proximity to one another near Monterrey, Mexico. Due to abstraction of water for agriculture reducing the groundwater supply, all four springs dried up and all four species were declared extinct in the wild by the early 1990s. Living specimens of two of the species, Cyprinodon longidorsalis *and* C. veronicae *were rescued and now persist only through the dedicated efforts of aquarium breeding programmes in North America and Europe. Sadly, the other two species went extinct, with one of these only being described after extinction. It was named appropriately* Cyprinodon inmemoriam [52]*.*

Lake Victoria in East Africa is the largest tropical lake in the world, with a globally outstanding aquatic diversity that includes a species flock of 600 endemic fish species. It was dubbed 'Darwin's dreampond' following evolutionary studies that demonstrated a spectacular adaptive radiation of the family Cichlidae, with a few species diversifying to about 600 in about 15,000 years – essentially a new species every 30 years [53]*. Following the introduction of the predatory Nile perch (*Lates niloticus*) in the 1960s, combined with overfishing, land-use change and siltation, the cichlids were nearly eradicated by the late 1980s, with hundreds of extinctions reported* [54]*. However, by the early 1990s the cichlids began to recover, with a recent report suggesting that the biomass in the lake has returned to 1979 levels and that biodiversity is increasing. Cichlid population structure has changed markedly with extensive hybridisation due to eutrophication affecting the visual sexual selection process and species extinction. The recovery is being explained by the cichlids' capacity for adaptation, overfishing of the Nile perch and reduced pollution, although deforestation and erosion are still major problems that threaten the lake's future* [53]*.*

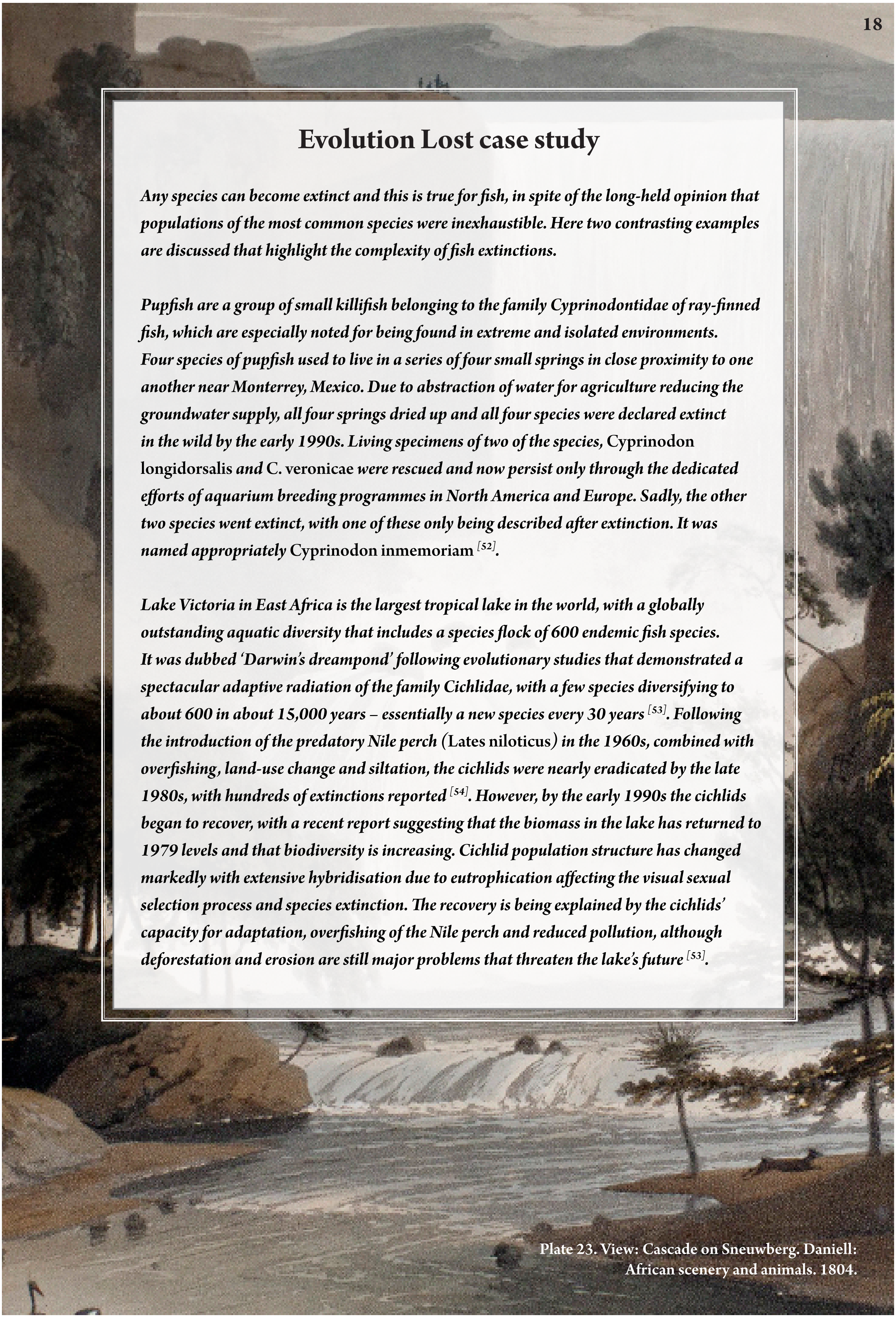


Plate 23. View: Cascade on Sneuwberg. Daniell: African scenery and animals. 1804.

Conservation

Fish conservation efforts need to reconcile the needs of both humans and ecosystems, reaching a compromise that balances human livelihoods with the persistence of aquatic ecosystems and their biodiversity. Given that over 80% of the world's marine fish stocks are currently fully or overexploited, it is clear that this balance is not being achieved. Overexploitation is facilitated by subsidies of US$35 billion per year globally [55-56], generally poor governance of ocean resources and a global fishing fleet that is much larger than required. These fundamental issues must be addressed if the balance of the sustainable exploitation of fish stocks is to be restored. In the marine realm, the most important priority is to reduce carbon emissions leading to ocean acidification, followed by addressing overfishing (including excessive bycatch and illegal fishing) as well as pollution. In the freshwater realm, the greatest priorities are to address pollution, water abstraction, habitat modification and introduced species.

The area of the ocean and freshwater that is effectively protected remains almost insignificant. While international commitments have set global marine protection targets that range from 10-30%, only 1.6% of the world's oceans are currently protected, with only 0.08% as no-take zones [57]. As an urgent first step towards such targets, the conservation of sites of global conservation significance for marine [58] and freshwater [59] fish species is a high priority. Whole catchment protection and management would be ideal for freshwater protected areas, but is extremely rare. Thus, terrestrial protected areas need to be designed to ensure that important aquatic concerns, such as whole catchment management integrity and preventing introductions of non-native species, are integrated into their management plans.

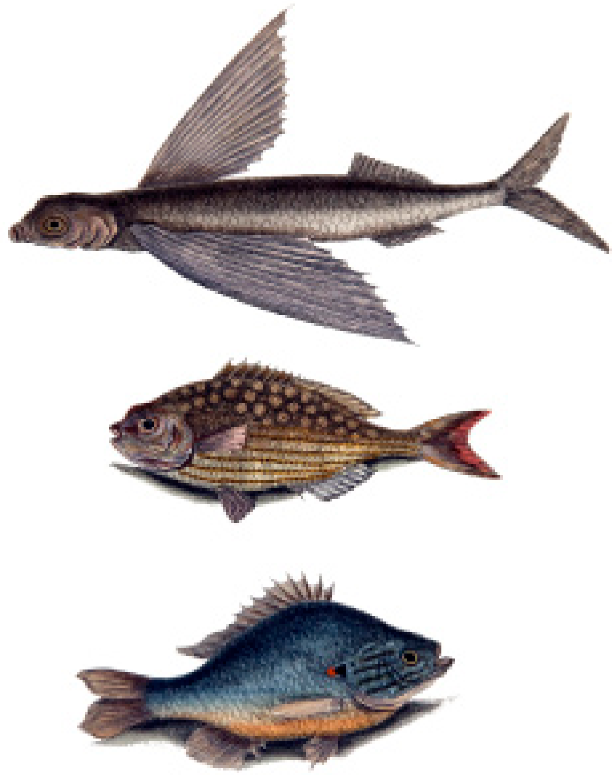


Plate 24. Presented in the original publication as *Hirundo*, *Perca marina sectatrix* & *Perca fluviatilis gibbosa ventre luteo*. Catesby: The natural history of Carolina, Florida and the Bahama Islands. 1731-43.

Aquaculture is rapidly replacing wild caught fish [39]. To avoid the frequently damaging ecological and environmental impacts of fish culture, including the loss of 35% of the world's mangroves [60] and the heavy reliance on wild fish as aquaculture food, it is important to improve our understanding of appropriate methods for sustainable aquaculture.

The public can help encourage the transition toward more sustainable fisheries practices through market forces by supporting independently certified sustainable seafood. Such initiatives are gaining momentum.

In many places, good legislation exists that would conserve fish species if it were properly enforced. There is a need to strengthen and enforce existing laws and develop new laws that ensure threatened fish species are protected and fisheries are sustainably managed.

Amphibia

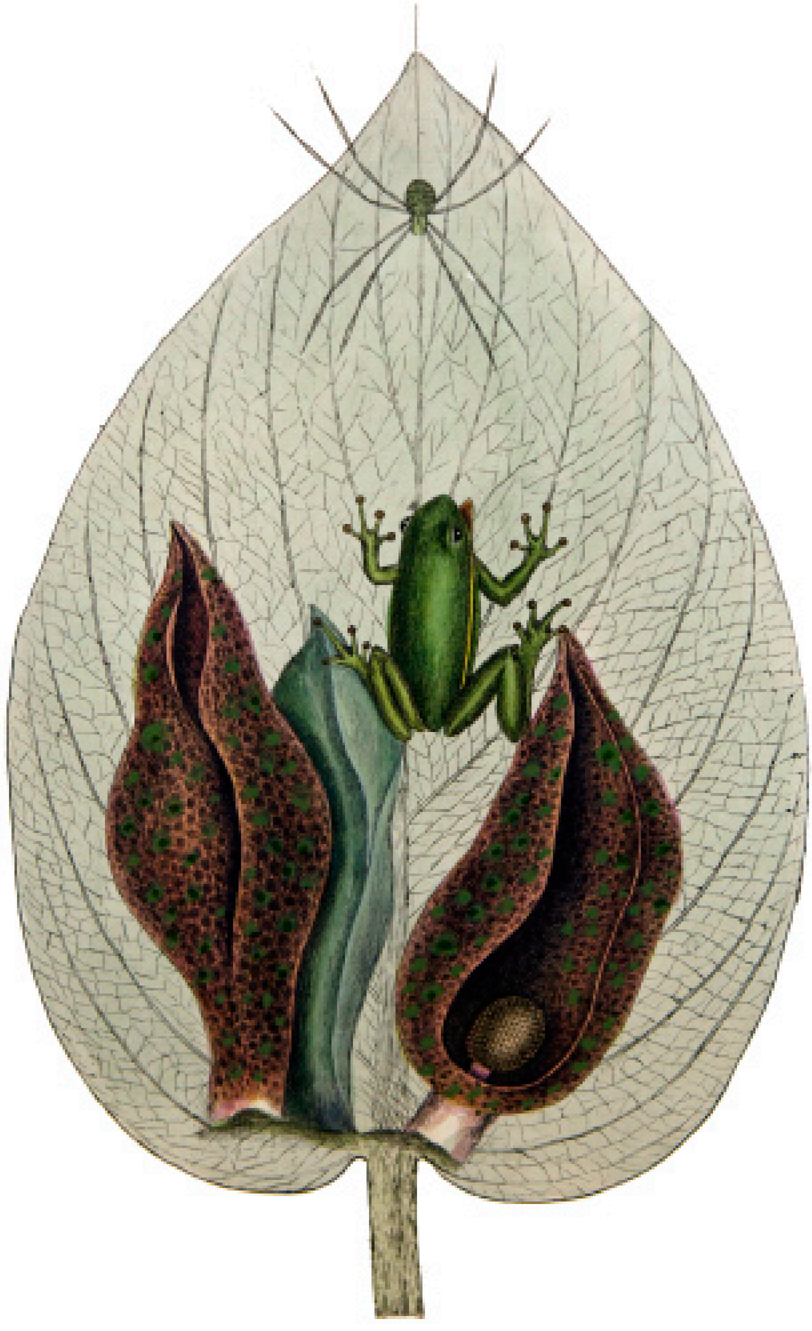


Plate 25. *Hyla cinerea*. Catesby:
The natural history of Carolina, Florida and the Bahama Islands. 1731-43.

Amphibia

Evolutionary History of Amphibians

Editors: Ariadne Angulo and Janine Griffiths

The first amphibious tetrapods evolved almost 400 million years ago during the Devonian period, originating from fish that had multijointed leg-like fins (related to the extant lungfish). These transitional animals may have been sit-and-wait ambush predators in shallow waters, similar to modern-day pike, and are known from fossils found in Europe, North America, Greenland and Australia [61-62].

Amphibians diversified into several major lineages during the subsequent Carboniferous period, many of which were sturdy, large-bodied, alligator-like animals with heavily armoured skulls, very unlike today's small amphibian species [3]. One of the primitive giant amphibians (*Koolasuchus*) survived as a living fossil until the Cretaceous period in Australia, about 100 million years after the Triassic-Jurassic extinction event during which the other primitive large amphibians of the same Order disappeared [63].

Today, there are over 6,638 known species of amphibians, arranged into three orders: frogs and toads, salamanders and caecilians. Little is known about the caecilians [64]; as underground burrowers they are ideally suited to their lifestyle with an earthworm-shaped body, small eyes and no limbs, but they are therefore generally difficult to survey and monitor [65]. Frogs and toads are by far the most species-rich and successful living amphibian group, having colonised every continent with the exception of Antarctica. The majority of amphibians metamorphose from tadpoles to adults, yet certain groups have other methods of reproduction, including giving birth to live young, which is common amongst the caecilians [64].

Plate 26. *Siphonops annulatus* & *Ichthyophis glutinosus*. Fitzinger: Bilder-Atlas zur wissenschaftlich-populären Naturgeschichte der Amphibien in ihren sämmtlichen Hauptformen. 1864.

Plate 27. *Rana catesbeiana*. Catesby: The natural history of Carolina, Florida and the Bahama Islands. 1731-43.

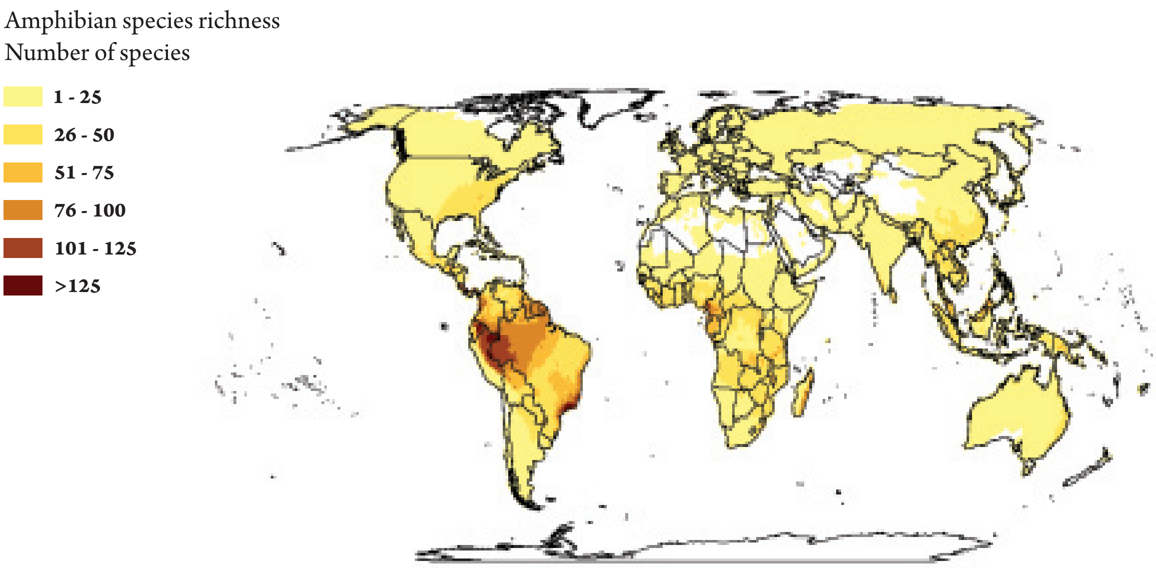


Figure 16: Global species richness of amphibians, based on an assessment of 6,118 amphibian species.

Amphibian species richness varies substantially among continents and latitudes, with a greater concentration of species in the Neotropical region of South and Central America. Therefore, it is no surprise that the countries and regions with greatest species richness globally are Brazil, Colombia, Ecuador and Peru, followed by Mexico, Asia and Africa (figure 16). The southeastern USA also has high species richness owing to the large number of salamander species native to this region. In contrast to other terrestrial vertebrate groups, there are relatively few oceanic island-endemic amphibians due to their intolerance of salt water.

Plate 28. *Rana arvalis*. Catesby: The natural history of Carolina, Florida and the Bahama Islands. 1731-43.

Status of amphibians

A global assessment indicates that 41% of the world's amphibians are threatened with extinction. This estimate assumes that Data Deficient species are threatened in the same proportion as data sufficient species. Estimates range from 30% if all Data Deficient species are not threatened to 56% if all Data Deficient species are threatened [14]. The IUCN Red List pie chart in figure 17 shows 30% of amphibian species are threatened, which is the lowest estimate. Among the vertebrates, amphibians have the highest proportion of Critically Endangered species and are also the group suffering the most recent extinctions. Amphibians also have the highest proportion of Data Deficient species of the vertebrate groups, the majority of which are found in the tropics [66].

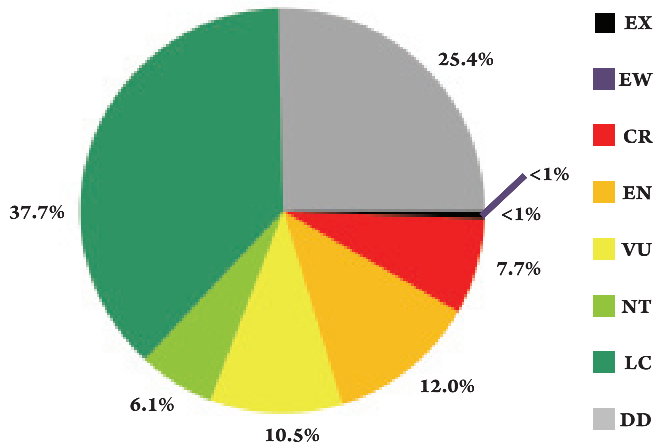


Figure 17: IUCN Red List assessment of amphibians (6,284 species assessed).

The highest species richness of threatened amphibian species are found in dense tropical and subtropical forested areas of the world, such as those of the northern Andes, the Caribbean region, Western Ghats, Malaysian Borneo and West Africa (figure 18).

Figure 18: Global species richness of threatened amphibians, based on an assessment of 1,890 amphibian species.

Trends in amphibian populations

The Living Planet Index for amphibians, with population trends for 357 populations of 162 amphibian species, shows an average of around 80% decline in those populations used to calculate the index (figure 19). Due to the fact that these data are collected from the limited literature available on amphibian population monitoring and many studies specifically focus on declining populations, the results should be interpreted with caution. Nevertheless, there is a great deal of supporting evidence that the group has experienced a major crash in numbers since the 1970s [14, 19-20, 29, 67].

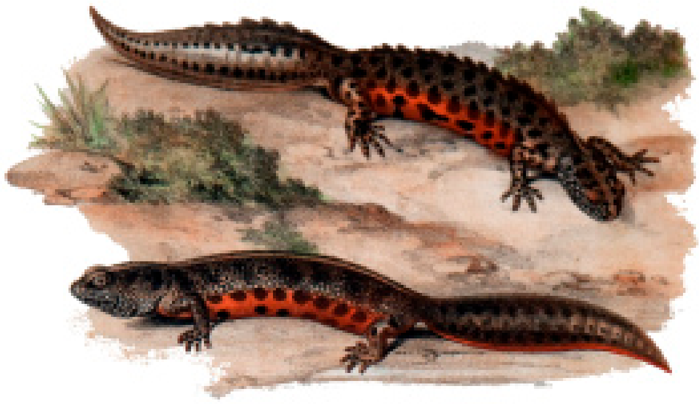


Plate 29. *Triturus karelinii*.
Fitzinger: Bilder-Atlas zur wissenschaftlich-populären Naturgeschichte der Amphibien in ihren sämmtlichen Hauptformen. 1864.

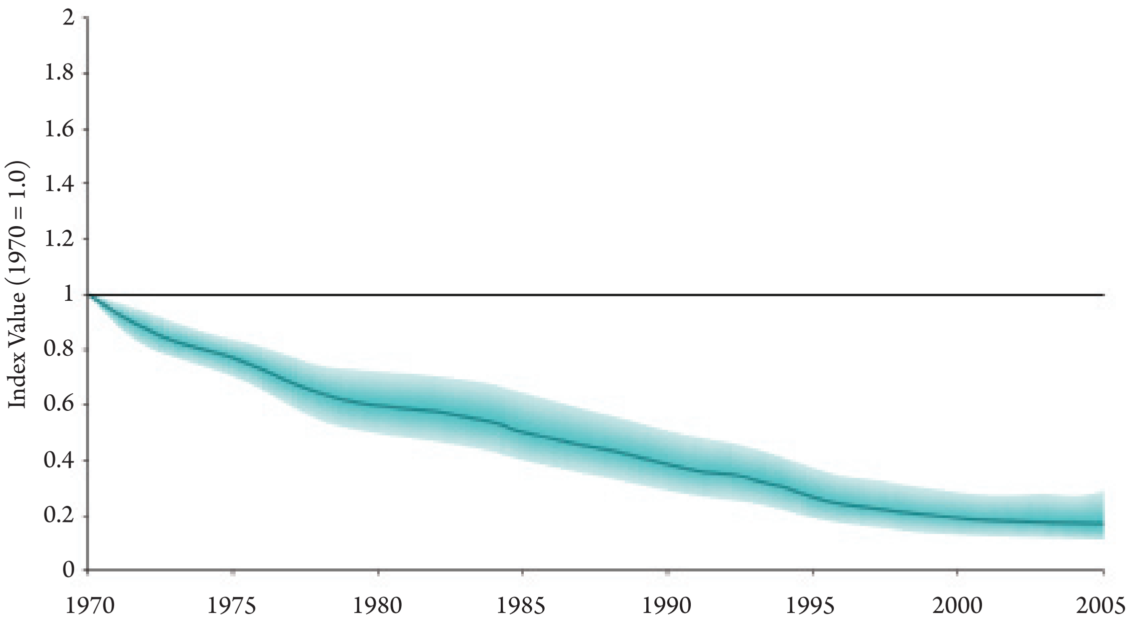


Figure 19: Living Planet Index for amphibians (357 populations of 162 species). Index value shown in bold line, shaded area shows 95% confidence limits.

Threats to amphibians

The one characteristic that exemplifies the majority of amphibians is their dependence on water for reproduction or other stages of their lifecycle, and therefore the majority of amphibians are found in moist tropical forests and freshwater ecosystems. Unfortunately, these habitats are under great human pressure, which includes rapid deforestation, habitat degradation and pollution and overuse of water.

Habitat loss is arguably the most ubiquitous threat to amphibians, in the form of agriculture and aquaculture, logging and development (figure 20).

A more recent yet considerable threat is chytrid fungus (*Batrachochytrium dendrobatidis*). First described in 1999, this fungus is now found on every continent inhabited by amphibians and is presumed to be responsible for causing mass mortalities amongst many populations [68-70]. While the full extent of the effects and interactions of the chytrid fungus are not yet understood (in several instances a synergy with dry weather spells and/or climate change is suspected), it could be particularly problematic in high altitude regions and in species that have restricted-range, aquatic lifestyles and low reproductive ability [19, 71-72].

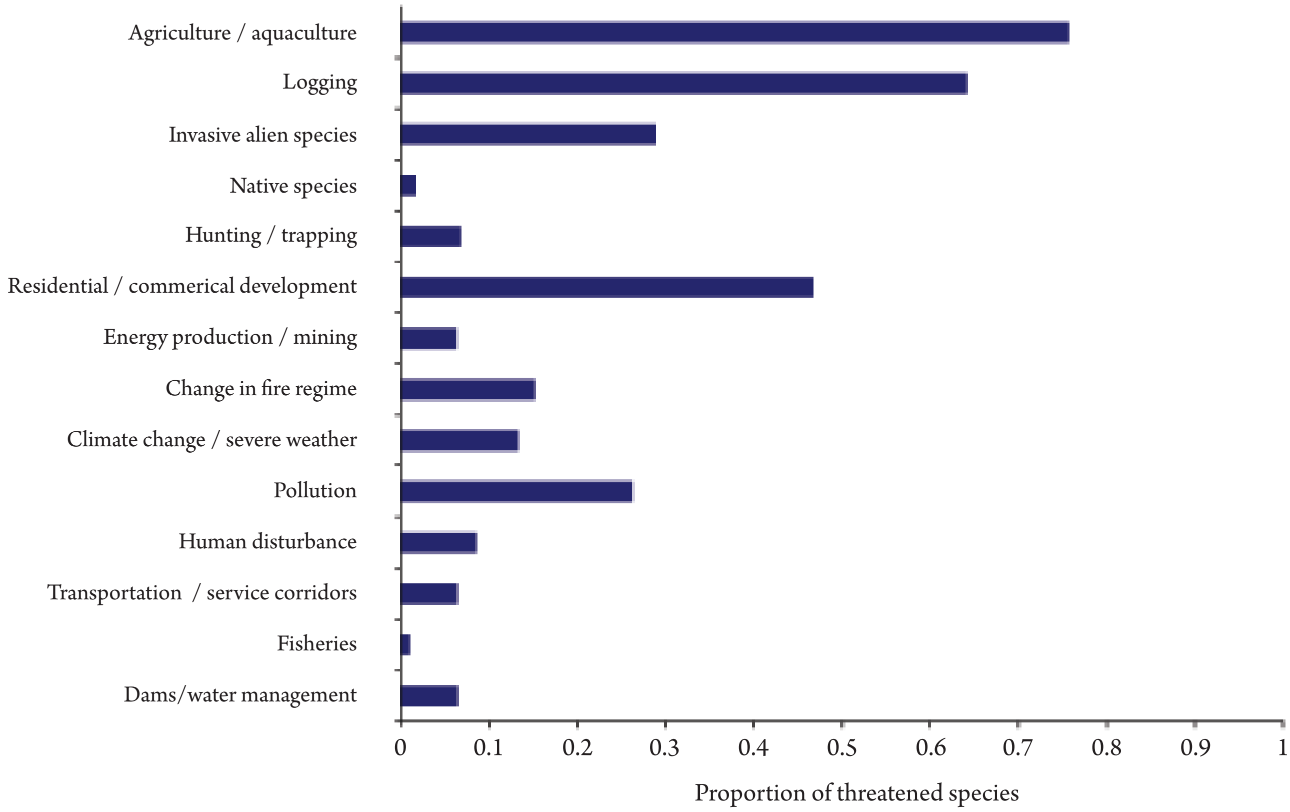


Figure 20: Global threats to amphibian species. Horizontal axis shows the proportion of threatened (CR, EN, VU) species affected by each of the threatening processes on the vertical axis. Note - these numbers may add up to more than 1 because species are often affected by multiple threats.

Evolutionarily Distinct and Globally Endangered (EDGE) Amphibians

Archey's frog (*Leiopelma archeyi*) is one of only four species belonging to the endemic New Zealand genus *Leiopelma*. Having diverged from all other amphibians in the late Triassic period, the genus *Leiopelma* therefore represents over 200 million years of unique evolutionary history.

Archey's frog possesses many unusual traits: it does not have eardrums or a vocal sac, so therefore cannot croak; it has inscriptional ribs and tail-wagging muscles, although it does not have a tail; it reproduces independent of water and the hatched froglets are carried around on the male's back; and it swims with an alternate-leg kick movement, unlike other frogs. Archey's frog is classified as Critically Endangered due to an 80% reduction in the population size in the last 10 years [46]. This devastating decline is considered to be primarily due to the effect of chytrid fungus [73].

Belonging to the Proteidae family of salamanders that diverged around 190 million years ago, the olm (*Proteus anguinus*) is native to freshwater underground caves in Europe. Recent studies concluded that these tadpole-like amphibians can live up to 100 years and survive without food for up to 10 years. The olm spends its entire life in the darkness of underground caves and so has developed translucent skin and hunts via an electrosensitivity mechanism. It has an excellent sense of hearing and smell which compensates for eyesight that degenerates with age. The olm is classified as Vulnerable on the IUCN Red List, owing to small and fragmented habitat and susceptibility to pollution [46].

Plate 30. *Rhinoderma darwinii*.
Fitzinger: Bilder-Atlas zur wissenschaftlich-populären Naturgeschichte der Amphibien in ihren sämmtlichen Hauptformen. 1864.

The Surinam toads (genus *Pipa*) and Darwin's frogs (genus *Rhinoderma*) have both evolved remarkable reproductive strategies. Surinam toads diverged from their closest relatives around 120 million years ago. The male fertilises the eggs on the female's back, after which the skin around the eggs swells until they are encased as developing embryos. Here they remain throughout the tadpole stage before bursting out of her back as developed froglets. While most Surinam toads are classified as Least Concern, Myers' Surinam toad (*Pipa myersi*) is classified as Endangered.

The genus *Rhinoderma* has just two species: Chile Darwin's frog and Darwin's frog, both of which are mouth-brooding frogs. After the eggs are fertilised and guarded by the male Darwin's frogs, the tadpoles are ingested by the male and spend several weeks in his vocal sac metamorphosing, until they hop out of his mouth as developed froglets. Chile Darwin's frog eggs are also swallowed by the male into his vocal sac, where they remain until the tadpoles develop jaws and digestive systems, whereupon they are released into suitable freshwater habitat to continue metamorphosis. Chile Darwin's frog is listed as Critically Endangered, although recent surveys suggest this frog may already be extinct.

Evolution lost

According to the IUCN Red List of Threatened Species, a total of 37 extinctions have been listed for amphibians, with an additional two species assessed as Extinct in the Wild. However, in total there are currently a further 157 amphibian species which, although officially classified as Critically Endangered, are feared extinct [46].

Some of the most recent species to have disappeared include the gastric brooding frogs, *Rheobatrachus silus* and *Rheobatrachus vitellinus*, both of which disappeared in the mid-1980s. This was the only known genus where the female incubated her young in her stomach. The reasons for decline are unknown, although habitat loss, invasive species and chytrid fungus are all suspected contributing factors [46]. Another famous recent amphibian disappearance is the golden toad (*Incilius periglenes*). This previously common toad was found in the tropical forests of Costa Rica and huge declines have been attributed to restricted range, pollution, climate change and/or chytrid fungus. The last individual of this brightly coloured and charismatic species was recorded in 1989 [46].

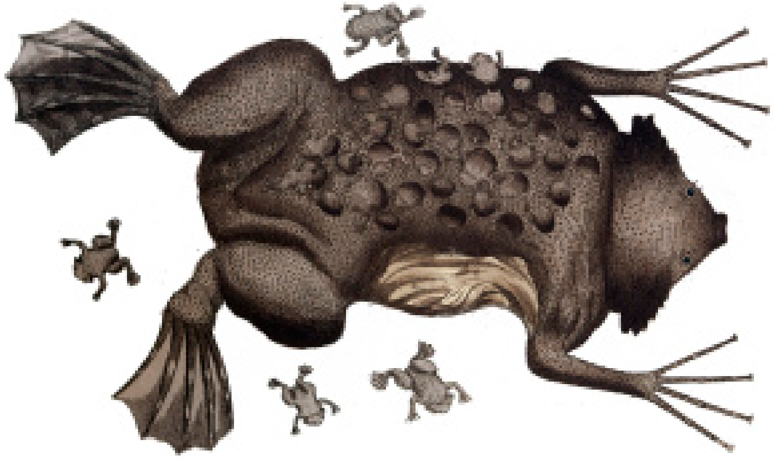


Plate 31. *Pipa pipa*. Shaw: The naturalist's miscellany. 1790.

Evolution Lost case study

*One of the few amphibian species believed to have disappeared before the late 20th century is the Las Vegas Valley leopard frog (*Lithobates fisheri*, formerly* Rana fisheri*). This species is part of a cryptic species complex of closely related large, black-spotted green frogs distributed across North and Central America, which show complicated patterns of geographical and morphological variation that have presented a major challenge to taxonomists and a fascinating case study for evolutionary biologists [74].*

*The Las Vegas Valley leopard frog was first described in 1893 and had a very restricted range, only being known from springs and streams isolated by surrounding desert in the northern part of Las Vegas Valley in Clark County, Nevada. The last two specimens of the species were collected in 1941, and although the following year the splashes of unidentified frogs jumping into the water were heard by two visiting herpetologists, A. A. Wright and A. H. Wright, no leopard frogs were seen [75]. The disappearance of the species is probably associated with depletion of spring water and ground water accompanying the major urbanisation that took place in the Las Vegas Valley associated with the expansion of the city of Las Vegas from the 1940s onwards, following the legalisation of gambling in 1931. The Wrights reported that several of the springs where the leopard frog had formerly been found during the early 20th century had been replaced by a municipal golf course and a fish hatchery. The regional introduction of bullfrogs (*Lithobates catesbeianus*), crayfish and game fish may also have contributed to the disappearance of the leopard frog.*

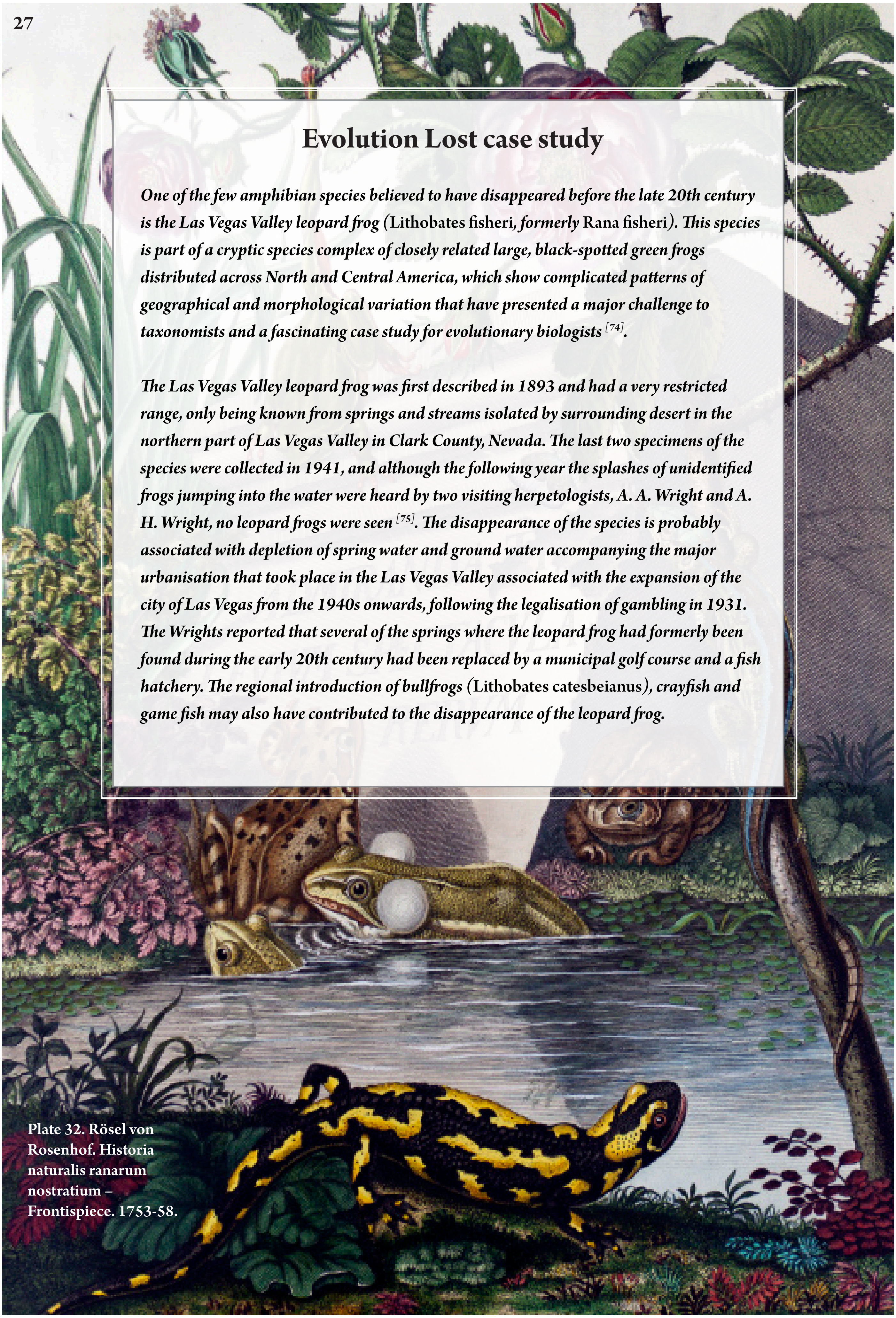


Plate 32. Rösel von Rosenhof. Historia naturalis ranarum nostratium – Frontispiece. 1753-58.

Conservation

Like all terrestrial vertebrates, habitat loss and degradation in the form of land conversion for agriculture, aquaculture, logging and urban development is by far the number one threat affecting most amphibians. Creating new protected areas and biological corridors and supporting those already in place to ensure proper management and enforcement, are key for the survival of many species, not just amphibians. This is particularly true given that the tiny range sizes of many amphibian species mean that safeguarding important sites is essential for their conservation; 408 amphibian species trigger the criteria for identifying Alliance for Zero Extinction sites holding the entire global population of at least one Critically Endangered or Endangered species, more species than any other taxon [76]. In addition, less conventional approaches, such as private conservation areas, land-use agreements with environmentally conscious landowners, and community stewardship projects, are gaining traction and have the potential to be very effective in curbing habitat loss and degradation.

Addressing the spread and impact of chytrid fungus is also an important research and conservation action. Recent research developments have shown promising potential for in situ treatment of chytrid fungus. One research line suggests that natural bacteria may have an inhibiting effect on the fungus, while another, more recent research line suggests that reducing fungal loads may increase the odds of population persistence. These results are encouraging, as up until recently it was thought that there was no way to address the effects of chytrid fungus in the wild.

Field work encompassing population management approaches (for example, removal of individuals, application of bacteria or antifungal components) has the potential to affect the dynamics of chytrid fungus and therefore the survival of populations in the wild.

Although comparatively lower on the scale of threats, amphibian harvesting and trade, both at the international and regional levels is a subject that is gaining increasing attention. Recent studies are strongly suggestive that amphibian harvest and trade levels are on the increase, are likely unsustainable and have so far gone largely unregulated and unmonitored. In addition, the existing international harmonised trade coding system is inadequate for capturing detailed trade information. Monitoring, reporting and certification of amphibians in trade as well as a revision of the existing trade code, are all necessary to better document current patterns and inform conservation actions.

Perhaps no action is quite as important as informing and involving the general public in the plight facing amphibians. Much of the challenge in amphibian conservation is successfully engaging a diverse range of stakeholders in the amphibian crisis in a sustained manner, so public outreach and educational programmes are very urgent actions.

Plate 33. *Xenopus laevis* & *Pipa pipa*. Fitzinger: Bilder-Atlas zur wissenschaftlich-populären Naturgeschichte der Amphibien in ihren sämmtlichen Hauptformen. 1864.

Reptilia

Plate 34. *Anolis carolinensis*. Catesby:
The natural history of Carolina, Florida and the Bahama Islands. 1731-43.

Reptilia

Evolutionary History of Reptiles

Editors: Neil Cox, Monika Böhm and Peter Paul van Dijk

Reptiles are a diverse vertebrate group that breathe air, lay tough-shelled eggs (although some are live-bearing) and have skin covered with scales. They have been a key component of terrestrial biodiversity since the Late Palaeozoic era and are the group from which both birds and mammals have evolved. The first true reptilian amniotes (vertebrates that lay amniotic eggs) evolved from labyrinthodont amphibians during the Carboniferous period around 320-310 million years ago, but they remained a small, relatively inconspicuous part of the terrestrial vertebrate fauna until the subsequent Permian period, when they diversified into a wide range of ecomorphs - morphologically adapting to the changing environment [77-78].

Plate 35. *Iguana iguana*. Catesby: The natural history of Carolina, Florida and the Bahama Islands. 1731-43.

Different reptile groups are defined by the number of openings they possess in the temporal region of the skull. The earliest reptiles, the anapsids, lacked any temporal openings. The amniotes subsequently diverged into two major lineages, each with more openings in the back of the skull to accommodate jaw musculature and permit a more powerful bite: the synapsids (with one temporal opening) and the diapsids (with two temporal openings). Other than turtles and tortoises, all living "reptiles" – crocodiles, lizards, snakes and tuatara – are diapsids, and during the Mesozoic era the archosaur lineage of diapsids also evolved into dinosaurs and birds. There are just over 9,000 species of reptile alive today [16]. The largest living species is the saltwater crocodile, but the largest dinosaurs exceeded 100 tonnes in body mass [79].

Biogeography of Reptiles

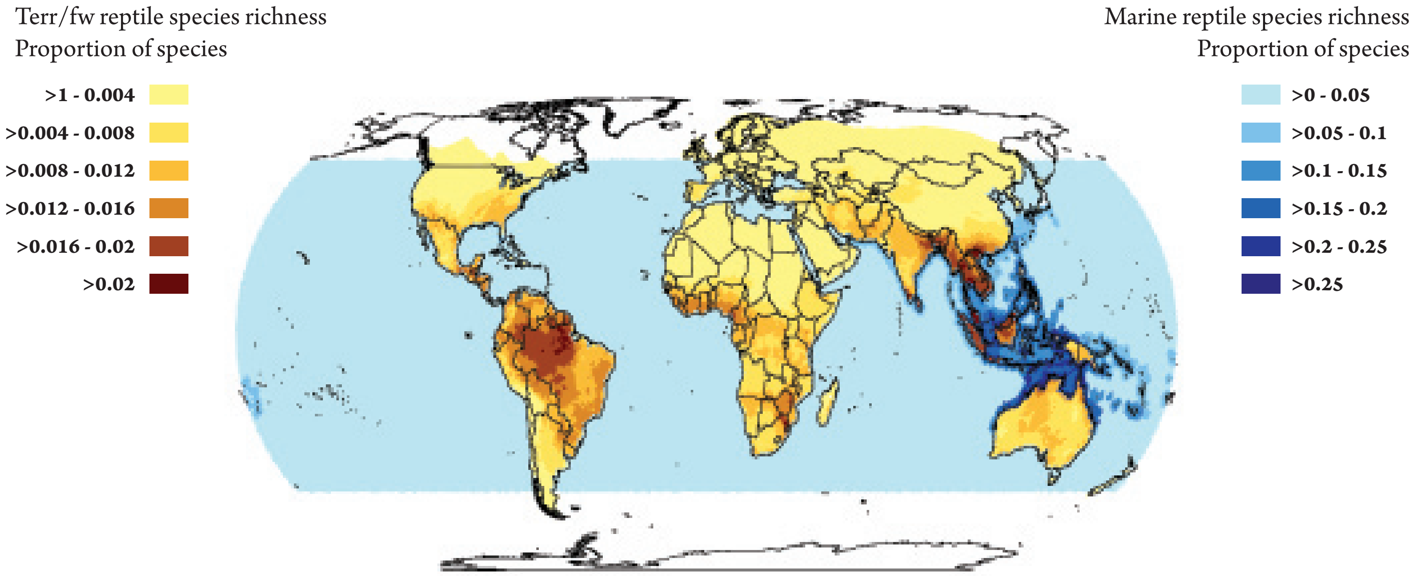


Figure 21: Global species richness of reptiles, based on an assessment of 1,496 reptile species. 'Terr' idicates terrestrial species and 'fw' indicates freshwater species.

As yet, the global assessment of reptiles has not been completed, and the Sampled Red List approach [15, 18] has been used to provide an indication of the current status of reptiles. The sample is sufficient to provide a global indication of the status of the group and its major threats, but may underrepresent some geographic areas where number of species or threatened species is relatively low.

Although reptiles are often the dominant vertebrates of arid regions, most species are distributed in the tropical forests of southeast Asia and South America (figure 21). Indonesia has the highest species richness of reptiles, although many other species-rich regions, such as the Congo basin are lacking in thorough reptilian surveys, and might yield higher species counts in the future. The marine reptiles, predominantly sea snakes, marine turtles and crocodilians, reach their highest diversity in the Indo-west Pacific, central Indo-Pacific, South China and Coral seas [80].

Plate 36. *Alligator mississippiensis*. Catesby: The natural history of Carolina, Florida and the Bahama Islands. 1731-43.

Status of reptiles

An assessment of a representative sample of 1,500 species suggests that nearly 22% of the world's reptiles are threatened with extinction. This estimate assumes that Data Deficient species are threatened in the same proportion as data sufficient species. Estimates range from 18% if all Data Deficient species are not threatened to 37% if all Data Deficient species are threatened [80]. The IUCN Red List pie chart in figure 22 shows 18% of reptile species are threatened, which is the lowest estimate. Just over half of the world's assessed reptiles are categorised as Least Concern. More research is needed to determine the status of the remaining 19.2% of sampled Data Deficient reptiles. The conservation status of reptiles varies greatly between groups; in particular, a high proportion of crocodilians and chelonians are threatened compared with a relatively lower number of snakes.

The highest species richness of threatened reptiles are found in the tropics, particularly in south and southeast Asia and the Ganges basin (figure 23) where extensive habitat loss and overexploitation have taken place [24, 81].

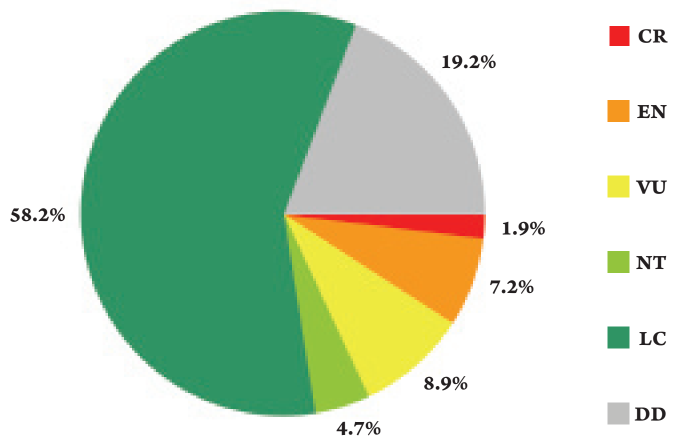


Figure 22: IUCN Red List assessment of reptiles (1,500 species assessed)

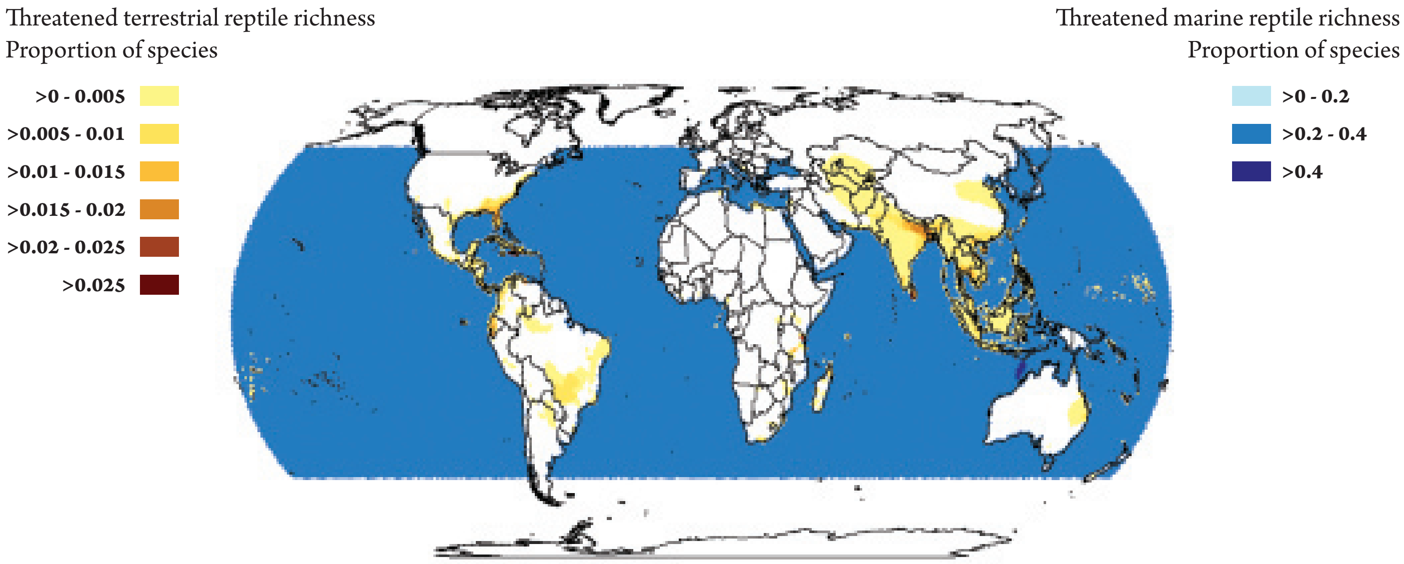


Figure 23: Global species richness of threatened reptiles, based on an assessment of 235 reptile species

Plate 37. *Dermochelys coriacea*. Fitzinger: Bilder-Atlas zur wissenschaftlich-populären Naturgeschichte der Amphibien in ihren sämmtlichen Hauptformen. 1864.

Trends in reptile populations

The Living Planet Index for reptiles tracks trends in 249 populations of 71 reptile species and indicates that the numbers of reptiles have fluctuated over time, but with an overall decline of around 7% (figure 24). It should be noted that the dataset is relatively small and the confidence intervals are large. However, with 18% of the world's reptiles threatened with extinction, it is likely that if major population declines have not already occurred, they can be expected in the near future. This figure for the whole Class also masks the rapid decline in certain orders such as turtles and tortoises, and worrying signs are being seen in certain regional-scale analyses of snakes [82], though such findings are yet to be corroborated at a global level.

Threats to reptiles

Habitat loss is by far the greatest threat to reptiles, principally in the form of agricultural expansion, logging and urban development resulting in habitat degradation or loss of range (figure 25). Hunting, trapping and overharvesting are particular threats to non-terrestrial reptiles (especially turtles), with species subject to overexploitation for both consumption and the pet trade. Terrestrial tortoises are also affected by such targeted collection, putting the entire order at risk.

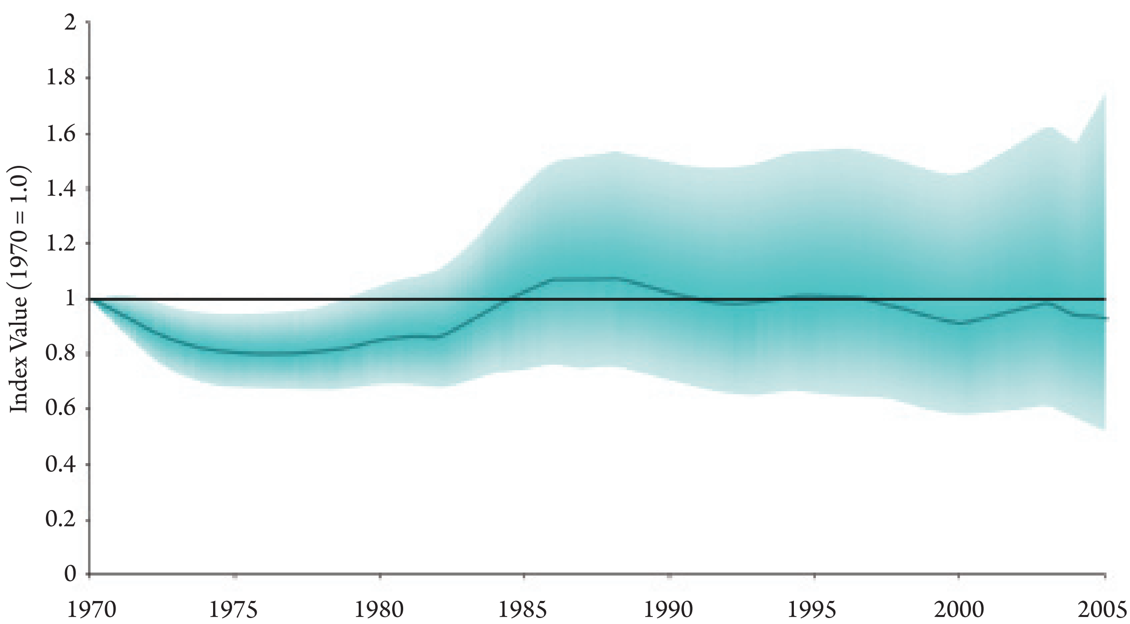


Figure 24: Living Planet Index for reptiles (249 populations of 71 species). Index value shown in bold line, shaded area shows 95% confidence limits.

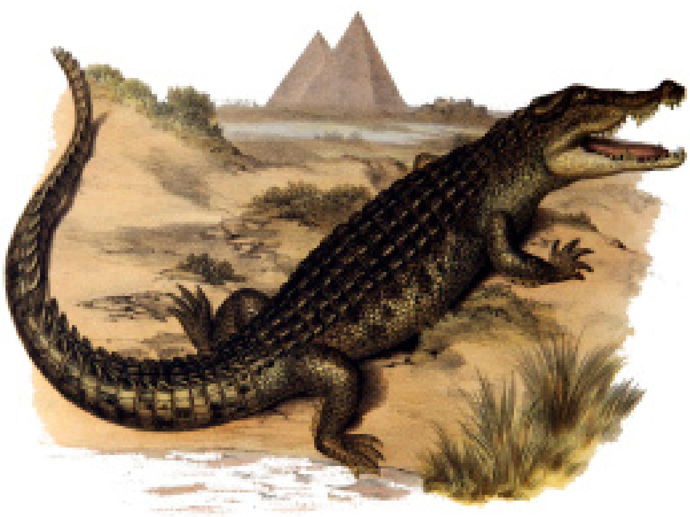


Plate 38. *Crocodylus niloticus*. Fitzinger: Bilder-Atlas zur wissenschaftlich-populären Naturgeschichte der Amphibien in ihren sämmtlichen Hauptformen. 1864.

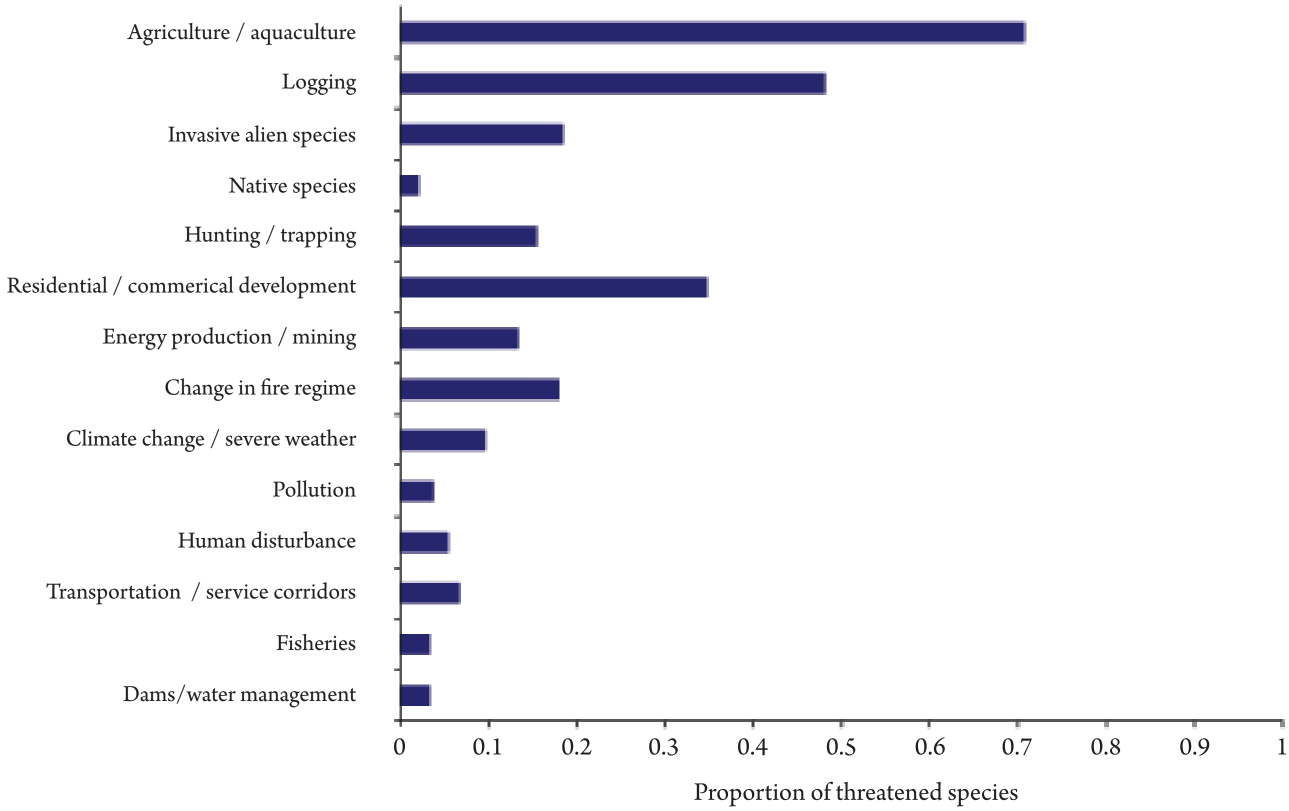


Figure 25: Global threats to reptile species. Horizontal axis shows the proportion of threatened (CR, EN, VU) species affected by each of the threatening processes on the vertical axis.
Note - these numbers may add up to more than 1 because species are often affected by multiple threats.

Plate 39. *Sistrurus miliarius*. Catesby: The natural history of Carolina, Florida and the Bahama Islands. 1731-43.

Evolutionarily Distinct and Globally Endangered (EDGE) Reptiles

The Brothers Island tuatara (*Sphenodon guntheri*) is one of the most evolutionarily distinct and globally endangered reptiles. It is one of only two species that make up the order *Sphenodontia* [83]. Both species of tuatara (which may possibly be geographic variants of the same species) are limited in distribution to the islands off mainland New Zealand. Although many more members of this order are known from the fossil record, these are now extinct and therefore the genus *Sphenodon* represents 200 million years of distinct evolutionary history.

Tuatara has the literal meaning 'peaks on the back' in Maori, referring to a defining characteristic of the tuatara: to the distinct crest of large triangular scales running over the spine. They have a unique combination of unusual attributes, including the presence of a 'third eye' which is thought to be used for absorbing and sensing ultraviolet light; the lack of an external ear, yet possession of adequate hearing; the lack of a penis in males, thus mating differently from all other reptiles; two rows of teeth in the upper jaw; and young tuatara are diurnal hunters, possibly in response to the nocturnal, cannibalistic behaviour of adults. Tuataras are believed to have the slowest growth rate of all reptiles. Growing for the first 35 years of life, they are believed to have a lifespan of around 100 years, although a captive male tuatara recently became a father for the first time at the age of 111.

The Brothers Island tuatara (*Sphenodon guntheri*) is currently categorised as Vulnerable and the Cook Strait tuatara (*Sphenodon punctatus*) is categorised as Least Concern, although reassessments are required. Conservation measures are currently focusing on pest and predator removal from the islands inhabited by tuatara and on habitat restoration efforts.

The Central American river turtle (*Dermatemys mawii*) is a large, completely aquatic turtle from southern Mexico, Belize and Guatemala. It is the last surviving species of the family Dermatemydidae, a family that once had a wide distribution across what is now North America dating back to the Eocene Epoch around 34-56 million years ago. It is intensively exploited for its meat, which is particularly in demand during Easter. It is now classified as Critically Endangered [46].

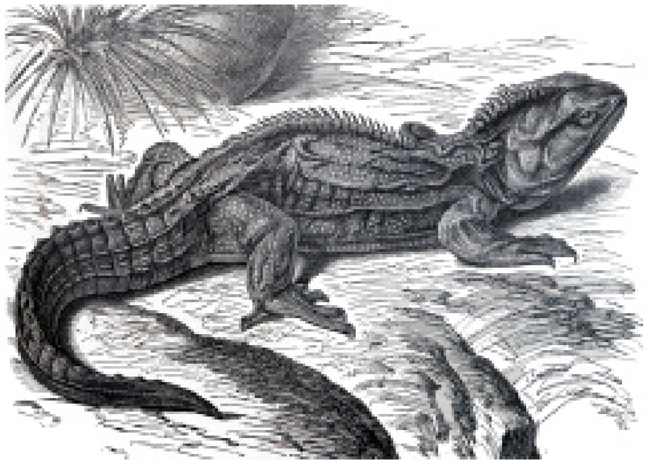


Plate 40. *Sphenodon*. Lydekker: The royal natural history. 1896.

The gharial (*Gavialis gangeticus*) is the only remaining species in the ancient family Gavialidae, and with fewer than 250 mature breeding individuals left in the wild, this reptile is classified as Critically Endangered by the IUCN. One of the largest of the crocodiles, the male gharial can grow 6-7 metres in length. The gharial has a characteristic long snout and mature males also have a ghara on the end of the snout: a bulbous growth that can make a buzzing noise as air passes through the nasal passage. Gharials have sensory organs on the scales of their lower body which are considered to act as salinity receptors and have dermal pressure receptors on the scales along the jaw to detect prey vibrations [84]. Once found in regions of south Asia, the gharial is now only found in India and Nepal and is threatened with habitat destruction and illegal fishing methods [46].

Evolution Lost case study

Although the giant tortoises of the Galápagos Islands (genus Geochelone*) are scientific icons, most famous for having helped Charles Darwin to recognise the process of evolution through natural selection, evolutionary radiations of giant tortoises are also characteristic of many other island faunas. The only other surviving insular giant tortoises (genus* Aldabrachelys *and* Dipsochelys*) are found today on the Seychelles, but five other Indian Ocean species of giant tortoise in the extinct genus* Cylindraspis *also survived on the Mascarene Islands until the arrival of European traders and settlers in the historical era. These tortoises reached the remote Mascarene Islands by overwater dispersal from Madagascar (which was also home to giant tortoises until the arrival of the first humans), whereby they became the dominant terrestrial herbivores of Mascarene ecosystems. In the absence of any native land mammals, they lost many anti-predator adaptations: they had no heavy scales on their fore and hind limbs and their shell was very thin (typically only 2 mm in thickness). A similar loss of anti-predator adaptations is also displayed to a lesser extent by Galápagos tortoises, and tortoises on both island groups show the repeated convergent evolution of animals with characteristic saddleback shells, which may confer an adaptive advantage in dry, open, shrubby habitats.*

*Early visitors to the Mascarene Islands reported the presence of huge numbers of tortoises which were soon massively overexploited for food. One 18th century traveller to Rodrigues reported that "in the three and a half months that I spent on the island, we ate almost nothing else: tortoise soup, fried tortoise, stewed tortoise, tortoise eggs, tortoise liver". Oil was extracted by boiling the tortoises in huge numbers, with 400-500 animals needed to make a single barrel. Similar numbers of tortoises were also loaded onto ships to provide food for ongoing sea voyages. Interestingly, whereas there was little contemporary interest in the existence or fate of the dodo (*Raphus cucullatus*) – now the most famous extinct species from the Mascarenes – the ongoing slaughter of giant tortoises elicited comment from numerous observers and led to protective legislation on Réunion in 1671. Other historical commentators blamed introduced mammals such as pigs and cats for destroying tortoise nests and killing their young. Tortoises became extinct on Mauritius and Rodrigues during the 18th century, and the last survivors of this evolutionary radiation persisted until the 1840s on Réunion [87].*

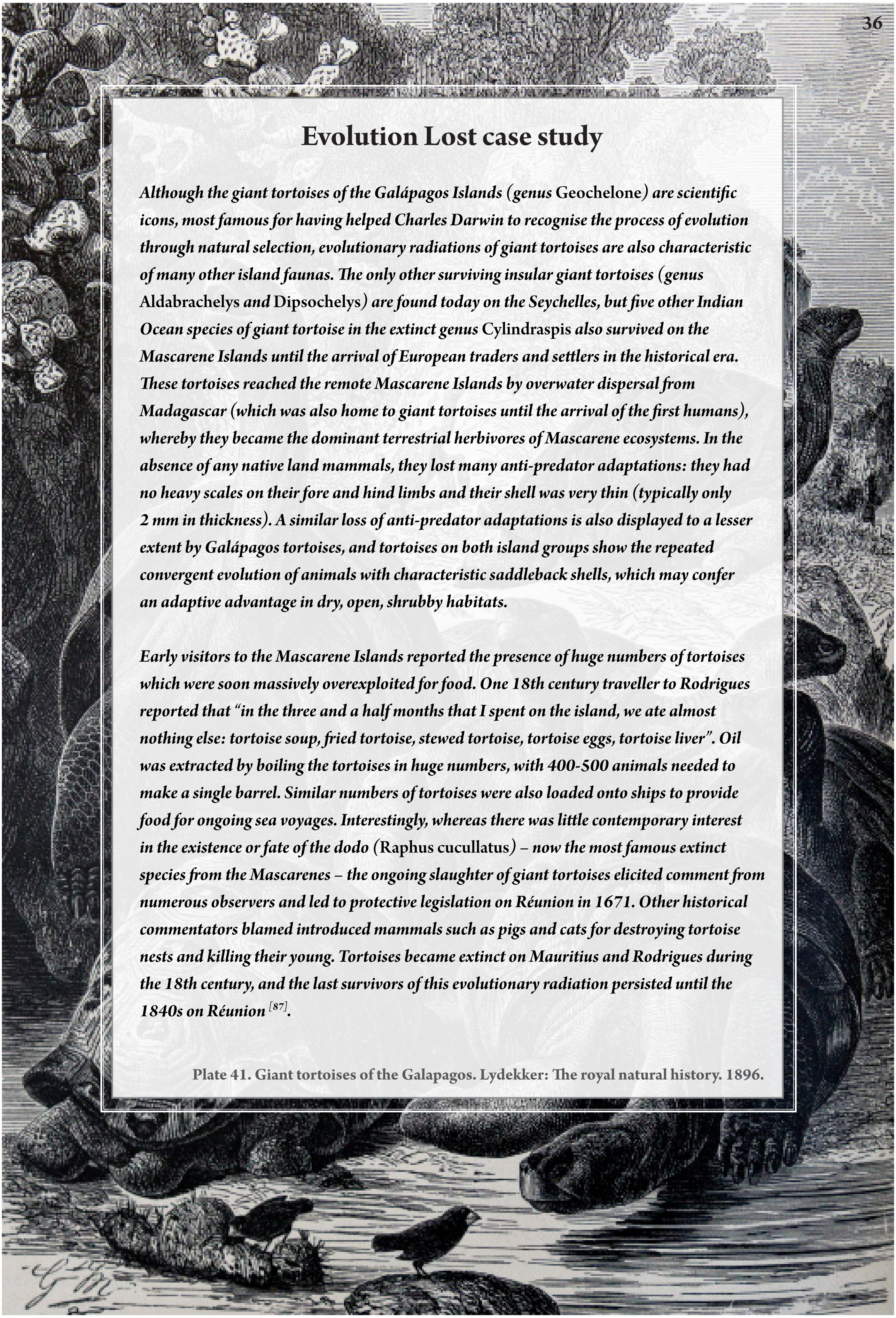


Plate 41. Giant tortoises of the Galapagos. Lydekker: The royal natural history. 1896.

Evolution lost

According to the IUCN Red List of Threatened Species, 20 reptile species have become Extinct and one species Extinct in the Wild since 1500 AD [46].

Examples of evolutionarily distinct species that have already disappeared included three monotypic (single species) genera of reptiles. The Round Island boa (*Bolyeria multocarinata*) from Mauritius formerly inhabited the topsoil layers of palm forests. The introduction of rabbits and goats in 1840 resulted in the overgrazing and deterioration of this habitat and the species has not been recorded since 1975 [85]. The Cape Verde giant skink (*Macroscincus coctei*) appears to have been restricted in range to the desert islands of Brancho and Razo (Cape Verde) in the Atlantic Ocean. The leading causes of extinction are believed to be prolonged drought and overharvesting of the species for food and medicinal use by people from neighbouring islands. It was last recorded in the early 20th century [46]. The large-bodied Tongan ground skink (*Tachygyia microlepis*), known from only two specimens, is likely to have become extinct following extensive habitat conversion from native forest to agricultural land, through predation by introduced animals and possibly also because of earlier hunting by people for food [46, 86].

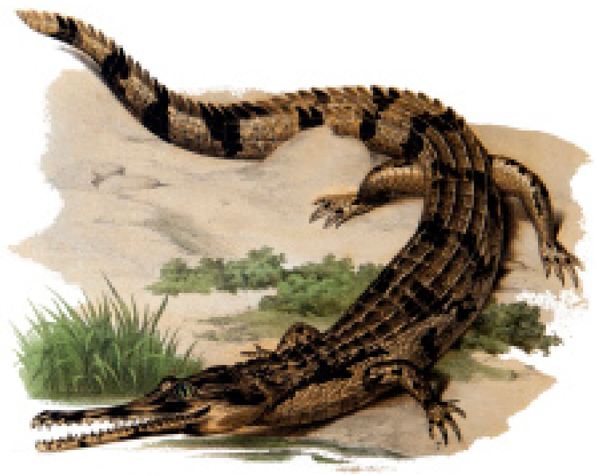


Plate 42. *Tomistoma schlegelii*.
Fitzinger: Bilder-Atlas zur wissenschaftlich-populären Naturgeschichte der Amphibien in ihren sämmtlichen Hauptformen. 1864.

Conservation

As with other vertebrate groups, habitat loss and fragmentation remain the main threats to reptile species and conservation responses in this regard are similar to those outlined for amphibians. The now undeniable warming of the world's climate is increasingly recognised as a threat to reptile species. A recent study suggests that as many as 40% of global lizard populations could be extinct primarily due to climate change by 2080 [88]. Many reptile species have temperature-dependent sex determination, and the effects of changing temperatures on population dynamics may be significant. The clearly identified solution to this global problem for life is the reduction of carbon emissions through the adoption of renewable energy sources and the conservation and restoration of remaining tracts of forest.

Reptiles are frequently harvested or trapped by people for their meat, skin, venom or for the pet trade. The utilisation of reptiles ranges from subsistence collection (often by some of the world's poorest people) to large-scale commercial international trade. Regulated sustainable trade (with appropriate levels of monitoring and enforcement) can benefit the conservation of reptile species. International trade in several reptile groups, most especially turtles and crocodilians, is monitored and regulated by the Convention on International Trade in Endangered Species. It is hoped that where species are seen to be of commercial value the incentive will exist to maintain viable populations.

Some reptile species, most notably snakes, are frequently persecuted by people. Snakes are regularly killed on sight regardless of whether they pose a threat to people or not. In many instances the species may be beneficial to people through their predatory control of mice, rats and other vermin. Only through better education of people to lessen the fear associated with snakes and stimulate an appreciation for their ecological role will this ancient threat be mitigated. The introduction of animals and plants outside of their natural ranges is a well-known threat to many species and reptiles are no exception. Introduced pigs and other exotic mammalian predators are major factors in the decline of turtle and other reptile species. Control programmes of invasive species can be costly, but may represent the last hope for many reptiles.

Mammalia

Plate 43. *Petaurista petaurista*.
Gould: The mammals of Australia. 1863.

Mammalia

Evolutionary History of Mammals

Editors: Luigi Boitani and Carlo Rondinini

Plate 44. *Tarsipes rostratus*.
Gould: The mammals of Australia. 1863.

Whereas reptiles and birds represent the sauropsid lineage of the amniotes, mammals have evolved from the second amniote lineage: the synapsids or "mammal-like reptiles". The earliest synapsid group from the Carboniferous and Permian periods were the dominant land vertebrates for around 40 million years. These animals had fairly standard reptilian physical characteristics with a sprawling gait, although several carnivorous and herbivorous species possessed tall 'sails' on their backs, consisting of elongated vertebral spines covered with skin which may have evolved for thermoregulation or display [3]. Subsequent reptilian synapsids, the therapsids, show adaptations towards progressively becoming warm-blooded and having a higher metabolic rate and upright gait, probably associated with selective pressures for an active carnivorous lifestyle [89]. Because modern mammalian soft-tissue features such as hair and mammary glands are not preserved in the fossil record, the appearance of the first true mammals during the Mesozoic era is defined by the pattern of evolution of the bones of the inner ear; in non-mammalian synapsids, the malleus and incus bones are still attached to the jaw joint, but in true mammals these bones have moved to the middle ear to amplify sounds and allow more acute hearing [89].

The first true mammals appeared during the Late Triassic or Early Jurassic period around 210 million years ago. By this time in Earth's history, terrestrial ecosystems were dominated by dinosaurs and other sauropsids, and although Mesozoic mammals diversified into several successful groups, they generally remained small-bodied and probably nocturnal. The largest known Mesozoic mammal, *Repenomamus giganticus*, was about the size of a Tasmanian devil (about 12 to 14 kg) and fed on juvenile dinosaurs [90]. Following the extinction of the dinosaurs 65 million years ago, mammals underwent a major evolutionary radiation [91-92], though modern molecular evidence suggests that the foundations for the evolutionary radiation of present-day mammals may have been laid much earlier [93]. Regardless, mammals came to dominate terrestrial ecosystems, with some lineages evolving powered flight and secondarily re-colonising aquatic ecosystems. Modern mammals range in body mass from the 1.6 gram Kitti's hog-nosed bat to the 160 tonne blue whale.

Living mammals are classified into three major groups, defined primarily by different reproductive strategies. Monotremes lay eggs instead of giving birth to live young; marsupials give birth to small, relatively undeveloped young, which are then carried in a pouch; and placentals, the most diverse living mammal group, give birth to larger, well-developed young that typically require a reduced amount of postnatal provisioning. There are over 5,000 species of living mammals arranged into 29 orders [94], though estimates suggest that more than 7,000 living species of mammals may eventually be recognised [95].

Plate 45. *Balaena mysticetus*. Fitzinger: Bilder-Atlas zur wissenschaftlich-populären Naturgeschichte der Säugethiere in ihren sämmtlichen Hauptformen. 1860.

Biogeography of Mammals

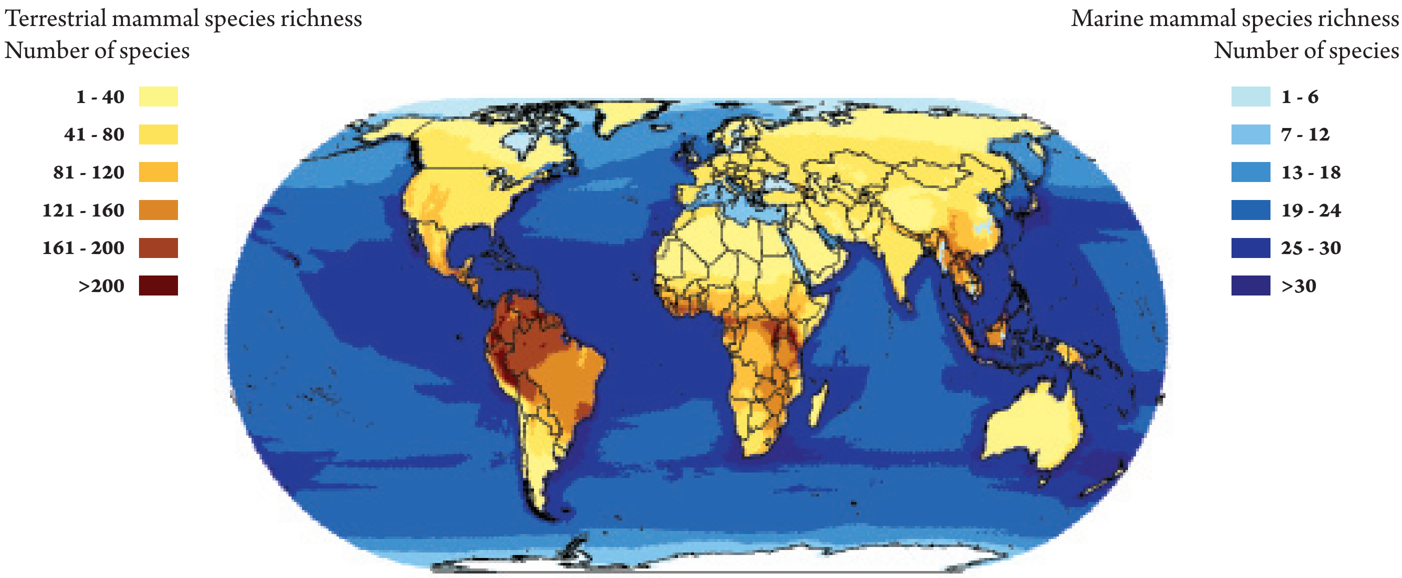


Figure 26: Global species richness of mammals, based on an assessment of 5,424 mammal species

Mammals are found across the world's terrestrial and aquatic environments (figure 26). South America, sub-Saharan Africa and southeast Asia contain the highest concentrations of species of terrestrial mammals, with the highest species richness found in the tropical rainforests of Brazil and Indonesia. Although aquatic mammals are found in every ocean, continental coastlines are the areas of the highest species richness.

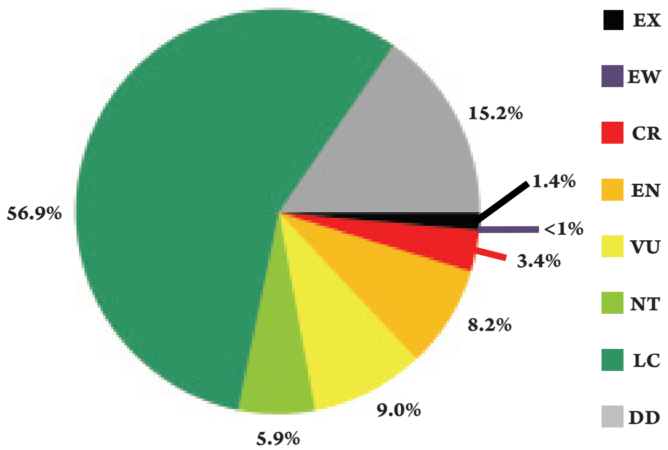


Figure 27: IUCN Red List assessment of mammals (5,489 species assessed)

Status of mammals

The IUCN Red List assessment of the world's mammals indicates 25% of mammal species are threatened with extinction. This estimate assumes that Data Deficient species are threatened in the same proportion as data sufficient species. Estimates range from 21% if all Data Deficient species are not threatened to 36% if all Data Deficient species are threatened [12, 46]. The IUCN Red List pie chart in figure 27 shows that 21% of mammal species are threatened, which is the lowest estimate. Of the mammal species classified as Data Deficient, 80% are found in the tropics. Tropical regions are undergoing some of the most rapid rates of land conversion and are subject to widespread development.

Bats and rodents are the two most numerous orders of mammals, but the highest proportion of threatened species are found in the Monotremata (egg-laying mammals) and Perissodactyla (odd-toed ungulates).

The greatest species richness of threatened terrestrial mammals is found in southeast Asia which is undergoing rapid rates of habitat degradation [24, 81]. The countries with the most threatened species include Mexico, Indonesia, Brazil, Papua New Guinea and Vietnam, and they are therefore the countries where conservation efforts should be focused in the following decades. The greatest species richness of threatened aquatic mammals is found around the coastal regions of Asia, Japan and in the north Atlantic and north Pacific, all regions that have been historically subject to intense overfishing (figure 28) [39].

Trends in terrestrial mammal populations

The Living Planet Index of terrestrial mammals tracks the fate of 1,307 populations of 360 terrestrial mammal species and shows a steady decrease in global abundance since the 1990s, with an overall 25% reduction (figure 30). Marine mammals are currently omitted from this analysis as the data are too sparse to make a robust index; however, cetaceans have experienced a well-documented dramatic decline over the past century [96].

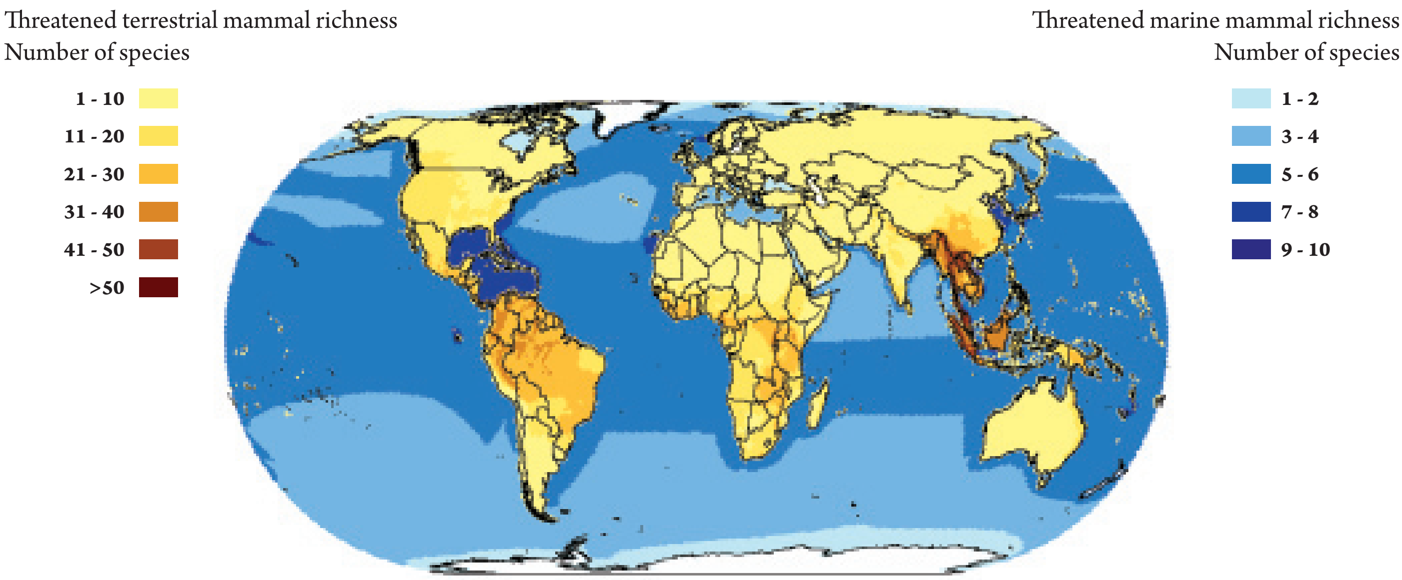


Figure 28: Global species richness of threatened mammals, based on an assessment of 5,424 mammal species

Threats to mammals

Globally, the highest proportions of terrestrial mammals are located in forest habitats and the majority of aquatic mammals are found in inland wetlands. With increasing deforestation and coastal development, habitat destruction is the biggest threat to all terrestrial mammal species (figure 29), especially from logging, wood harvesting and small-holder farming. Another threat to mammals is overexploitation. Hunting, both for sport and subsistence of local human populations and for use in traditional medicines, is threatening the future of numerous species. All of these threats are directly linked to the growth of human populations and their increasing exploitation of wild habitats and species.

Plate 46. *Rhinolophus megaphyllus*.
Gould: The mammals of Australia. 1863.

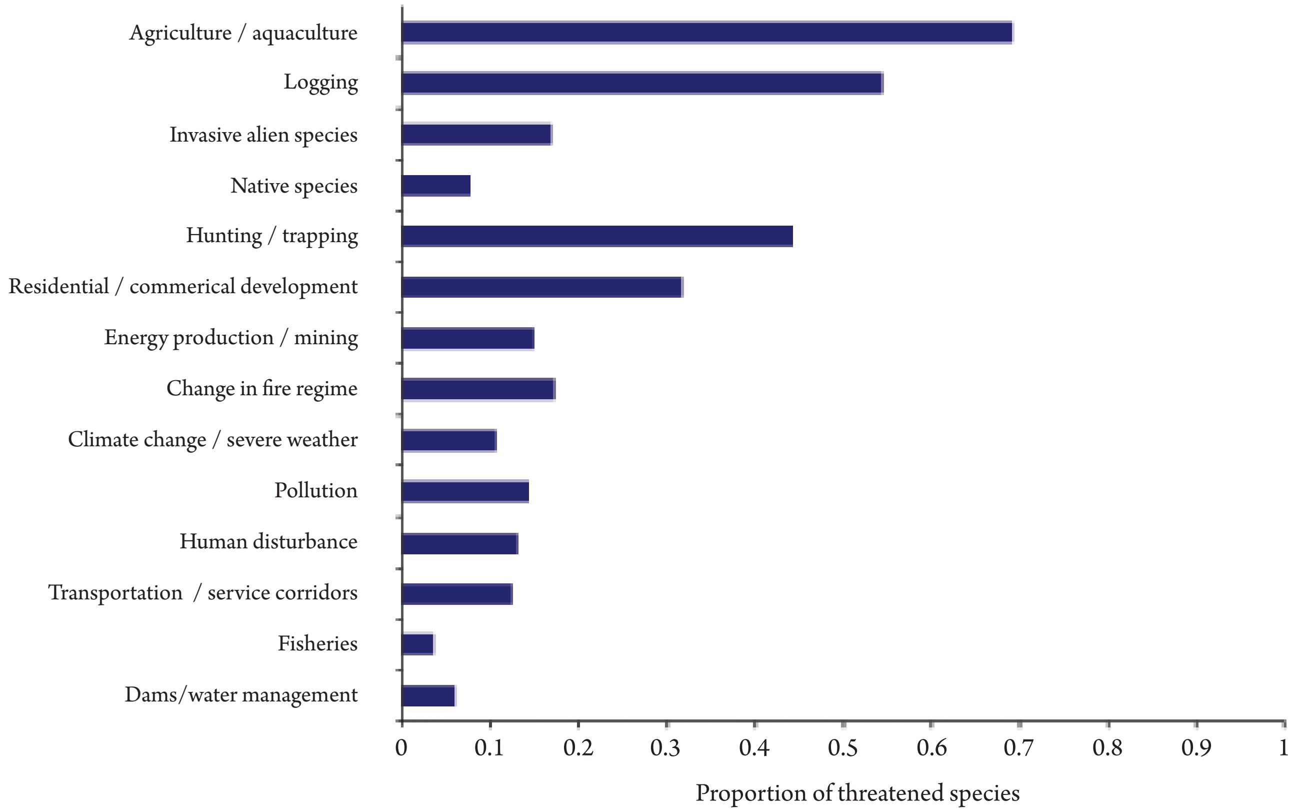


Figure 29: Global threats to mammal species. Horizontal axis shows the proportion of threatened (CR, EN, VU) species affected by each of the threatening processes on the vertical axis. Note - these numbers may add up to more than 1 because species are often affected by multiple threats.

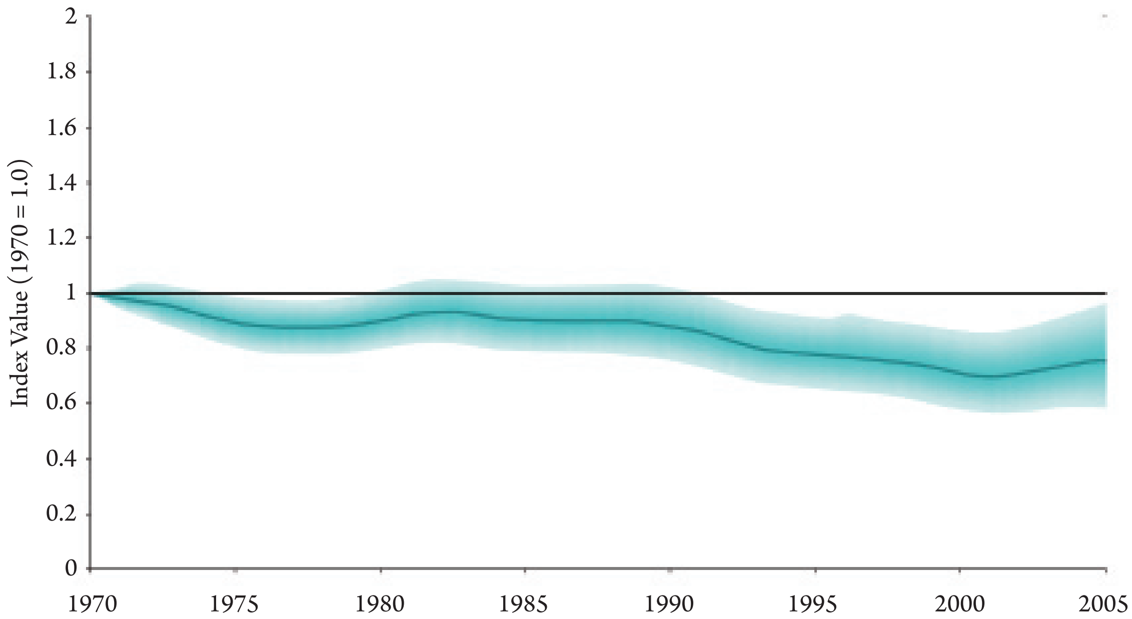


Figure 30: Living Planet Index for terrestrial mammals (1,307 populations of 360 species). Index value shown in bold line, shaded area shows 95% confidence limits.

Evolutionarily Distinct and Globally Endangered (EDGE) Mammals

Monotremes are the most ancient lineage within modern mammals, having diverged before the evolution of many characteristic mammalian features such as giving birth to live young. The only surviving members of this clade are the duck-billed platypus and four echidna species.
The three long-beaked echidnas are endemic to New Guinea (*Zaglossus attenboroughi, Z. bartoni* and *Z. bruijnii*). These species are covered in spines which become fully erect when threatened and they have long snouts which account for two-thirds of the length of the head and tongues covered in spikes in lieu of teeth. With huge population decreases and a threat of habitat loss and traditional hunting using trained dogs, all three long-beaked echidna species are now classified as Critically Endangered [46]. Increased awareness amongst local communities, full legal protection and educational and monitoring programmes are necessary to protect the 20 million years of evolutionary history represented by these echidnas and the 180 million years of evolutionary history represented by the ancient monotremes as a whole.

Plate 47. *Ornithorhynchus anatinus*.
Gould: The mammals of Australia. 1863.

Native to Madagascar, the fossa (*Cryptoprocta ferox*) has historically caused much confusion amongst taxonomists with its short dog-like muzzle yet sharp semi-retractable cat-like claws. An unusual characteristic of this species is its 'mating tree' system, whereby a single female climbs high up a tree and mates with a number of males who have congregated lower down the same tree. After a week, the female is replaced by another and the ritual continues, with the same select tree used for many breeding seasons, spanning numerous years. The fossa is now classified as the only extant species in the genus *Cryptoprocta* and its population is estimated to be around 2,500 individuals.

The mountain pygmy possum (*Burramys parvus*) is only found in three isolated and distinct populations at elevations above 1,400 metres in Australia's alpine region. This 45 gram nocturnal, hibernating marsupial has a range of around 7 km^2, which unfortunately also coincides with many downhill skiing resorts. This species is principally threatened with habitat loss due to urban developments for ski sports, though the effects of climate change are also predicted to have a significant impact on this species in the future. Classified as Critically Endangered, this possum has an estimated population of around 2,200 individuals and is the only extant species of the genus *Burramys*.

Plate 48. *Cryptoprocta ferox*.
Transactions of the Zoological Society of London. 1835.

Evolution lost

Seventy-six mammal species are classified as Extinct by IUCN, with a further two Extinct in the Wild since 1500 AD. However, many more have been classified as 'Critically Endangered: Possibly Extinct' [46], so may have been lost.

A number of evolutionarily distinct mammals have recently disappeared. The crescent nailtail wallaby (*Onychogalea lunata*) from central Australia was last reliably recorded in the1950s. This mammal was predated by foxes and cats and threatened by habitat loss and degradation. The Caribbean monk seal (*Monachus tropicalis*) has not been seen since 1952. The blue-grey mouse (*Pseudomys glaucus*) was last recorded in 1956. One of the most notable evolutionarily distinct species to disappear is the Guam flying fox (*Pteropus tokudae*) – the species has not been recorded with certainty since 1968. Hunted for food, its overexploitation was the probable cause for its demise [46]. However, it is extremely difficult to declare the final status for species that have not been seen for decades and could, theoretically, have survived in small pockets of habitat and at very low density [97-100].

Plate 49. *Dusicyon australis*.
Mivart: A monograph of the Canidae. 1890.

Conservation

The conservation of mammals – with ranges spanning all continents and oceans, with species ranging several orders of magnitude in size and occupying all types of ecological systems – is not an easy task. Like other vertebrate groups, effective protected area management combined with a landscape- or seascape-scale approach is the most important conservation action in the short term [103]. However, such efforts are under increasing pressure with growing global demand for forestry products, minerals, energy-related resources and bushmeat. The impact of climate change further complicates future strategies.

The need to face the immediacy of species surviving with few individuals has often captured most of the available conservation resources, especially when these species are large charismatic animals well known to the public. However, targeting highly threatened species is just one of the strategies for conservation and cannot remain the only one. There is an urgent need to re-integrate the conservation of rare populations with that of all mammals under a broader framework that can bring together effective policy and targeted research. This is the first and most important solution that we need to implement in order to optimise the limited financial resources available to conservation. Global databases featuring mammal distribution, threat categories and conservation needs are now available that would support this kind of approach, for example the Global Mammal Assessment. This provides a reference tool for large conservation non-governmental organisations and funding agencies to guide activities and international cooperation.

The conservation units and techniques that are currently available are likely to remain the core of most conservation action (endemic species, species which carry distinct evolutionary significance, protected areas, habitat management and restoration, exploitation control, economic incentives, compensation payments and so forth), but we also need to be more innovative on ad hoc solutions to fit ecological and socio-economic conditions at the country level. The mere application of the usual conservation tools without a global strategic framework may yield some success, but has shown limitations on a larger scale.

Evolution Lost case study

A species that is certainly extinct is the Falkland wolf or fox (Dusicyon australis), locally known as the warrah, and it remains one of the most enigmatic and poorly understood carnivore species. As island faunas typically lack mammalian carnivores, the wolf was the only land mammal found on the Falkland Islands, and the question of how the species reached these remote islands – which are approximately 480 kilometres from the South American mainland – has long been debated. The morphological characteristics of the Falkland wolf have been variously interpreted by different researchers as indicating a close phylogenetic relationship with South American foxes, North American coyotes or domestic dogs. It has sometimes been considered that the 'species' may in fact be nothing more than a feral dog population and the South American equivalent of a dingo, introduced to the islands by Amerindians. However, recent genetic analysis has revealed that the Falkland wolf is a distinct species that was in fact most closely related to the South American maned wolf (Chrysocyon brachyurus), and that different Falkland wolf specimens sampled for the study last shared a common ancestor around 330,000 years ago, indicating that the species had colonised the islands without human assistance by the late Pleistocene [101].

The Falkland wolf was first discovered in 1690 and was still relatively common when Charles Darwin visited the Falkland Islands in 1833. However, Darwin noted that "within a very few years after these islands shall have become regularly settled, in all probability this fox will be classed with the dodo, as an animal which has perished from the face of the Earth." As extinction was only widely recognised as a real phenomenon by the scientific community at the very end of the 18th century, Darwin's observation represents one of the first recorded instances of a historical observer realising that a particular species was in danger of extinction. The Falkland wolf displayed extreme naiveté towards humans, a trait commonly displayed by isolated island species, and was therefore very easy to catch and kill. Shortly after Darwin's visit, the species became exploited commercially for its fur. Following the introduction of sheep to the Falkland Islands by Scottish settlers, the wolves were further persecuted with poisoning campaigns. The last known Falkland wolf is believed to have been killed in 1876 [102]. Although live animals were exhibited by the Zoological Society of London in the 19th century, relatively few museum specimens of this intriguing species are known to exist.

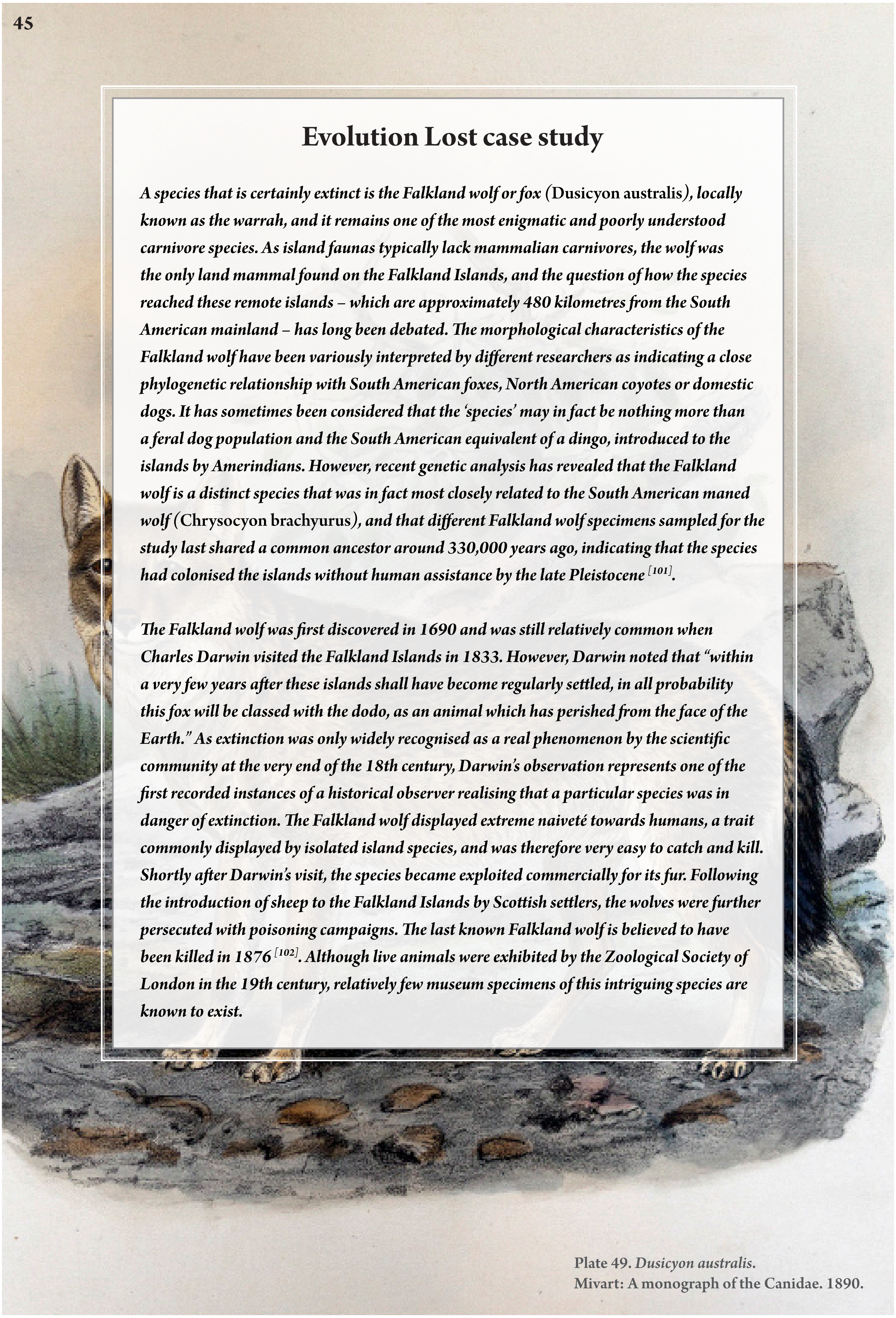


Plate 49. *Dusicyon australis*.
Mivart: A monograph of the Canidae. 1890.

Aves

Plate 50. *Epimachus fastuosus*.
Bowdler Sharpe: Monograph of the Paradiseidae. 1891-98.

Aves

Evolutionary History of Birds

Editors: Stuart H. M. Butchart, Thomas M. Brooks and Andy Symes

Insights from the fossil record about the first birds, and the evolution of flight have been a central topic in evolutionary biology for 150 years. In 1860, just one year after the publication of Darwin's "*Origin of Species*", a fossil bird feather was discovered in a limestone quarry containing late Jurassic deposits near Solnhofen in Germany. The first skeleton of the earliest known bird, the magpie-sized *Archaeopteryx*, was excavated from Solnhofen the following year. *Archaeopteryx* displays a mosaic of avian and reptilian features, including broad wings and feathers, jaws with sharp teeth, three fingers with claws and a long bony tail – making it a classic 'missing link' in evolutionary biology [104]. More recently, Early Cretaceous period fossil beds from northeast China have been found to contain a variety of fossils of early birds and feathered dinosaurs. These extraordinary fossils have helped to reconstruct the early evolutionary history of birds, and it is now generally accepted that birds evolved from small carnivorous dinosaurs [105]. Birds are therefore phylogenetically contained within the Dinosauria and represent the only dinosaurs to have survived the end-Cretaceous mass extinction 65 million years ago that still occur today.

Plate 51. *Strix aluco*. Gould: The Birds of Europe. 1837.

The Cenozoic era witnessed substantial evolutionary change and speciation among birds, and today there are over 10,000 species in 23 orders [106]. Birds are a highly diverse group, ranging from hummingbirds weighing just a few grams to the recently extinct flightless giant elephant birds (*Aepyornis*) and giant moa (*Dinornis*) which weighed over 250 kg [107]. Modern birds share defining characteristics: hard-shelled eggs, feathered plumage, a relatively lightweight skeleton and the presence of wings and toothless beaks.

Birds are found on all seven continents of the world; they have colonised all terrestrial and freshwater habitats and are found across all the world's oceans. An estimated 22% of extant bird species are migratory, many of which travel thousands of kilometres every year between breeding and wintering grounds. Many species are also dependent on single habitats, with forest habitats supporting around 75% of bird species. Shrubland grassland, savanna and inland wetlands also support a high number of species [108].

Biogeography of Birds

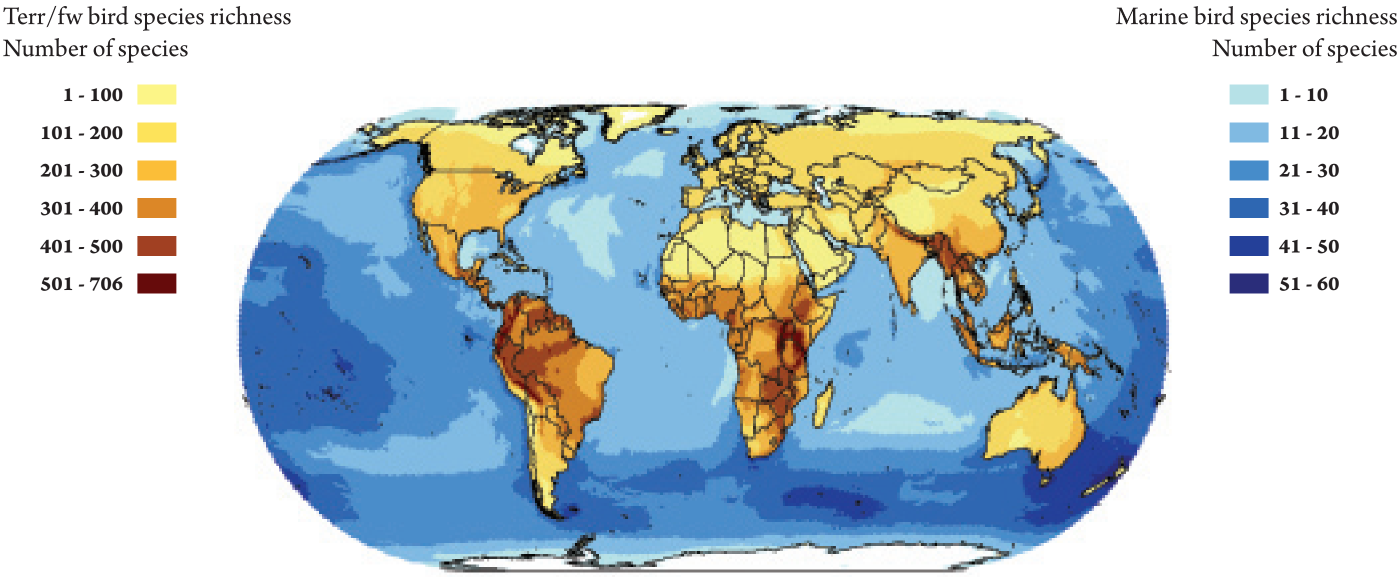


Figure 31: Global species richness of birds, based on an assessment of 9,899 bird species

The Neotropics hold the highest number of bird species (36% of all land bird species), particularly Colombia, Peru, Brazil and Ecuador. This is followed by the Afrotropical, Indomalayan and Australasian realms (figure 31).

Status and Trends of the World's Birds

Status of birds

Thirteen percent of bird species are threatened with extinction. This estimate assumes that Data Deficient species are threatened in the same proportion as data sufficient species. Estimates range from 12% if all Data Deficient species are not threatened to 13% if all Data Deficient species are threatened [13, 46]. The IUCN Red List pie chart in figure 32 shows that 12% of bird species are threatened, which is the lowest estimate. Birds are the best studied of all the vertebrate groups, with less than 1% of species classified as Data Deficient.

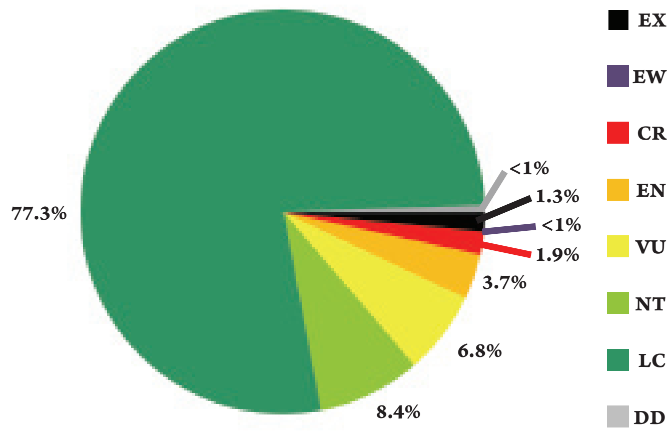


Figure 32: IUCN Red List assessment of birds (10,027 species)

Plate 52. *Vanellus vanellus*.
Gould: The Birds of Europe. 1837.

Some regions and countries have particularly high densities of threatened bird species, for example the tropical Andes, the Atlantic forests of Brazil, the eastern Himalayas, eastern Madagascar and the archipelagos of southeast Asia (figure 33). The overall avifaunas of some countries are particularly threatened, including several of the most important in terms of absolute numbers of threatened birds (for example, Indonesia, Peru and Brazil), but also several territories that have highly threatened avifaunas despite relatively low total avian diversity (for example, French Polynesia and Norfolk Island).

Trends in bird populations

The Living Planet Index (LPI) for birds tracks trends in 3,926 populations of 1,072 bird species and shows an overall 8% decline since 1970 (figure 34). However, because a large amount of data is available from Europe and North America (809 out of 1,072 species) the majority of species for which we have data occur in temperate regions. Temperate and tropical zones have therefore been equally weighted in this analysis to avoid masking the decline of tropical species, which have suffered a 28% decline since 1970. Two studies containing a large number of species from two small areas in the tropics were removed as they were having an undue influence on the trend of the index. If these studies were included the global bird LPI would decline by 20% in total.

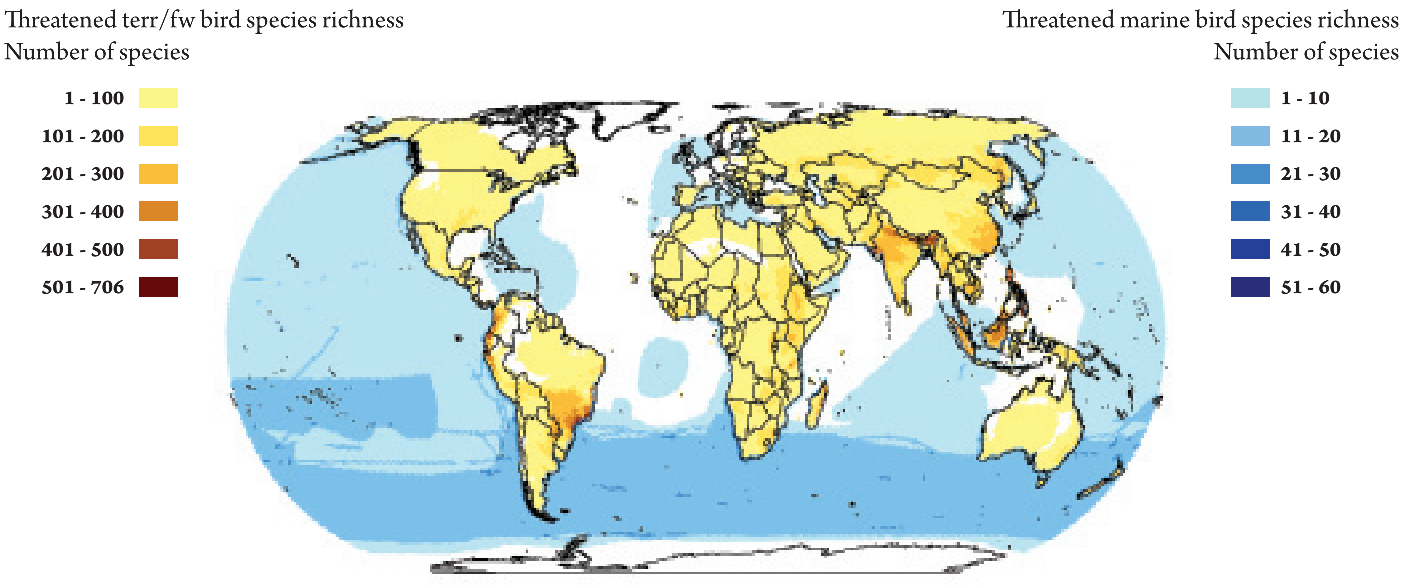


Figure 33: Global species richness of threatened birds, based on an assessment of 1,240 bird species

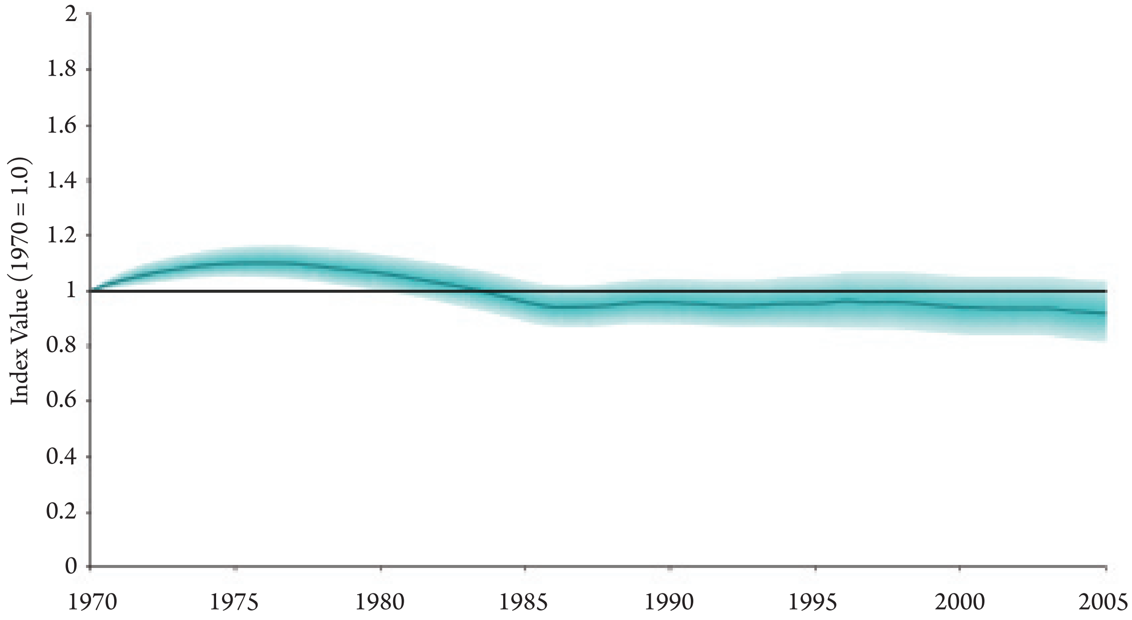


Figure 34: Living Planet Index for birds (3,926 populations of 1,072 species) .
Index value shown in bold line, shaded area shows 95% confidence limits.

Threats to birds

There are a number of threatening processes driving declines in bird populations. Foremost among them are the spread of agriculture, logging and wood harvesting as well as the impacts of invasive alien species. In addition, residential and commercial development, hunting and trapping, changes to fire regimes and pollution are having serious negative impacts (figure 35). Climate change represents an emerging and increasingly serious threat to species, which often exacerbates the impact of existing threats.

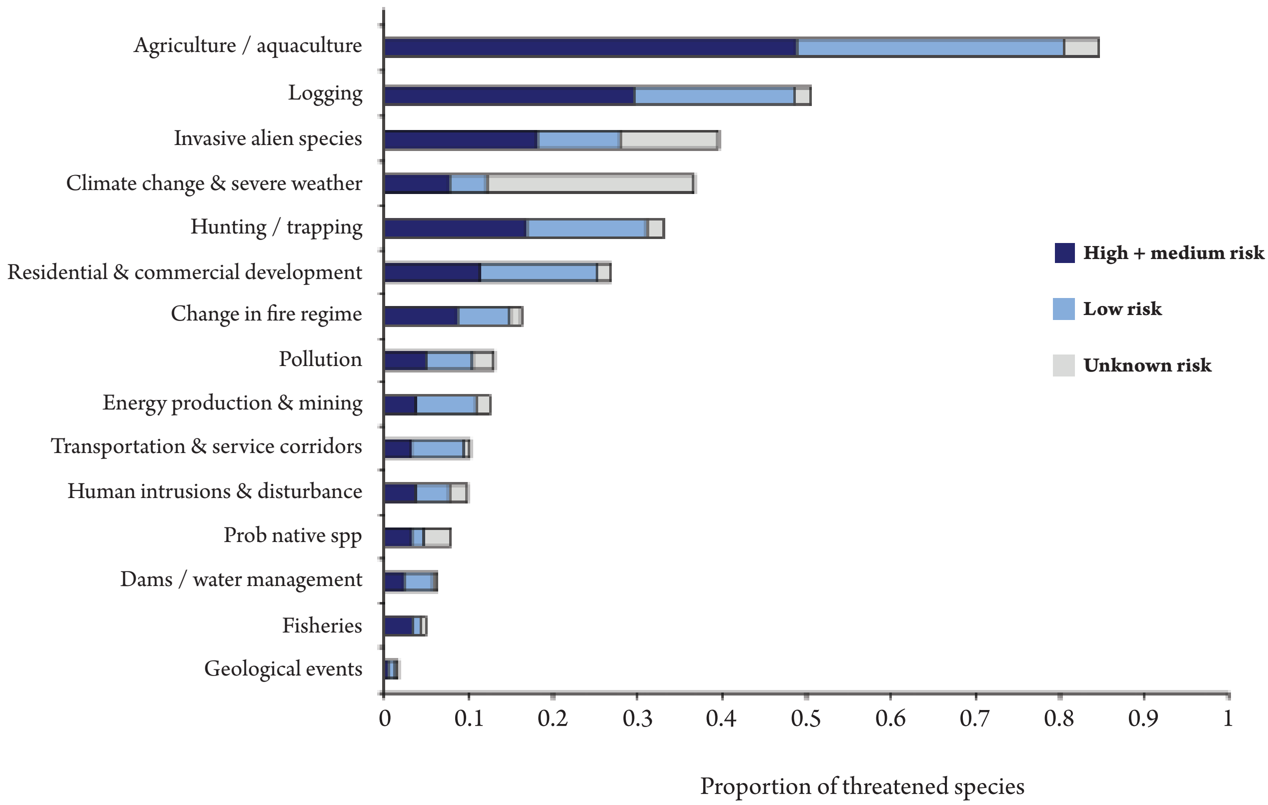


Figure 35: Global threats to bird species. Horizontal axis shows the proportion of threatened (CR, EN, VU) bird species affected by each of the threatening processes on the vertical axis. Subdivisions represent the relative impact of each threat, high+medium, low and unknown. Note - these numbers may add up to more than 1 because species are often affected by multiple threats.

Evolutionarily Distinct and Globally Endangered (EDGE) Birds

The most Evolutionarily Distinct and Globally Endangered (EDGE) bird species is the kagu (*Rhynochetos jubatus*), a small, flightless, threatened species that is endemic to New Caledonia. It is the sole extant representative of the family Rhynochetidae and therefore represents around 40 million years of unique evolutionary history. The kagu is primarily threatened by invasive alien species, mainly through predation by dogs, cats and rats and habitat degradation by pigs and deer. Its forest habitat is also being slowly degraded by mining, logging and fire, and the species is also hunted at low levels [106]. The kagu is classified as Endangered due to its small, fragmented and declining population. Current conservation efforts focus on the management of nature reserves and efforts to reduce predation by dogs. Effective predator control and increased education efforts are essential to the survival of this 'ghost of the forest'.

The kakapo (*Strigops habroptila*) is the world's largest and only flightless parrot, and is endemic to New Zealand. The species has many unique characteristics for a parrot, being solitary, nocturnal, having a polygynous 'lek' mating system and owl-like whiskers. Being flightless, the species was historically vulnerable to hunting and habitat loss, but the key threat remains predation by invasive mammals. Now extinct across its natural range, the species has only survived through translocations to predator-free offshore islands, covering just 26 km^2 in total, and intensive subsequent management [106]. With a little over 100 individuals remaining and historical declines only recently reversed through intensive conservation action, the species is classified as Critically Endangered. Assigned to its own sub-family Strigopinae, the kakapo is one of the world's most Evolutionarily Distinct and Globally Endangered birds.

The maleo (*Macrocephalon maleo*) is a megapode (mound-building terrestrial gamebird) endemic to the island of Sulawesi, Indonesia. The species lays and buries its large eggs in sand and volcanic soils, abandoning them to be incubated by geothermal and solar energy. Upon emerging, megapode chicks are fully independent [106]. Listed as Endangered, the maleo has undergone a rapid population decline owing to over-harvesting and habitat destruction, particularly at the nesting grounds.

Evolution lost

Since 1500 AD, 132 bird species have become Extinct and four have become Extinct in the Wild, with a further 14 flagged as 'Critically Endangered: Possibly Extinct' or 'Critically Endangered: Possibly Extinct in the Wild' [46, 109]. The islands of the southwest Pacific have experienced high levels of human-caused bird extinctions following the successive arrival of Polynesians and Europeans, and it has been suggested that as many as 8,000 bird populations (many of which may have been distinct species) may have been lost from the region [110]. For example, 58 (26%) of the 223 original breeding bird species on New Zealand have become extinct since first human contact around 800 years ago [107].

Examples of evolutionarily distinct species that have gone extinct include the dodo (*Raphus cucullatus*), a bird endemic to Mauritius which went extinct during the 17th century, a loss which was directly attributable to human overexploitation [46]. A more recent example is the Po'ouli (*Melamprosops phaeosoma*), the only member of the genus *Melamprosops* which became extinct in 2004. It is believed to have belonged to an ancient lineage of honeycreepers. The exact cause of extinction is unknown, but habitat loss, avian malaria, predation and a decline in its main food source (native tree snails) have been implicated.

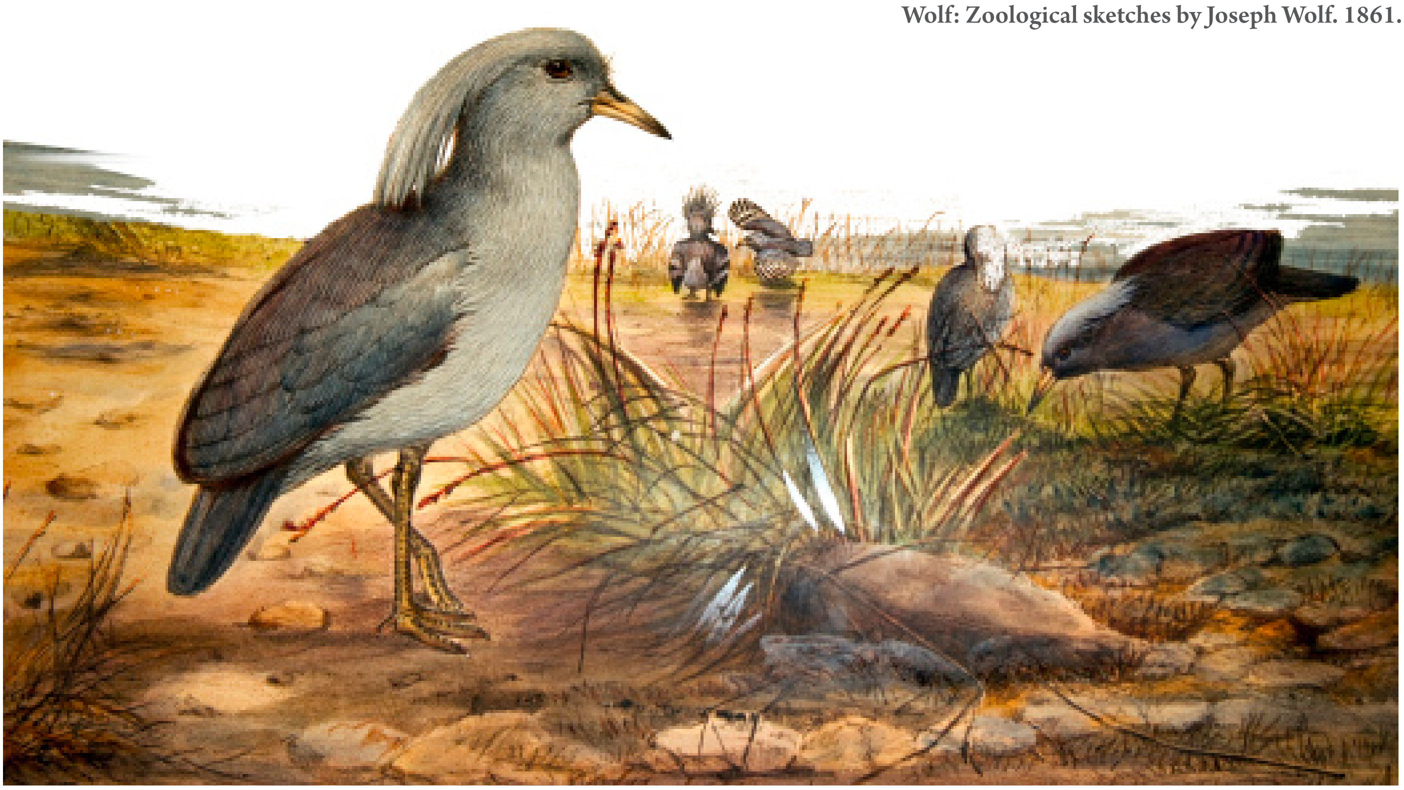
Plate 53. *Strigops habroptila*.
Buller: A history of the birds of New Zealand. 1873.

As with other taxonomic groups, a suite of actions at a range of scales is required in order to prevent extinctions, reverse declines and improve the status of the world's birds. Similar to amphibians, reptiles and mammals, habitat protection is paramount. One important approach is the protection of Important Bird Areas or IBAs, which are 11,000 key sites identified worldwide for bird conservation [112]. Only 39% of the area of each IBA is protected on average, and 74% of sites lack any protection or are only partially protected [113]. While formal protection of IBAs is often preferable, other approaches can also be effective, including establishing community management of resources, ensuring that effective safeguard policies are applied and securing thorough environmental impact assessments for development projects.

Managing at the site level often involves managing habitats to benefit particular species or suites of species, making forestry practices more sustainable and improving farming practices so as to reduce threats to forests. Such activities may be supported by efforts to control or eradicate invasive alien species, reduce overexploitation and prevent or minimise the impacts of industrial and residential development.

As information on birds is so much more comprehensive than for other taxa, they can play a unique role in targeting conservation efforts and monitoring progress in tackling biodiversity loss. Birds are also uniquely popular, with many species being diurnal, conspicuous, colourful, beautiful, vocal, musical and responsive to feeding, making them attractive, interesting, watchable and identifiable. Across the world, millions of people watch birds, and hundreds of thousands of people contribute to monitoring activities and environmental action to support bird conservation. Birds, thus provide a wonderful window onto biodiversity, and play an important role in promoting the urgency and importance of conserving wild nature on our planet.

Plate 54. *Rhynochetos jubatus*.
Wolf: Zoological sketches by Joseph Wolf. 1861.



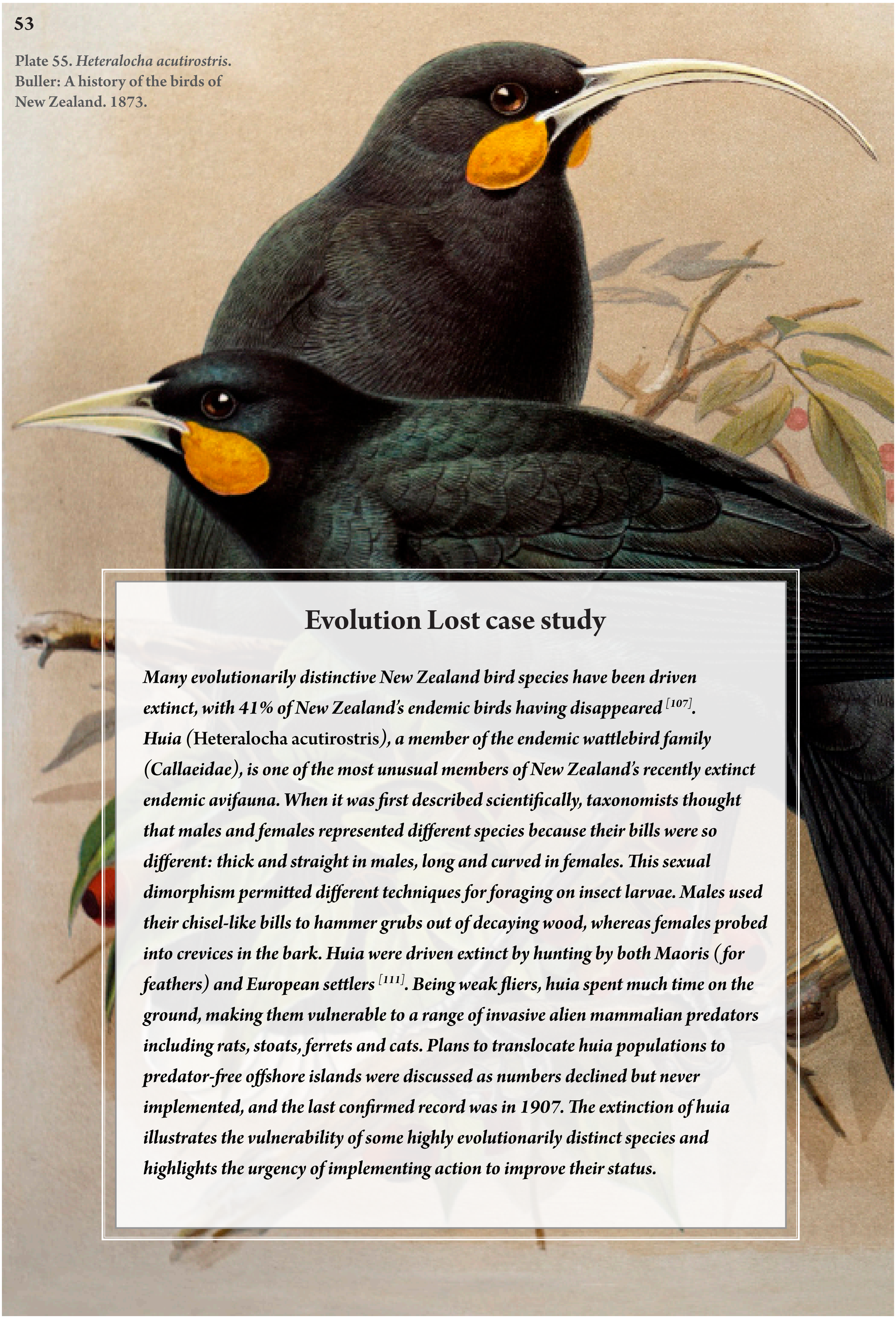


Plate 55. *Heteralocha acutirostris*. Buller: A history of the birds of New Zealand. 1873.

Evolution Lost case study

Many evolutionarily distinctive New Zealand bird species have been driven extinct, with 41% of New Zealand's endemic birds having disappeared [107]. Huia (Heteralocha acutirostris ***), a member of the endemic wattlebird family (Callaeidae), is one of the most unusual members of New Zealand's recently extinct endemic avifauna. When it was first described scientifically, taxonomists thought that males and females represented different species because their bills were so different: thick and straight in males, long and curved in females. This sexual dimorphism permitted different techniques for foraging on insect larvae. Males used their chisel-like bills to hammer grubs out of decaying wood, whereas females probed into crevices in the bark. Huia were driven extinct by hunting by both Maoris (for feathers) and European settlers [111]. Being weak fliers, huia spent much time on the ground, making them vulnerable to a range of invasive alien mammalian predators including rats, stoats, ferrets and cats. Plans to translocate huia populations to predator-free offshore islands were discussed as numbers declined but never implemented, and the last confirmed record was in 1907. The extinction of huia illustrates the vulnerability of some highly evolutionarily distinct species and highlights the urgency of implementing action to improve their status.***

Invertebrata

Plate 56. *Astacus astacus*. Leach:
British species of the Linnean genus Cancer. 1815-70.

Invertebrata

Are Vertebrates Representative of Animal Biodiversity as a Whole?

Editors: Michael Samways and Monika Böhm

Vertebrates represent just 4.6% of the world's animal species, with invertebrates contributing to the remaining 95.4% [114]. There are 1.3 million described invertebrate species, with many more being discovered daily. Despite their diversity and abundance, in comparison to vertebrates very little is known about invertebrate biology or the conservation challenges that they face. Yet it is crucial to understand the conservation status and trends of invertebrates, since it is these often cryptic and overlooked species that are essential for the functioning of ecosystems [115]. With more information available on vertebrates, one of the most pressing questions to address is whether vertebrate conservation status and trends are representative of animal biodiversity as a whole.

Evolutionary history of invertebrates

A huge variety of invertebrate groups, including all of the major modern phyla, appear relatively suddenly in the fossil record around 530 million years ago, in an event known as the 'Cambrian Explosion'. There has been intense debate among palaeontologists and evolutionary biologists over how and why this event took place or whether complex animal life may have actually evolved earlier, during the Precambrian [116-117]. Sponge spicules are known from 580 million years ago in China, and other Neoproterozoic era fossils, notably the Ediacaran fauna, have been interpreted by some researchers as containing representatives of modern invertebrate groups [118-119]. However, Ediacaran fossils are soft-bodied and preserved in relatively coarse-grained sediments, making interpretation of these fossils an ongoing challenge.

Evolution and diversification of the major invertebrate groups continued through the Phanerozoic eon, and different geological periods and eras are defined by distinct invertebrate faunas. Diversification of invertebrates such as bivalves, cephalopods, corals and echinoderms continued in the seas of the Ordovician period (488-444 million years ago [120]). The oldest insect fossils are known from the 400 million year-old Rhynie Chert from the early Devonian period. Other fossils resembling many of our modern insects, such as dragonflies, have been dated back to the late Carboniferous and Permian periods (around 300-250 million years ago [121]). Some Carboniferous terrestrial arthropods grew to very large sizes, possibly due to higher oxygen levels [122]: the myriapod Arthropleura, a relative of centipedes and millipedes, grew to over 2.5 metres long. The dragonfly-like *Meganeura* had a wingspan of around 75 cm, an equivalent wingspan to the modern wood pigeon *Columba palumbus*. At the time, these large insects ruled the air, long before birds and even pterodactyls.

Plate 57. *Papilio*. Rösel von Rosenhof: De natuurlyke historie der insecten. 1764.

Biogeography of Invertebrates

Invertebrates have colonised every habitat on Earth. An amazing number of species, such as giant clams, tube worms and crustaceans, can even exist in the extreme conditions around deep ocean hydrothermal vents, which can reach temperatures as high as 80° C, while others can live in the very deep sea, where pressure rises to 1,000 atmospheres and no natural light can penetrate. They even live in Arctic and Antarctic environments, where temperatures may dip to below -50° C. Insects adapted to Arctic conditions survive the cold by producing antifreeze proteins to prevent body fluids from freezing [123]. Others can even thrive in arid deserts where droughts may last for months or even years. However, as with vertebrates, invertebrate species richness is highest in the tropics.

The diversity of tropical flora has led to high levels of specialisation, which has led to vast numbers of species making up certain species groups, such as beetles; the weevil family for example, has 30,000 described species. A well-known, yet possibly apocryphal, story, describes how the biologist John B.S. Haldane was asked by a group of theologians what one could conclude about the nature of The Creator from the study of his creation, to which Haldane replied "An inordinate fondness for beetles." Indeed, around 40% of described insects are beetles [124] and they have been particularly successful at colonising a large number of habitats, although they do not occur in marine or polar environments. Their success has come about in part through their very successful body form of chewing mouthparts, strong exterior cuticle (including the forewings which are modified into hard protective shields) and highly variable body size.

Status of the world's invertebrates

Until recently, information on the conservation status of invertebrates has been lacking (although see [125]), with conservation assessments primarily being carried out for vertebrates. A new approach has been devised to tackle this discrepancy at the species level, while not forgetting landscape-scale conservation which has been so beneficial for so many species [126]. The Sampled Red List Index project aims to broaden the species coverage of the IUCN Red List and develop an indicator which is broadly representative of global biodiversity as a whole [15, 18, 127]. Among the first results, an IUCN Red List assessment of all described species of 1,280 freshwater crabs and 590 crayfish indicates that 32% of crabs and 31% of crayfish are threatened with extinction (with a range of 16% to 65% of crab species and 25% to 46% of crayfish species threatened, based on all Data Deficient species being either not threatened (the lower margin) or threatened (the upper margin), [128] figures 36a and b). Dragonflies on the other hand are faring better, despite their association with freshwater, one of the most highly threatened of terrestrial ecosystems, with 13% of species in a random sample of 1,500 species threatened with extinction (range of 9 - 44% [129], figure 36c).

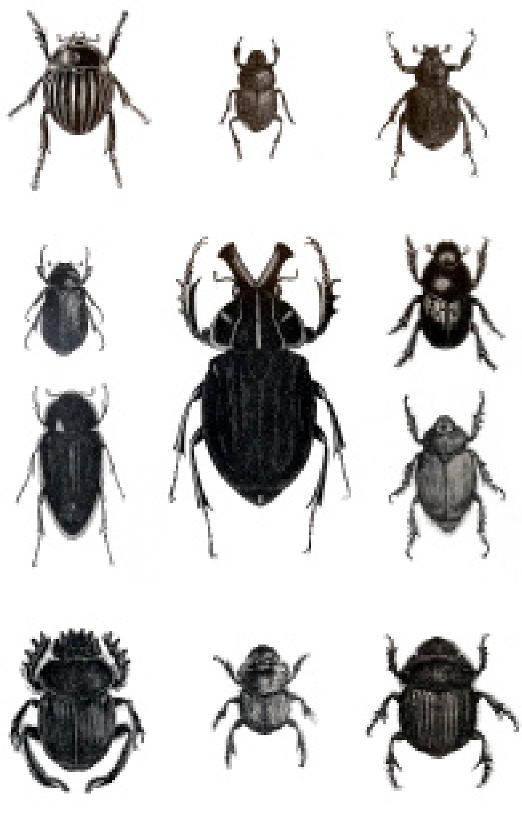


Plate 58. Scarabaeoidea presented in the original publication as Scarabaeid beetles. Kingsley: Standard Natural History. 1884.

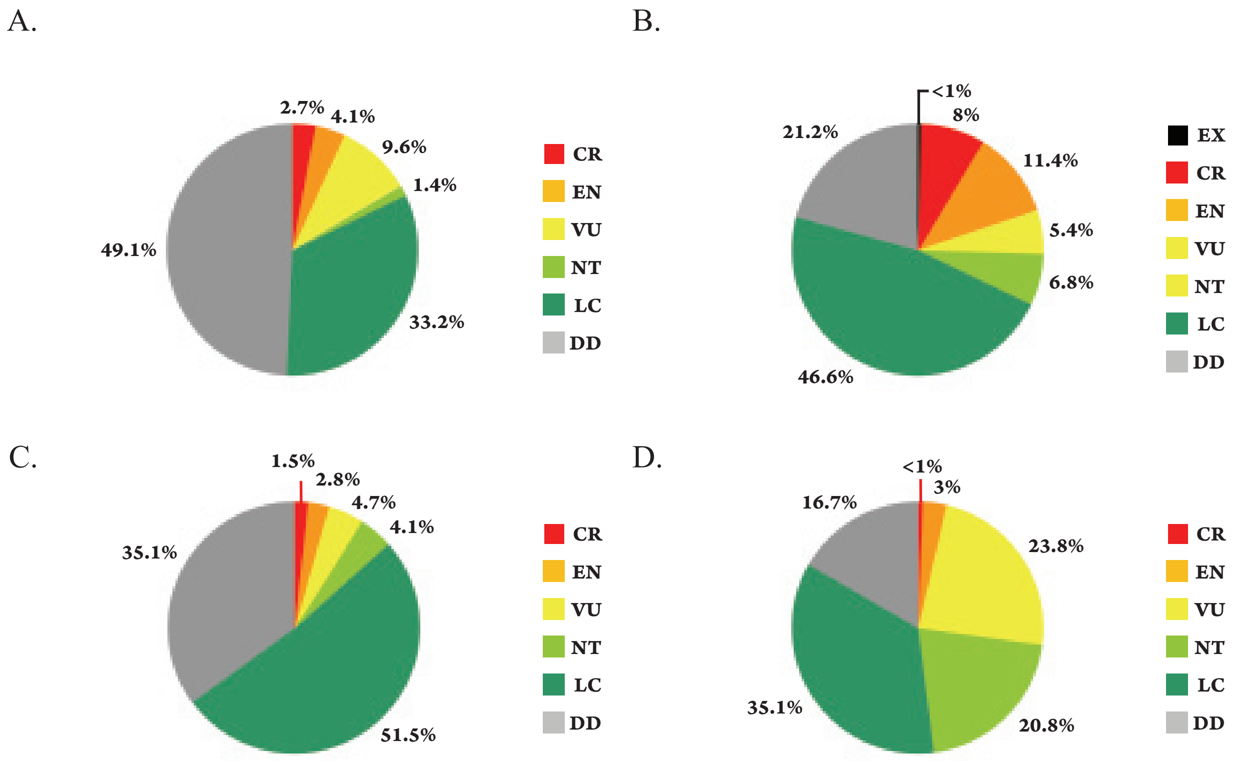


Figure 36: IUCN Red List assessment of selected groups of invertebrates: a) freshwater crabs, b) crayfish, c) dragonflies, d) reef-building corals.

Extinction risk of freshwater invertebrates, based on the available data for crayfish, dragonflies and damselflies and freshwater crabs, appears to be highest in south Asia, in particular in Sri Lanka (figure 37), with other centres of threat located in southeastern USA and along the east coast of Australia. The biggest threats to freshwater invertebrates are habitat degradation and loss (particularly from deforestation and alteration of drainage patterns via damming and water abstraction) and pollution [128-131].

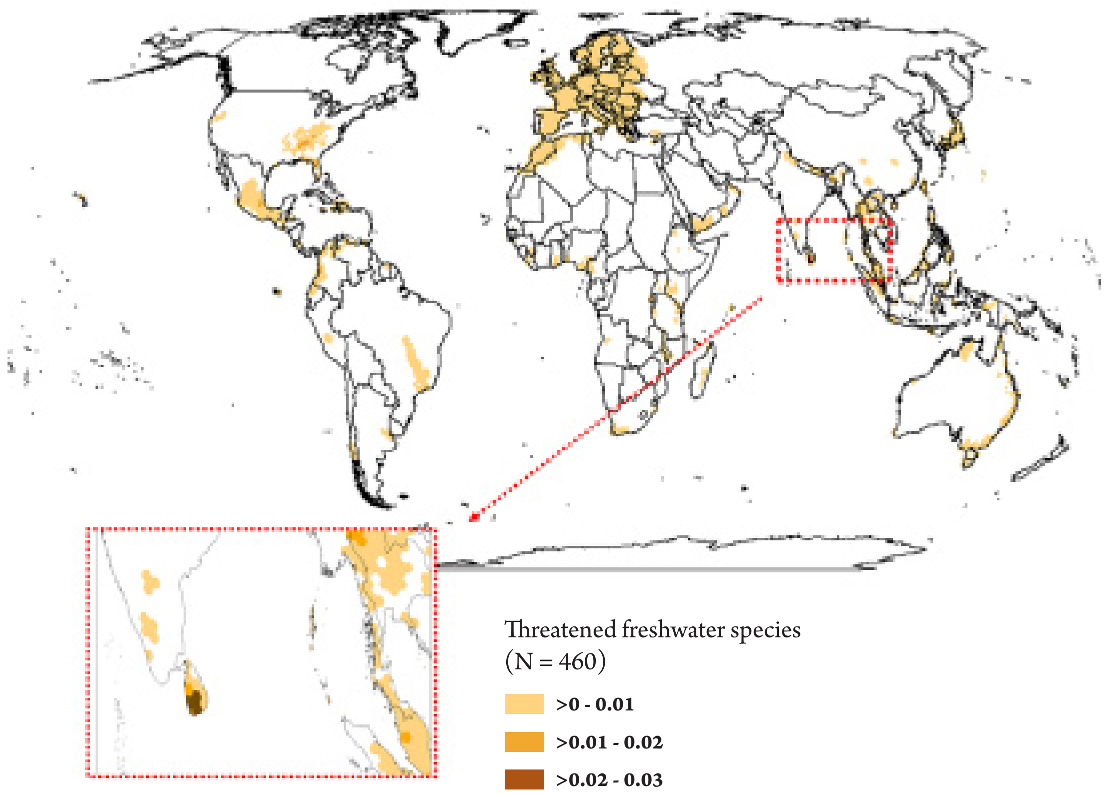


Figure 37: Global richness of threatened freshwater invertebrates, based on a sampled assessment of 1,500 species of dragonflies and damselflies, and complete assessments of 590 crayfish and 1,280 freshwater crabs.

Within the marine environment, corals have received particular conservation attention due to the occurrence of bleaching events which threaten the survival of corals and entire coral reef ecosystems. Red List assessments of all 845 known species of reef-building corals showed 33% of species to be threatened with extinction (range: 27 - 44% [132], figure 36d). Comprehensive assessments of lobsters and cephalopods are still in progress, but initial results suggest that extinction risk in lobsters will be lower than that observed in their freshwater crustacean counterparts (L. Allcock & N. Richman, *pers. comm.*).

First indications suggest that terrestrial invertebrate species - and insects in particular - are faring better than their freshwater counterparts. Initial results suggest that around 5% of Afrotropical butterflies are listed as globally threatened, although this number may mask higher levels of threat in endemic island taxa (O. Lewis, *pers. comm.*). Similarly, 11% of species in a random sample of 1,500 species of dung beetle are threatened with extinction (S. Spector, *pers. comm.*). It is suspected that 11,200 species of insects have become extinct since the year 1600, and over the next 300 years a further 100,000 to 500,000 species of insect may become extinct [133]. McKinney [134] even suggests that the estimated number of insect extinctions may be far too conservative, with possibly a quarter of all insect species under imminent threat of extinction.

Plate 59. *Trichodactylus fluviatilis*. Lucas: Histoire naturelle des crustacés, des arachnides et des myriapodes. 1840.

Vertebrate vs. invertebrate conservation status

While much information is available on the conservation status of vertebrates, particularly with regard to mammals, birds and amphibians, our knowledge of invertebrate conservation status is currently limited and will always be incomplete. If vertebrate conservation status and trends are representative of trends in animal biodiversity as a whole, a conservation prioritisation mechanism aimed at vertebrates would also provide an adequate mechanism for invertebrates. So, are trends in vertebrates representative of animal biodiversity as a whole?

Overall, initial assessments of invertebrate conservation status indicate that the levels of threat we see in the vertebrate world are not dissimilar from what is being unearthed among the invertebrates [15], and it is likely that around 15-20% of the world's species are currently threatened with extinction (figure 38). However, these figures are likely to be an underestimate because of delayed and knock-on effects from gradual loss of food plants, food chain alterations (as invertebrates are highly connected in many food webs) and adverse synergistic effects such as the interaction between habitat loss and global climate change.

As with vertebrates, conservation status of different groups of invertebrates varies dramatically from very high extinction risk in some groups to relatively low extinction risk in others. This suggests that there are certain traits which make some species or species groups more vulnerable to human threats than others, and these factors may hold true for both vertebrates and invertebrates [135-139]. For example, it is often those species with specialist living and feeding requirements that are most at risk. Some overriding patterns do appear to emerge from both the vertebrate and invertebrate assessments. For example, freshwater species are generally more threatened than terrestrial species, and highly mobile species such as certain insects and birds are relatively less threatened than less mobile species. Broadening the coverage of the IUCN Red List to include a wide variety of animal life has helped a great deal in highlighting these distinct patterns and will continue to help us understand the impact we are having on the world's species and how to alleviate the effect of human pressure.

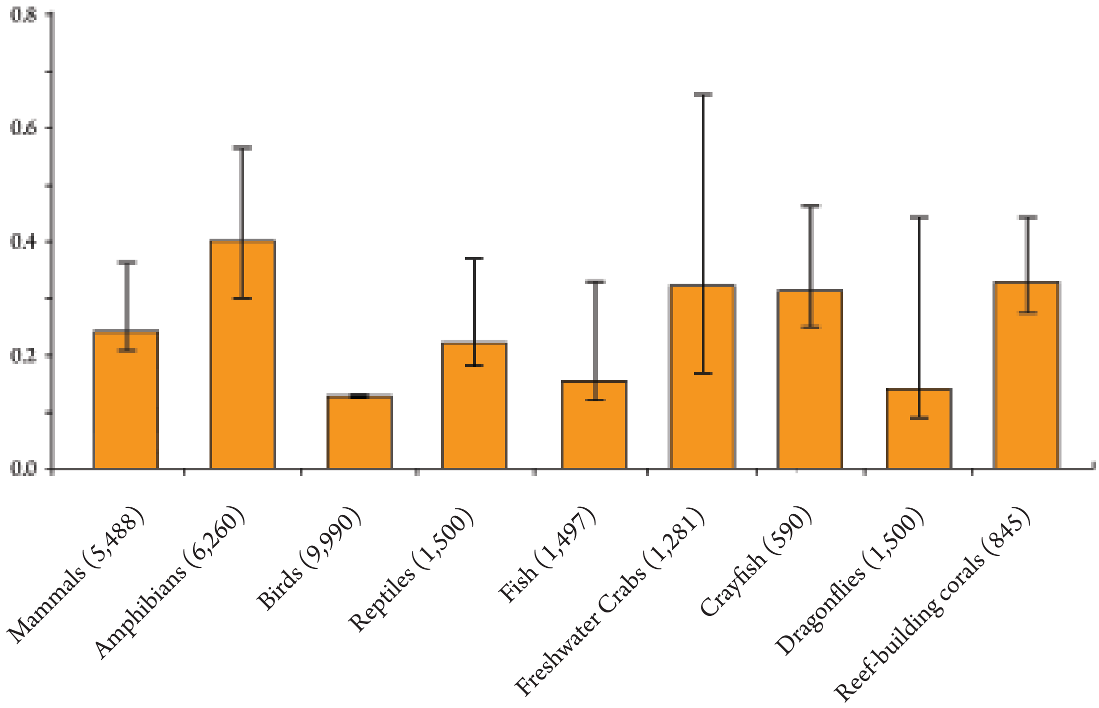


Figure 38: Comparison of the proportion of threatened species between vertebrate and invertebrate species groups. Numbers in brackets denote the number of species assessed.

Evolutionarily Distinct and Globally Endangered (EDGE) Invertebrates

Invertebrates have undergone a much longer period of diversification than vertebrates, and many evolutionarily unique and ancient lineages have survived until the present time. However, as invertebrate conservation assessments are very much in the early stages, not much is known about the extinction risk faced by many of these phylogenetically distinct species.

Members of the cephalopod family Nautilidae are likely to be one of the world's most Evolutionarily Distinct and Globally Endangered invertebrates. Six species of nautilus are currently recognised. Conservation assessments for these species were previously impossible due to a lack of adequate data. However, it is more than likely that at least some of the species of this family will be recognised as threatened on future updates of the IUCN Red List (L. Allcock, *pers. comm.*). Members of this family show many symptoms of high risk, including a low reproductive output. Also, their attractive shells make them a desirable target for collectors.

As with the nautilus, horseshoe crabs are often referred to as "living fossils", appearing relatively unchanged since their early beginnings in the Late Ordovician period, some 444 million years ago [140]. Horseshoe crabs are particularly interesting to humans for their medical potential, especially for the use of blood cell extracts as a test for bacterial endotoxins in the pharmaceutical industry [141]. All four species of horseshoe crab, belonging to three genera, have been previously assessed for the IUCN Red List, but these assessments are in urgent need of updating [46], as they were last assessed 14 years ago. Slow onset of maturity makes these organisms particularly vulnerable to exploitation, and the tendency to occur in large numbers makes them a desirable and easy target for collectors.

Another living fossil is the tadpole shrimp (*Triops cancriformis*), which is widely distributed throughout Europe and the Middle East and into India. It is thought that this species has not changed since the Triassic period, around 220 million years ago, and has been referred to as one of the oldest extant species on earth. It is classed as Endangered in parts of its range, such as the United Kingdom, since it is very sensitive to pollution, particularly from veterinary product runoff [142].

Evolution lost

Although invertebrate extinctions are not as widely reported or studied as vertebrate extinctions, 380 species of invertebrates are currently listed as Extinct on the IUCN Red List [46].

The eelgrass limpet (*Lottia alvaeus*) was the first reported historical extinction of a marine invertebrate [143]. It occurred in eelgrass beds along the west Atlantic coast of North America, where it was still common in the late 1920s. It is thought that the extinction was caused by a slime mould which eliminated around 90% of the standing stock of eelgrass and thus the vast majority of habitat available to the limpet.

As with vertebrates, many of the known invertebrate extinctions occurred on islands. On Hawaii, three of the five members of the endemic genus *Emperoptera* are thought to be possibly extinct [144]. *Emperoptera* are flightless flies and their demise has been attributed to predation by introduced ants. So far, however, only one species, *Emperoptera mirabilis*, has been listed as Extinct on the IUCN Red List [46].

Large numbers of invertebrate species are still waiting to be discovered and described, so that many species may become extinct without us even knowing about them. The Lake Pedder earthworm (*Hypolimnus pedderensis*), for example, is only known from a single specimen collected in 1971 [46]. The species is thought to be endemic to Lake Pedder, Tasmania, and while recent surveys managed to find several new species, none of these was *H. pedderensis*. Finally, a salient reminder of the immense impact of humans on these small creatures is the complete demise of the Antioch katydid from San Francisco, which was only described after it became extinct and bears this epithet in its scientific name: *Neduba extincta*.

Plate 60. *Libellula vulgata*. Rösel von Rosenhof: De natuurlyke historie der insecten. 1764.

Conservation

The conservation of the whole range of invertebrates in any one area will almost always involve large-scale landscape and seascape initiatives, rather than focusing on conservation at the species level, as is the case with most threatened vertebrate species. This does not of course preclude certain species-level activities which in some cases, especially in Europe and North America, have been very successful especially for butterflies. The salient point is that conservation of invertebrates is about conservation of ecosystem processes as much as it is about the conservation of the focal species.

Landscape- and seascape-scale conservation of invertebrates enables the conservation of compositional and functional biodiversity. One of the underlying reasons for the success of this 'coarse filter' approach is simply the complexity of the focal organism assemblage. This is borne out by the fact that 1,000 species (a reasonable figure for even a small area such as a temperate pond) begets, at least theoretically, half a million potential interactions. In short, we are aiming to conserve a huge complexity of which we know very little. So, if we aim to conserve fairly large, connected areas, the precautionary approach is the best we can do given our limited knowledge of the components and our even more limited knowledge of the interactions between those components. Yet such a precautionary approach is not vague, but can be underpinned by a set of design and management guidelines that should be weaved into a synthetic management approach [145]. These are a fundamental set of approaches, such as the introduction of ecological networks that can be applied anywhere on the planet, but tailored according to local conditions and opportunities. This set of approaches takes into account increasingly challenging issues such as the presence of adverse interactions (where different threats compound each other) and global climate change. For terrestrial invertebrates at least, this set of approaches enables the invertebrate individuals to move back and forth across the landscape, so that they can continually select optimal ecological conditions for their life functions. Additionally, from an evolutionary perspective, extensive landscapes then promote better opportunity for ongoing evolutionary processes.

Plate 61. Coleoptera presented in the original publication as beetles in a flood. Lydekker: The royal natural history. 1896.

Conclusions

Humans and the Extinction Crisis

Plate 62. *Thylacinus cynocephalus*.
Wolf: Zoological sketches by Joseph Wolf. 1861.

Conclusions

Humans and the Extinction Crisis

Editors: Jonathan E.M. Baillie and Ben Collen

The hominin lineage, represented today only by our own species *Homo sapiens*, diverged from the great apes approximately six million years ago; our genus originated in Africa over two million years ago, and our species appeared approximately 200,000 years ago.

Population growth rates of *Homo sapiens* remained relatively low until the Industrial Revolution, at which point the human population boomed with a maximum growth rate of 2.2% per year in the early 1960s [146-147]. This rate has since decreased, but approximately 75 million humans are being added to this already overpopulated planet each year. In one week, *Homo sapiens* are adding more individuals to the planet then the total population of all the other great apes combined. This rapid human expansion and increased use of resources has had an unprecedented impact on the rest of the world's species and ecosystems, with the result that almost roughly one-fifth of the world's vertebrates and plants are now threatened with extinction.

Ironically, our closest relatives are now some of the most threatened, with all the great apes (bonobos, chimpanzees, gorillas and orang-utans), classified as either Critically Endangered or Endangered.

While extinction of species is a natural process, the present day rate of extinction is extremely high and far outpaces the current rate of speciation [24]. By comparing current and background extinction rates, we can confidently predict we are heading for the next mass extinction. This time, humans are the perpetrators – yet only we have the ability to reverse the loss of species and destruction of ecosystems.

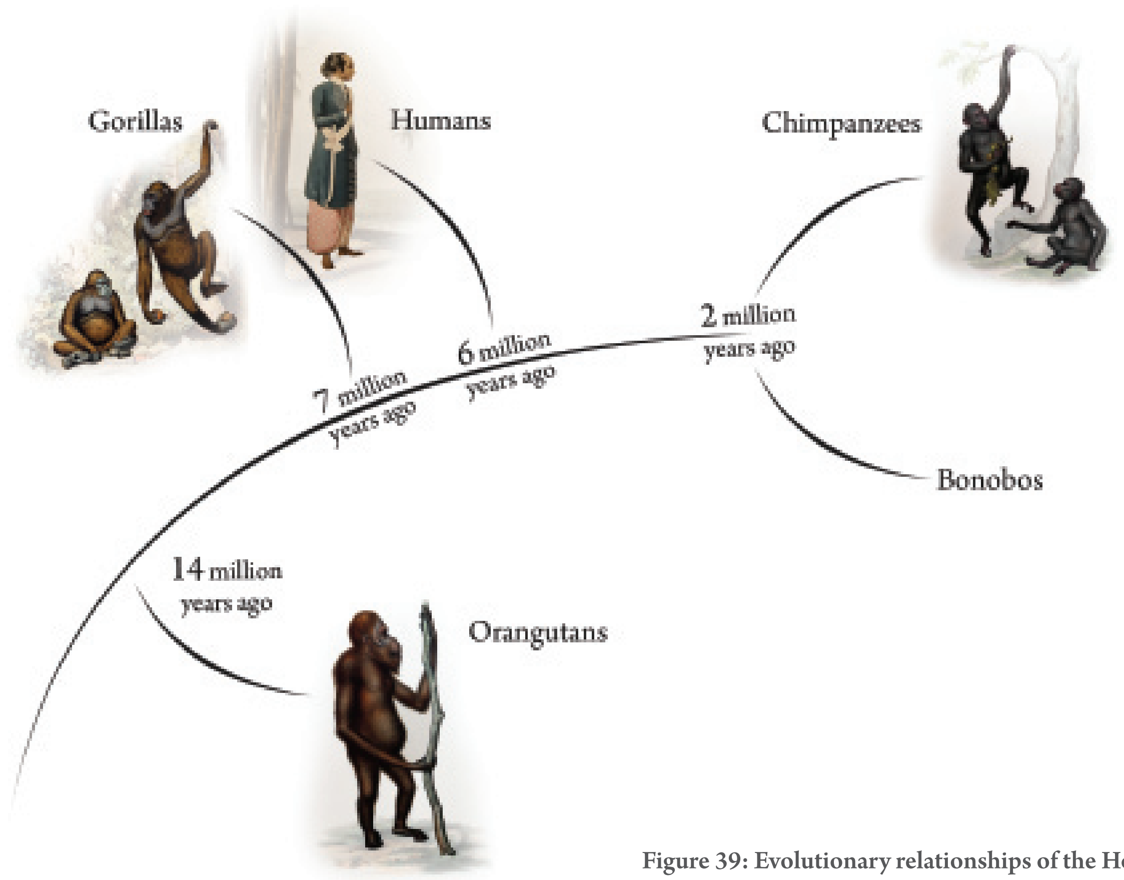


Figure 39: Evolutionary relationships of the Hominidae

Recent extinctions

Compared to the background rate of extinction, which is the average extinction rate found in the fossil record, extinctions have increased to between 100 and 1,000 times greater than the rate they were in the distant past (figure 40). It is believed that future extinction rates will be 10-100 times what they are today. The main causes of extinctions across all groups include habitat loss or degradation, primarily driven by agricultural development and logging, followed by invasive species and human overexploitation. The impact of climate change is now beginning to be felt by many species groups [148-149]. Climate change will likely be the greatest driver of extinction this century, with an estimate of 25% of all species committed to extinction by 2050 [see 88, 149 - 154].

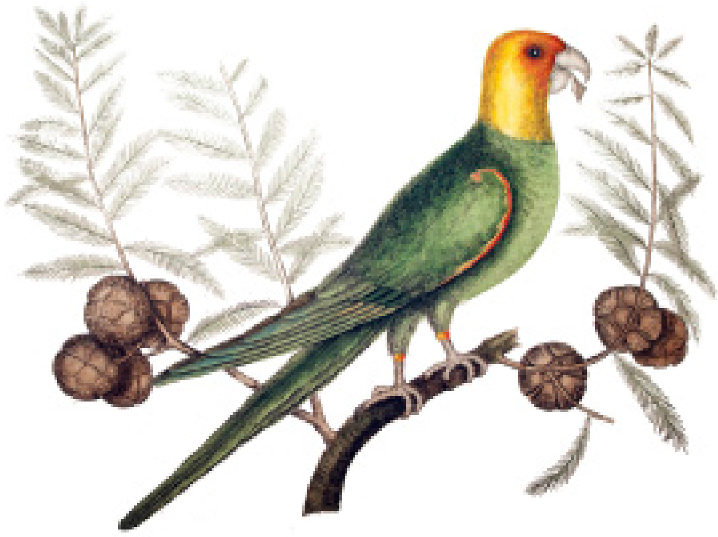


Plate 63. *Conuropsis carolinensis*.
Catesby: The natural history of Carolina, Florida and the Bahama Islands. 1731-43.

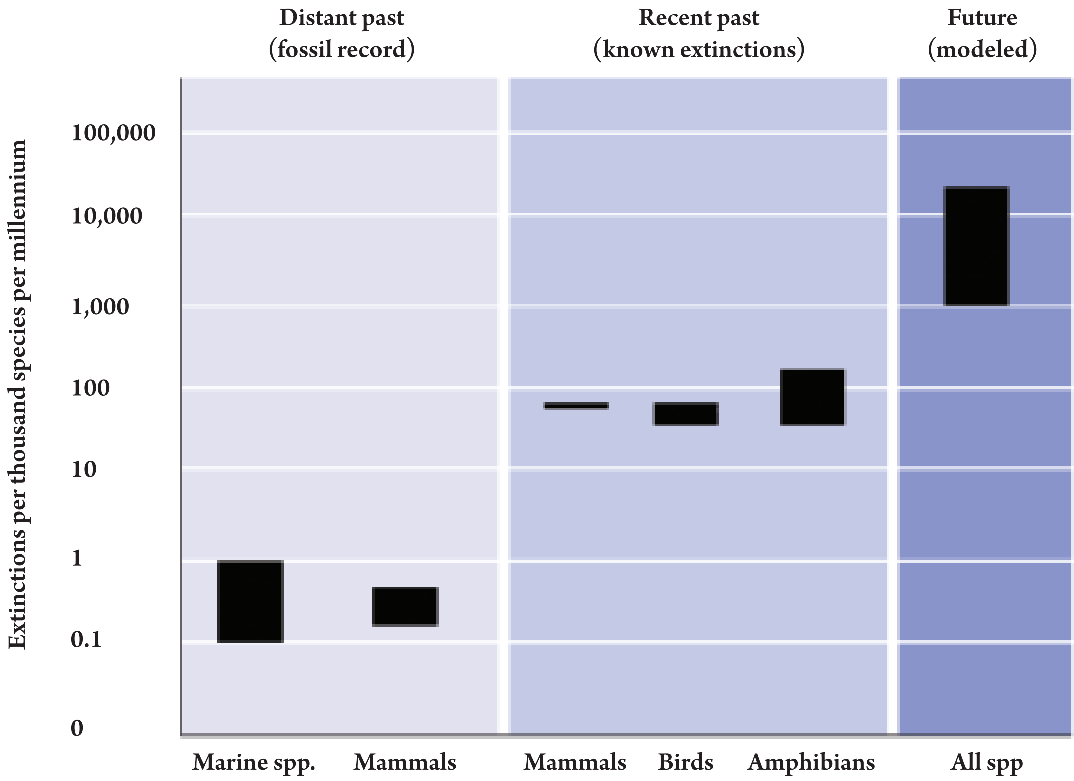


Figure 40: Background, current and future predicted extinction rates. Figure adapted from the Millennium Ecosystem Assessment [24].

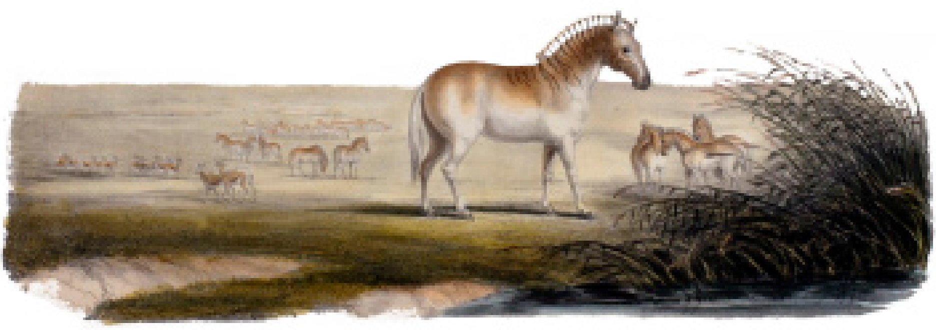


Plate 64. *Equus quagga*.
Harris: Portraits of the game and wild animals of Southern Africa. 1840.

Evolution lost

The threats to the world's species are increasing and the world's vertebrates continue to decline at a steady rate. Entire lineages are at risk of being lost, including marine turtles, Hawaiian honey creepers, pandas, sturgeons, elephants, rhinos, Darwin's frogs and coelacanths. When lineages such as these disappear we lose millions of years of evolutionary history, the associated genetic diversity and iconic creatures that are of extreme importance both culturally and scientifically.

How many lineages can we afford to lose before there are major implications for humanity? No-one knows for certain as the ecology of the earth is extremely complicated, but we do know that species are the building blocks of ecosystems and that functioning ecosystems are essential for human survival. One area where the balance between biodiversity and human well-being is likely to become more evident is in the delicate relationship between biodiversity and food security, especially as we near 2050 when the earth will need to provide food for an estimated 9.2 billion people.

Our first priority in addressing the extinction crisis will have to be to conserve the ecosystem services that we need for our survival. The oceans and forests provide vital ecosystem services, replenishing the oxygen we need to live, regulating our climate, providing essential food resources and storing carbon. However, we also have to ensure that the great diversity of vertebrates which has taken millions of years to evolve is not lost in the next few decades. Increasing conservation efforts will be a fundamental step in reversing declines, but little will change if, as a society, we cannot address population growth, overconsumption and poor governance.

We no longer have time to avoid the facts or talk in half measures - we need to rapidly move towards governance structures and economic systems that encourage the sustainable management of Earth's limited resources. If this is not achieved, nature will find its own balance with unthinkable consequences for all species, including humans.

Plate 65. *Raphus cucullatus*. Strickland & Melville: The dodo and its kindred. 1848.

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Plate 2. *Paradisaea minor*.

Plate 50. *Epimachus fastuosus* presented in the original publication as *Epimachus speciosus*.

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Plate 53. *Strigops habroptila*.

Plate 55. *Heteralocha acutirostris*.

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Plate 3. Holocanthus ciliaris presented in the original publication as *Perca vulgaris*.

Plate 5. *Pantherophis obsoletus* presented in the original publication as *Anguis niger*.

Plate 10. *Balistes vetula* presented in the original publication as *Turdus oculo radiato guaperva Maxima caudata*.

Plate 15. Presented in the original publication as *Orbis laevis variegatus*.

Plate 16. *Muraena*.

Plate 17. *Aluterus scriptus* presented in the original publication as *Piscis bahamensis*.

Plate 21. Presented in the original publication as *Turdus rhomboidalis* & *Turdus cauda convexa*.

Plate 22. *Fistularia tabacaria* presented in the original publication as *Salpa purpurascens variegata*.

Plate 24. Presented in the original publication as *Hirundo*, *Perca marina sectatrix* & *Perca fluviatilis gibbosa ventre luteo*.

Plate 25. *Hyla cinerea* presented in the original publication as *Rana viridis arborea*.

Plate 27. *Rana catesbeiana* presented in the original publication as *Rana maxima Americana aquatica*.

Plate 28. *Rana arvalis* presented in the original publication as *Rana terrestris*.

Plate 34. *Anolis carolinensis* presented in the original publication as *Lacertus viridis carolinensis*.

Plate 35. *Iguana iguana* presented in the original publication as *Lacertus indicus*.

Plate 36. *Alligator mississippiensis* presented in the original publication as *Lacertus omnium maximus*.

Plate 39. *Sistrurus miliarius* presented in the original publication as *Vipera caudisona americana* minor.

Plate 63. *Conuropsis carolinensis* presented in the original publication as *Psittacus carolinensis*.

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Plate 23. View: cascade on Sneuwberg.

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Plate 9. *Iguana iguana* presented in the original publication as *Hypsilophus tuberculatus*.

Plate 11. *Necturus maculosus* presented in the original publication as *Necturus lateralis*.

Plate 13. *Chelonia mydas*.

Plate 26. *Siphonops annulatus* & Ichthyophis glutinosus presented in the original publication as *Siphonops annulatus* & *Epicrium glutinosum*.

Plate 29. *Triturus karelinii* presented in the original publication as *Triton cristatus*.

Plate 30. *Rhinoderma darwinii*.

Plate 33. *Xenopus laevis* & *Pipa pipa* presented in the original publication as *Xenopus boiei* & *Asterodactylus dorsiger*.

Plate 38. *Crocodylus niloticus*.

Plate 37. *Dermochelys coriacea*.

Plate 42. *Tomistoma schlegelii*.

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Plate 6. *Tachyglossus aculeatus*.

Plate 43. *Petaurista petaurista*.

Plate 44. *Tarsipes rostratus*.
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Plate 49. *Dusicyon australis*.

Plate 46. *Rhinolophus megaphyllus*.
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Plate 40. *Sphenodon*.

Plate 41. Giant tortoises of the Galápagos.

Plate 61. Coleoptera presented in the original publication as beetles in a flood.

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Plate 32. Rösel von Rosenhof. Historia naturalis ranarum nostratium – Frontispiece.

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Plate 57. *Papilio*.

Plate 60. *Libellula vulgata*.

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Plate 31. *Pipa pipa*.

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Plate 65. *Raphus cucullatus*.

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Plate 14. *Equus zebra*.

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Plate 54. *Rhynochetos jubatus*.

Plate 62. *Thylacinus cynocephalus*.

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Plate 48. *Cryptoprocta ferox*.

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Cover illustration. *Okapia johnstoni*.

Glossary

Amniotes - amniotic egg-laying vertebrates

Amniotic egg - egg containing amniotic sac and other membranes to protect the foetus

Anadromous - predominantly ocean-dwellers, reproduce in freshwater

Anapsids - reptiles with a skull lacking openings

Archaeopteryx - earliest known bird

Archosaur - group containing crocodiles, modern birds and dinosaurs

Cambrian explosion - rapid appearance of many major groups of phyla

Catadromous - predominantly freshwater-dwellers, reproduce in oceans

Chondrostean - primitive ray-finned bony fishes

Chordates - vertebrates and some closely related invertebrates

Clade - group of organisms derived from a common ancestor

Convergent evolution - a common trait in unrelated lineages

Craniata - chordate species with a skull

Diapsids - reptiles with a hole each side of the skull

Ecomorphs - species populations which have morphologically adapted to the environment

Endemics - exclusively native to a particular region

Evolutionary Distinct and Globally Endangered (EDGE) - see page 8

Evolutionary grade - group of species united by morphological traits that have given rise to another group that differ markedly from the ancestral condition, and thus not considered part of the ancestral group

Evolutionary radiation - increase in taxonomic diversity

Extant - alive today

Gnathostomes - fish with vertically biting jaws

Hominin - any member of the "sub-tribe" Hominina ("tribe" Hominini, family Hominidae, order Primates), of which only one species exists today – *Homo sapiens*

Labyrinthodont - extinct sub-class of amphibians

Lek - mating display preformed by a group of males

Lineage - species descending from a common ancestor

Living Planet Index (LPI) - see page 6

Malleus and incus - bones of the middle ear

Monotypic - taxon with a single subordinate taxon

Phylogeny (and phylogenetic supertrees) - study of how species are related

Placoderm - prehistoric fish

Polygynous - one male and multiple females per mating system

Red List - see page 4

Sampled Red List Index (SRLI) - see page 4

Sauropsids - group containing reptiles and birds

Sexual dimorphism - differences between sexes of the same species

Speciation - divergence of new species

Speciose - high number of species in a group

Synapsids - group containing mammals

Tetrapods - vertebrates with four legs (or other appendages)

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Cover illustration by P.J. Smit of the okapi (*Okapia johnstoni*). Transactions of the Zoological Society of London. Vol. XVI. 1902.

Inspired by reports of an unknown horse-like creature in Africa, Sir Harry Johnston, a Fellow of the Zoological Society of London, set out to find this mysterious species in 1900, and the okapi (*Okapia johnstoni*) was subsequently described at a meeting of the Society in 1901 from specimens he sent back to London. The species is endemic to the high canopy forests of north-eastern and central Democratic Republic of Congo and threatened with habitat loss and hunting aggravated by long-term civil unrest. With 10,000 - 35,000 individuals estimated to remain in the wild, this species is classified as Near Threatened, but remains poorly-known to scientists. As a result, ZSL is now leading efforts to improve understanding of the species to enable a reassessment of its conservation status.

The Zoological Society of London (ZSL), a charity founded in 1826, is a world renowned centre of excellence for conservation science and applied conservation. ZSL's mission is to promote and achieve the worldwide conservation of animals and their habitats. This is realised by carrying out field conservation and research in over 50 countries across the globe and through education and awareness at our two zoos, ZSL London Zoo and ZSL Whipsnade Zoo, inspiring people to take conservation action.

We strive to achieve our mission by:

- Conducting world-leading conservation science
- Implementing effective field conservation projects globally
- Providing decision-makers with the best conservation advice
- Building conservation capacity and inspiring people to connect with the natural world

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