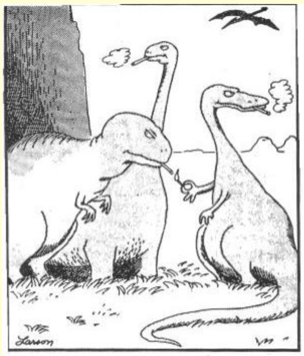
Extinction

"The worst thing that can happen during the 1980s is not energy depletion, economic collapse, limited nuclear war, or conquest by a totalitarian government. As terrible as these catastrophes would be for us, they can be repaired within a few generations. The one process ongoing in the 1980s that will take millions of years to correct is the loss of genetic and species diversity by the destruction of natural habitats. This is the folly that our descendants are least likely to forgive us."

E.O. Wilson (1985)



The real reason dinosaurs became extinct

"The Passenger Pigeon was no mere bird, he was a biological storm". Aldo Leopold

Martha, the last passenger pigeon (1885 - 1914)
Died in captivity at the Cincinnati Zoo
Picture of study skin by Valerie Hartigan at Smithsonian

Some context

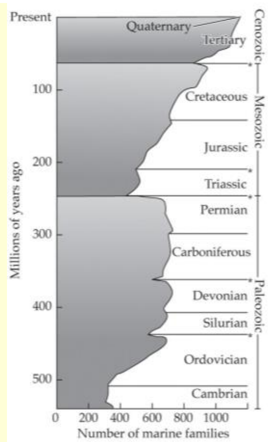
- Estimated that four billion species have evolved on Earth over last 3.5 billion years
- 99% of these are thought to be extinct
- So, is extinction natural?
- Does it vary uniformly through time?

Barnosky et al. (2011; Nature)

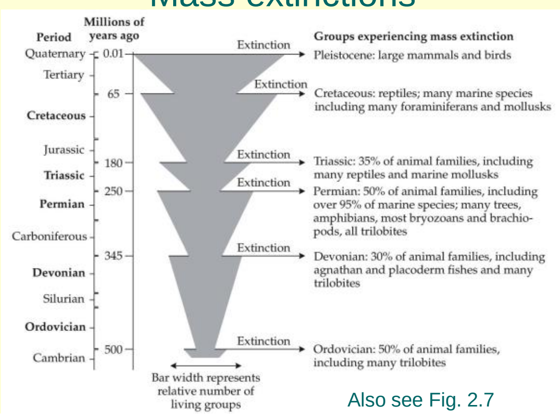
Family diversity over a long time

About 1-2 new families added each million years

Fig. 2.5



Mass extinctions



Also see Fig. 2.7

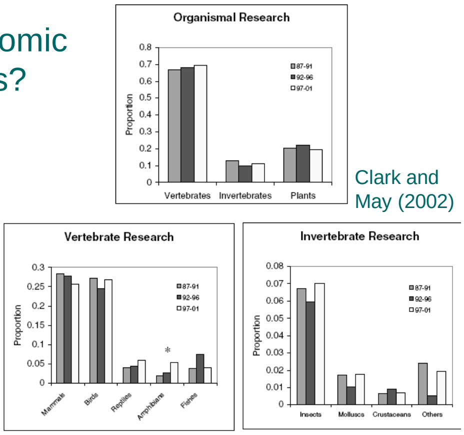
Recorded extinctions since 1600

Taxon	# Extinct	% of taxon
Mammals	85	2.1
Birds	113	1.3
Reptiles	21	0.3
Amphibians	2	0.05
Fishes	23	0.1
Invertebrates	98	0.01
Angiosperms	384	0.2

= 726 Reid and Miller (1989)

IUCN estimates 915 species to be extinct using their methods

Taxonomic bias?



Clark and May (2002)

Trying to remove the bias

- A focus on threats in well-studied regions

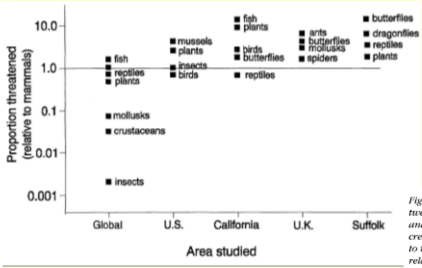
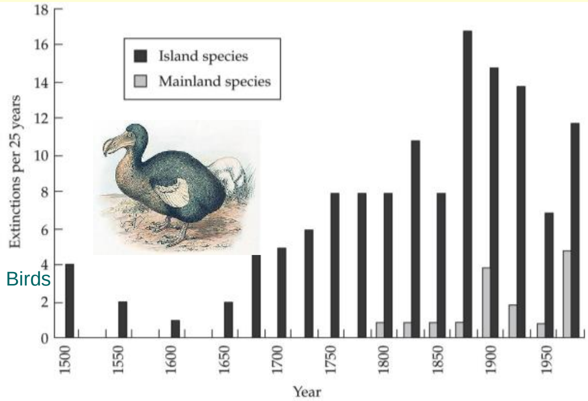


Figure 5. Observed relationship between similarity of threat among taxa and reduction of understudy biases (increasing resolution). All taxa in regions to the right of "Global" on the x-axis are relatively well studied. Log scale on vertical axis measures proportion of threatened species in each taxon divided by proportion of mammals threatened in that region (y = 1 where taxon percentage = mammal percentage).

McKinney (1999)

Another area of concern



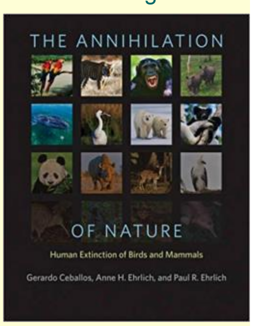
Background extinction rates (1)

- NOT = mass extinctions
- How do you calculate something over such long time scales?
- Often use fossil record to estimate *extinctions per million species years*, = **E/MSY**
  - Sample calculation:
    - 1 extinction per 10,000 spp. per 100 years = 1 E/MSY
      - 1 extinction / 10,000 spp / 100 yr = 0.000001 E / species year
      - 0.000001 E/SY * 1 million years = 1 E/MSY
  - Or, if there are 1 million species on the planet expect 1 extinction each year if =1 E/MSY

Background extinction rates (2)

- Some data from the fossil record:
  - Mostly marine fauna:
    - 0.1 to 1 E/MSY
    - (Ceballos et al. 2015)
  - Mammals:
    - 1.8 E/MSY
    - (Barnosky et al. 2011)

And a segue…



2015

Current extinction rates

Table 2. Estimates of extinction rates for various taxonomic groups.

Taxonomic group	Estimate (E/MSY)	Reference
Vertebrates	30	Ceballos et al. 2015
Mammals	39 72 (1900–2014: 243) 82–702 (island species) 0.89–7.4 (continental species) 36–78	Ceballos et al. 2015 Pimm et al. 2014 Loehle and Esenbach 2012 Regan et al. 2001
Birds	30 49 (1900–2014: 132) 98–844 (island species) 0.69-5.9 (continental species) 26 (1850–2006: approximately 100)	Ceballos et al. 2015 Pimm et al. 2014 Loehle and Esenbach 2012 Pimm 2006
Amphibians	45 66 (1900–2014: 132) 12	Ceballos et al. 2015 Pimm et al. 2014 McCollum 2007
Reptiles	16	Ceballos et al. 2015
Freshwater fish of North America	305 (1900–2010)	Burkhead et al. 2012
Freshwater gastropods of North America	954 (1900–2010)	Johnson et al. 2013
Angiosperms of Australia	3.6–7.1	Regan et al. 2001

Note: Contemporary extinctions from 1500 through publication year unless otherwise noted. Background rate of comparison may be slightly higher or lower than 1 extinction per million species-years (E/MSY).

Lamkin & Miller (2016; *BioScience*)

A new mass extinction? The Anthropocene?

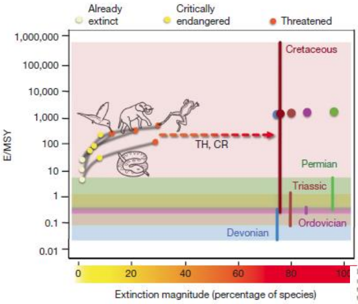


Figure 3 | Extinction rate versus extinction magnitude. Vertical lines on the right illustrate the range of mass extinction rates (E/MSY) that would produce the Big Five extinction magnitudes, as bracketed by the best available data from the geological record. The correspondingly coloured dots indicate what the extinction rate would have been if the extinctions had happened (hypothetically) over only 500 years. On the left, dots connected by lines indicate the rate as computed for the past 500 years for vertebrates: light yellow, species already extinct; dark yellow, hypothetical extinction of 'critically endangered' species; orange, hypothetical extinction of all 'threatened' species. TH: if all 'threatened' species became extinct in 100 years, and that rate of extinction remained constant, the time to 75% species loss—that is, the sixth mass extinction—would be ~240 to 540 years for those vertebrates shown here that have been fully assessed (all but reptiles). CR: similarly, if all 'critically endangered' species became extinct in 100 years, the time to 75% species loss would be ~890 to 2,270 years for these fully assesed terrestrial vertebrates.

Barnosky et al. (2011; *Nature*)

What will it take to convince geologists?

The Anthropocene is functionally and stratigraphically distinct from the Holocene

Colin N. Waters,* Jan Zalasiewicz, Colin Summerhayes, Anthony D. Barnosky, Clément Poirier, Agnieszka Gałuszka, Alejandro Cearreta, Matt Edgeworth, Erle C. Ellis, Michael Ellis, Catherine Jeandel, Reinhold Leinfelder, J. R. McNeill, Daniel deB. Richter, Will Steffen, James Syvitski, Davor Vidas, Michael Wagreich, Mark Williams, An Zhisheng, Jacques Grinevald, Eric Odada, Naomi Oreskes, Alexander P. Wolfe

Science (2016)

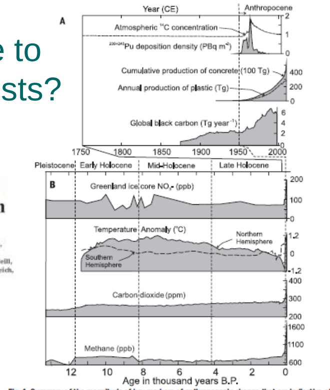


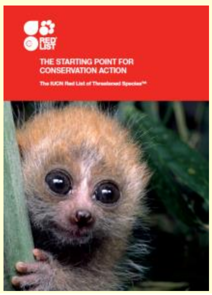
Fig. 1. Summary of the magnitude of key markers of anthropogenic change that are indicative of the Anthropocene. (**A**) Novel markers, such as concrete, plastics, global black carbon, and plutonium (Pu) fallout, shown with radiocarbon (^{14}C) concentration. (**B**) Long-ranging signals such as nitrates (NO_3^-), CO_2, CH_4, and global temperatures, which remain at relatively low values before 1950, rapidly rise during the mid-20th century and, by the late 20th century, exceed Holocene ranges.

Also see Lewis & Maslin (2015, *Nature*)

Keeping track of vulnerable species

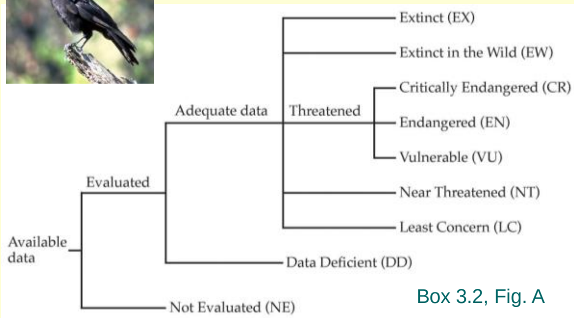
- IUCN—The International Union for Conservation of Nature

The IUCN Red List of Threatened Species™ Summary Statistics



IUCN conservation categories

Hawaiian crow

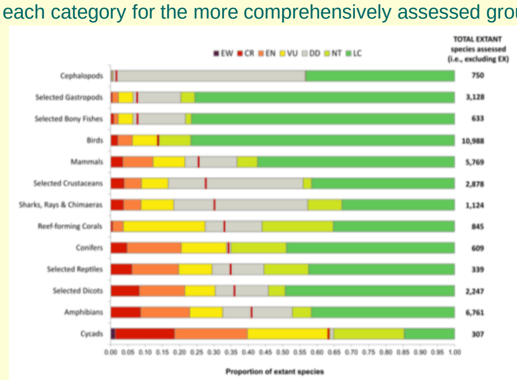


Box 3.2, Fig. A

DATA

- IUCN categorization depends on data for at least one of the following:
  - Observable reduction in abundance
  - Total geographical area occupied by a species
  - A predicted decline in abundance
  - Number of mature individuals alive
  - Probability of the species going extinct in certain number of years or generations
- Compare species data to specific thresholds for each category
  - *e.g., Crit. End. if < 50 mature individuals*

The proportion of extant (i.e., excluding Extinct) species in *The IUCN Red List of Threatened Species. Version 2019.3* assessed in each category for the more comprehensively assessed groups.



US numbers

NatureServe
A Network Connecting Science With Conservation

Proportion of spp threatened with extinction in the US

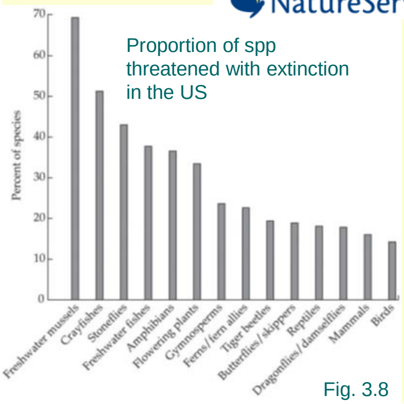


Fig. 3.8

Margaritifera margaritifera

Species characteristics & vulnerability (1)

- Very narrow geographical range
- Specialized niche requirements
- Only one or a few populations
- Population size is small
- Population size is declining

Rare

Rabinowitz & rarity; see Table 3.5

Species characteristics & vulnerability (2)

- Harvested or hunted by people
- Need a large home range
- Large body size

Species characteristics & vulnerability (3)

- Poor dispersers
- Seasonal migrants
- Little genetic variability
- "Pristine" environment
- Form aggregations
- No prior contact with people
- Related species are extinct/threatened

Bachman's warbler

Extinction and climate change

- Thomas et al. (2004)

Extinction risk from climate change

Chris D. Thomas[1], Alison Cameron[1], Rhys E. Green[2], Michel Bakkenes[3], Linda J. Beaumont[4], Yvonne C. Collingham[5], Barend F. N. Erasmus[6], Marinez Ferreira de Siqueira[7], Alan Grainger[8], Lee Hannah[9], Lesley Hughes[4], Brian Huntley[5], Albert S. van Jaarsveld[10], Guy F. Midgley[11], Lera Miles[8*], Miguel A. Ortega-Huerta[12], A. Townsend Peterson[13], Oliver L. Phillips[8] & Stephen E. Williams[14]

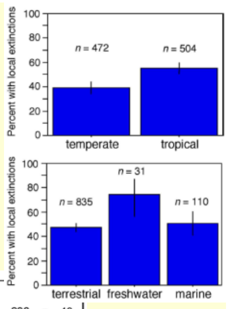
[1]Centre for Biodiversity and Conservation, School of Biology, University of Leeds, Leeds LS2 9JT, UK
[2]Royal Society for the Protection of Birds, The Lodge, Sandy, Bedfordshire SG19 2DL, UK, and Conservation Biology Group, Department of Zoology, University of Cambridge, Downing Street, Cambridge CB2 3EJ, UK
[3]National Institute of Public Health and Environment, P.O. Box 1, 3720 BA Bilthoven, The Netherlands
[4]Department of Biological Sciences, Macquarie University, North Ryde, 2109, NSW, Australia
[5]University of Durham, School of Biological and Biomedical Sciences, South Road, Durham DH1 3LE, UK
[6]Animal, Plant and Environmental Sciences, University of the Witwatersrand, Private Bag 3, WITS 2050, South Africa
[7]Centro de Referência em Informação Ambiental, Av. Romeu Tórtima 228, Barão Geraldo, CEP:13083-885, Campinas, SP, Brazil
[8]School of Geography, University of Leeds, Leeds LS2 9JT, UK
[9]Center for Applied Biodiversity Science, Conservation International, 1919 M Street NW, Washington, DC 20036, USA
[10]Department of Zoology, University of Stellenbosch, Private Bag X1, Stellenbosch 7602, South Africa
[11]Climate Change Research Group, Kirstenbosch Research Centre, National Botanical Institute, Private Bag x7, Claremont 7735, Cape Town, South Africa
[12]Unidad Occidente, Instituto de Biologia, Universidad Nacional Autónoma de México, México, D.F. 04510 México
[13]Natural History Museum and Biodiversity Research Center, University of Kansas, Lawrence, Kansas 66045 USA
[14]Cooperative Research Centre for Tropical Rainforest Ecology, School of Tropical Biology, James Cook University, Townsville, QLD 4811, Australia

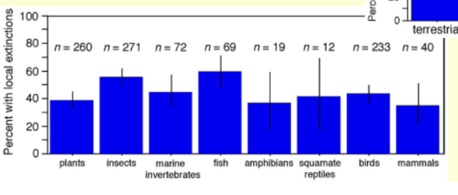
American crocodile example

From prediction to reality

PLOS | BIOLOGY

RESEARCH ARTICLE
Climate-Related Local Extinctions Are Already Widespread among Plant and Animal Species





Wiens (2016)