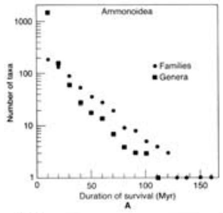
EXTINCTION

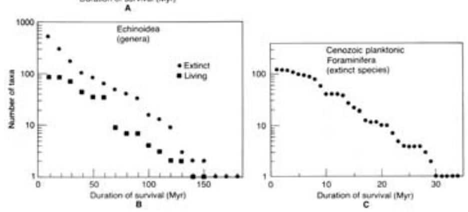
Suddenly, Bobby felt very alone in the world.

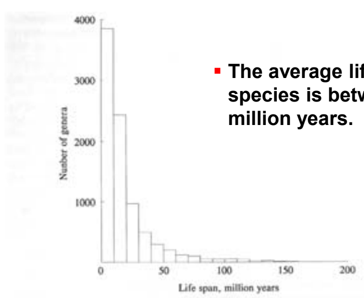
CALCULATING RATES OF ORIGINATION AND EXTINCTION

α = origination rate
Ω = extinction rate



- SPECIES AND GENERA EXTINCTION CURVES INDICATE THAT MOST SPECIES ONLY PERSIST FOR A **FEW MILLION YEARS**.





- The average lifespan of a species is between 1 – 3 million years.

FIGURE 1 Life spans of about 17,500 extinct genera of marine animals (vertebrate, invertebrate, and microfossil) tabulated from data compiled by Sepkoski (1989).

MORE COMPLEX AND LARGER ORGANISMS HAVE SHORTER PERSISTENCE TIMES

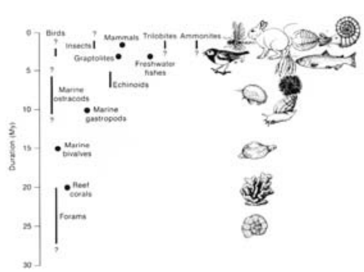


FIGURE 9-2
Hierarchy of average species durations estimated for major taxa. See text for sources of data.

POPULATION SIZE IS NEGATIVELY CORRELATED WITH BODY SIZE

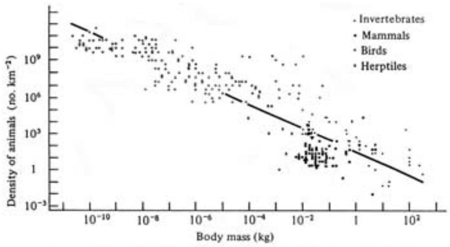
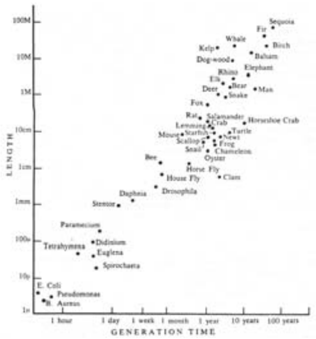


Fig. 16. The general relationship between the body size of different animals and their population density (abundance). (From Peters 1983, Copyright © by Cambridge University Press.)

GENERATIONS TIME IS CORRELATED WITH BODY SIZE



GEOGRAPHIC RANGE IS CORRELATED WITH PERSISTANCE TIME

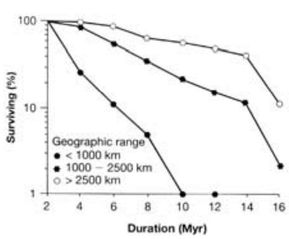


Figure 13.4 **Geographic range affects the survivorship of fossil bivalve and gastropod species** Jablonski (1986a) broke the species in his study into three groups: those with broad, intermediate, and narrow geographic ranges along the Atlantic coast of North America, and created separate survivorship curves. The slope of these curves gives the extinction rate, as in Figure 13.2. Species with large ranges survived much longer in the fossil record than species with more restricted ranges.

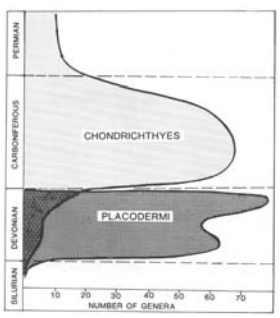
DARWIN'S VIEW OF EXTINCTION

…species and groups of species gradually disappear, one after another, first from one spot, then from another, and finally from the world.

The inhabitants of each successive period in the world's history have *beaten their predecessors* in the race for life, and are, insofar, higher in the scale of nature.

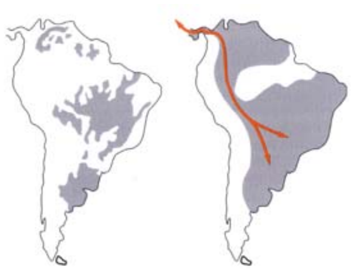
Darwin 1859

FAUNAL REPLACEMENT AMONG SIMILAR ECOTYPES

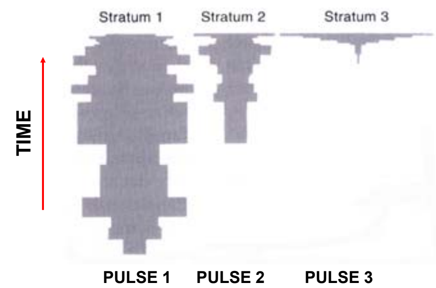


THE GREAT AMERICAN INTERCHANGE

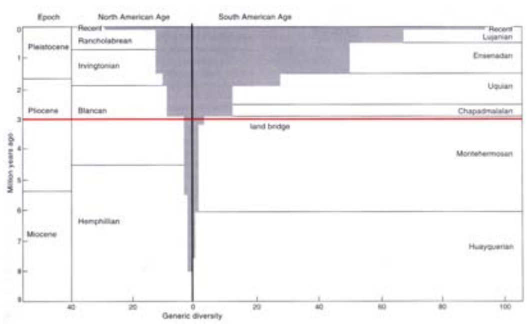
- **During periods of glaciation (called glacial pulses) faunal exchange between North and South America was enhanced by a continuous wet forest habitat.**



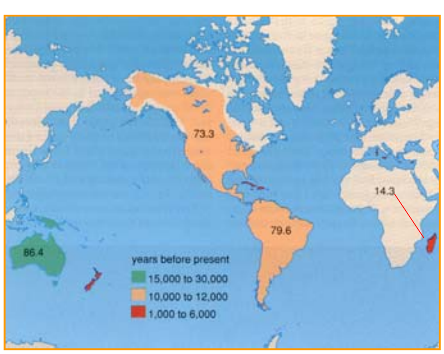
SPECIES DIVERSITY IN SOUTH AMERICA



FAUNAL EXCHANGE LEADS TO AN INCREASE IN DIVERSITY



SOME SPECIES INTERACTIONS CLEARLY DO RESULT IN ELEVATED EXTINCTION RATES



SIMPSON'S CONTRASTING VIEW OF EXTINCTION

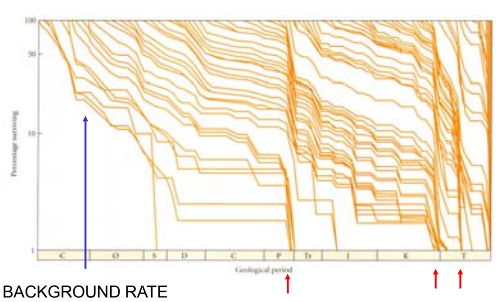
In the history of life it is a striking fact that major changes in the taxonomic groups occupying various ecological positions *do not, as a rule, result from direct competition* of the groups concerned in each case and the survival of the fittest. … On the contrary, the usual sequence is for one dominant group to die out, leaving the zone empty, before the other group becomes abundant…

Simpson 1944

TWO FACTORS IN THE PACE OF EXTINCTIONS

- **Background extinction:** the normal rate of extinction for a taxon or biota
- **Mass extinction:** a statistically significant increase above background extinction rate

BACKGROUND VERSUS MASS EXTINCTION RATES AMONG MARINE FAMILIES



BACKGROUND RATE OF EXTINCTION

MASS EXTINCTIONS

- **PULSES OF EXTINCTION**

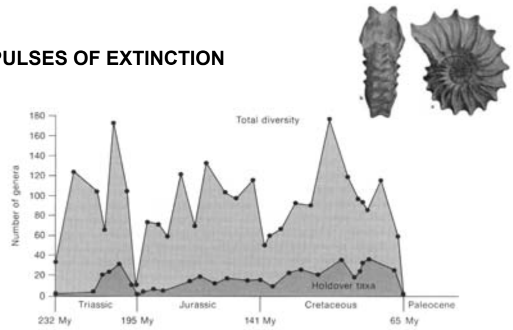


FIGURE 10-3
High rate of generic turnover in the evolution of the Ammonitina. (From Kennedy, 1977.)

THE "BIG FIVE" EXTINCTION EVENTS

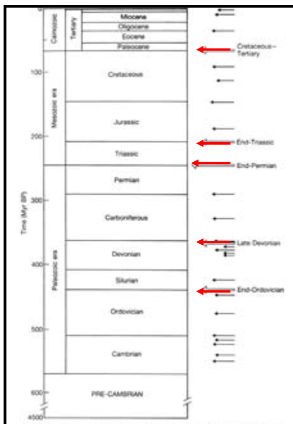
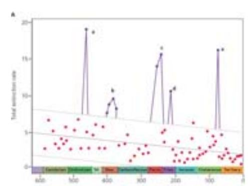
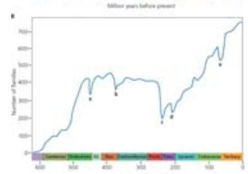


Figure 22.10 Five mass extinctions are particularly clear: Cretaceous, Triassic, Permian, Devonian, and Ordovician. Arrows represent the intensity of extinctions. From Raup (1991).





SPECIES LOSS DURING MASS EXTINCTIONS

TABLE 1 Comparison of species extinction levels for the Big Five mass extinctions

Extinction episode	Age, Myr before present	Percent extinction
Cretaceous (K–T)	65	76
Triassic	208	76
Permian	245	96
Devonian	367	82
Ordovician	439	85

Extinction data are from Jablonski (1991).

TABLE 14.2 Proposed Causes of the Big Five Mass Extinctions

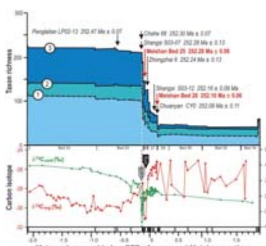
Event	Proposed Causes
The Ordovician Event Ended 443 million years ago; within 3.3 to 1.9 million years 57% of genera were lost, an estimated 86% of species.	Onset of alternating glacial and interglacial episodes; repeated marine transgressions and regressions. Uplift and weathering of the Appalachians affecting atmospheric and ocean chemistry. Sequestration of carbon dioxide, lowering average global temperatures.
The Devonian Event Ended 359 million years ago; within 29 to 2 million years 35% of genera were lost, an estimated 75% of species.	Global cooling (followed by global warming), possibly tied to the diversification of land plants, with associated weathering, soil formation, and fall in atmospheric concentrations of carbon dioxide. Evidence for widespread deep-water anoxia and the spread of anoxic waters by transgressions. Some evidence exists of impacts of an asteroid or comet, but their timing and importance are a subject of debate.
The Permian Event Ended 252 million years ago; in less than 60,000 years 56% of genera were lost, an estimated 96% of species.	Siberian volcanism. Global warming. Spread of deep marine anoxic waters. Elevated hydrogen sulfide and carbon dioxide concentrations in both marine and terrestrial realms. Ocean acidification. Evidence for an impact still debated.
The Triassic Event Ended 200 million years ago; within 8.3 million years to 600,000 years 47% of genera were lost, an estimated 80% of species.	Activity in the Central Atlantic Magmatic Province thought to have elevated atmospheric carbon dioxide levels, which increased global temperatures and led to a calcification crisis in the world oceans.
The Cretaceous Event Ended 65 million years ago; within 2.5 million years to less than a year 40% of genera were lost, an estimated 76% of species.	An impact in the Yucatán is thought to have led to a global cataclysm and caused rapid cooling. Preceding the impact, biota may have been declining owing to a variety of causes: volcanism in India that released carbon dioxide leading to rapid global warming; tectonic uplift altering biogeography and accelerating erosion, potentially contributing to ocean eutrophication and anoxic episodes.

Causality?

- Global Change in the Environment?
- Glaciations?
- Asteroid impacts?
- Volcanism?
- Elevation of CO_2 levels?

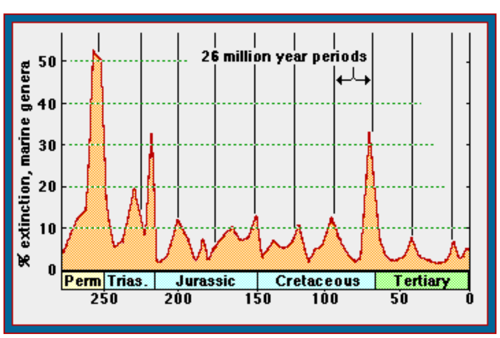
Calibrating the End-Permian Mass Extinction

The end-Permian mass extinction was the most severe biodiversity crisis in earth history. High-precision U-Pb dating reveals that the extinction peak occurred just before 252.28 ± 0.08 Ma, following a decline of 2‰ in δ13C over 90,000 years, and coincided with a δ13C excursion of - 5‰ that is estimated to have lasted ≤20,000 years. **The extinction interval was less than 200,000 years, and synchronous in marine and terrestrial realms; associated charcoal-rich and soot-bearing layers indicate widespread wildfires on land. A massive release of thermogenic carbon dioxide and/or methane may have caused the catastrophic extinction.**



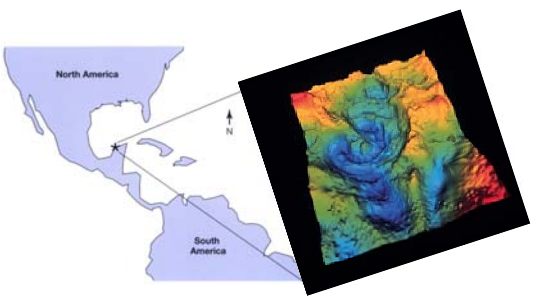
Sciencexpress / www.sciencexpress.org / 17 November 2011 / Page 1 / 10.1126/science.1213454

CYCLES OF EXTINCTION???

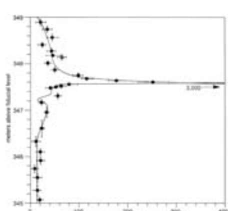


- Did a large meteor impact precipitate the extinction event at the K/T boundary?

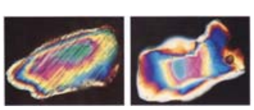
IMPACT SITE OF THE CHICXULUB METEOR



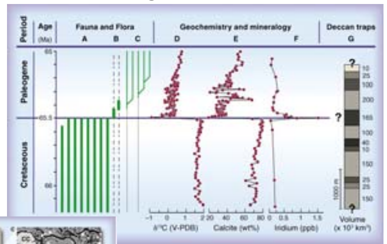
IRIDIUM LAYER AT THE K/T BOUNDARY

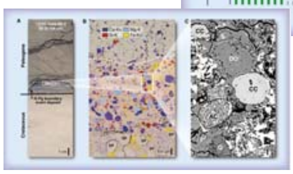


SHOCKED QUARTZ



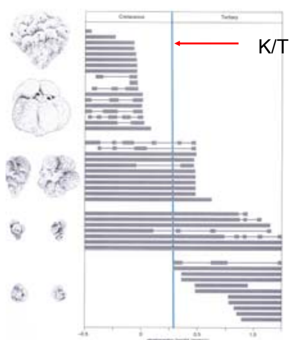
The Chicxulub Asteroid Impact and Mass Extinction at the Cretaceous-Paleogene Boundary





Science 5 March 2010:
Vol. 327. no. 5970, pp. 1214 - 1218
DOI: 10.1126/science.1177265

EXTINCTIONS IN MANY TAXA DO NOT CORRESPOND TO THE K/T BOUNDARY



EXTINCTIONS ARE CORRELATED WITH ENVIRONMENTAL CHANGE

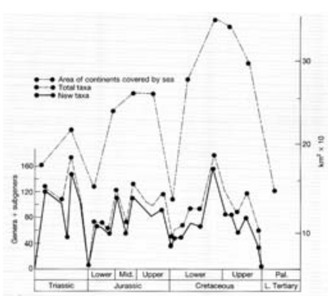
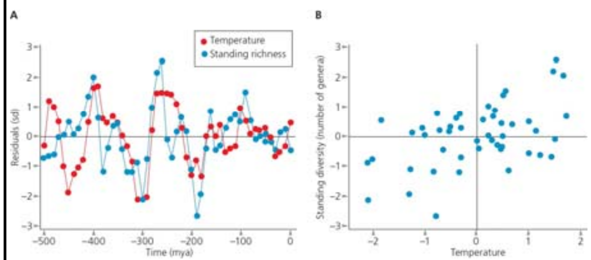


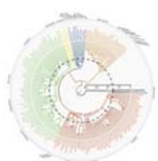
Figure 22.11 Three successive rounds of ammonite extinction were correlated with declines in the sea level (expressed here as area of continents covered by sea: when the sea is higher, it covers more of continental land). From Hallam (1963).

TAXONOMIC DIVERSITY POSITIVELY CORRELATED WITH MEAN TEMPERATURE

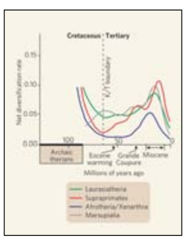


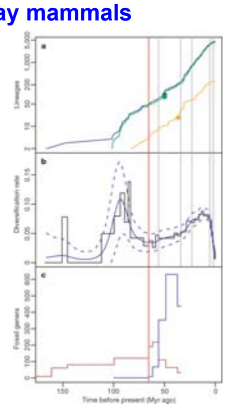
The delayed rise of present-day mammals

Bininda-Emonds et al. Nature 2007 446:507-512

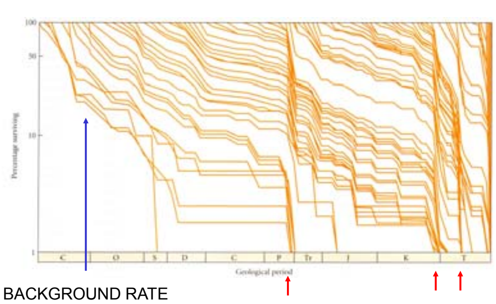


Mammalian supertree of 4,510 extant species





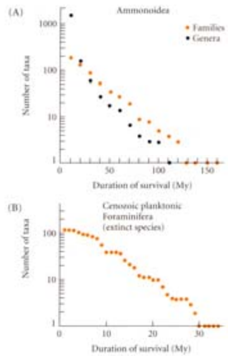
BACKGROUND VERSUS MASS EXTINCTION RATES AMONG MARINE FAMILIES



BACKGROUND RATE OF EXTINCTION

MASS EXTINCTIONS

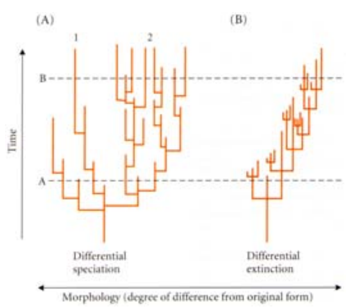
- **The observation of constant rates of background extinction suggests that as the evolution of a group proceeds, *it becomes neither more or less resistant to new changes in the environment*.**
- **This observation has been proposed to be evidence for the Red Queen hypothesis. (Van Valen 1973). The continual coevolution of other species prevents species from attaining a higher level of fitness.**



ARE MAJOR TRENDS IN THE FOSSIL RECORD DUE TO SELECTION OPERATING AT THE LEVEL OF SPECIES?

- **The possibility that long-term trends in the fossil record are due to *differential survival* of species raises the question of whether selection can operate at multiple levels.**
- **Usually we think of the individual as the unit of selection, but is there any evidence that selection can operate on groups or lineages?**

SPECIES SELECTION CAN BE DUE TO DIFFERING RATES OF SPECIATION OR EXTINCTION

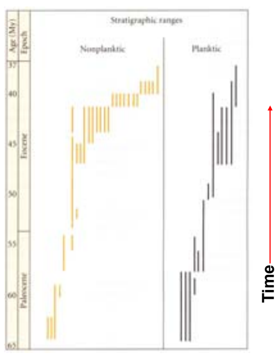


CONDITIONS **NECESSARY** FOR SPECIES SELECTION

- **The character showing the trend (e.g., body size) is correlated with the extinction rate, or speciation rate, or both.**
- **The character shows "heritability" through speciation events. For example, species with larger than average body size tend to give rise to new species with larger than average body size.**

TREND DUE TO SPECIES SELECTION

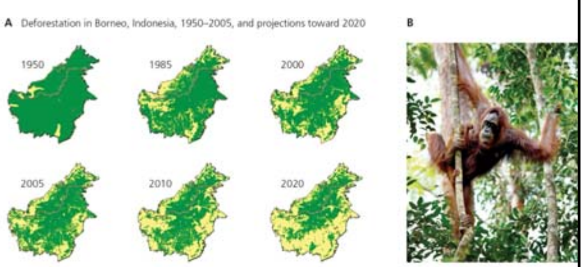
- **The abundance of volutid snails shows a higher rate of speciation in lineages without a planktonic larval stage (NP) than in lineages that have a planktonic larvae (P).**
- **Over time the ratio of NP to P species increased**



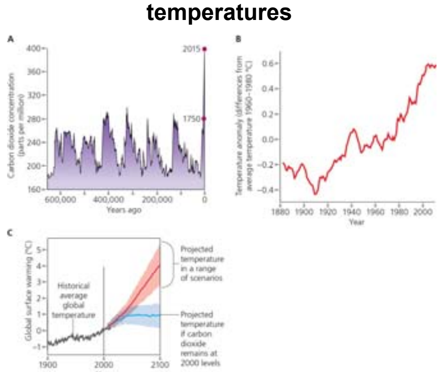
EXTINCTION SUMMARY

- There are two contrasting views of extinction. Competitive replacement due to natural selection (Darwin) and ecological change (Simpson). This latter view can be expressed as ….**species simply running out of niche space**…(Williams).
- Catastrophic events cause an abrupt elevation in the background extinction rate extinction. This effect is likely due to a combination of rapid environmental change and a cascade effect caused by break up of complex biotic interactions.
- The process of *differential extinction* may contribute to long-term trends in evolution.

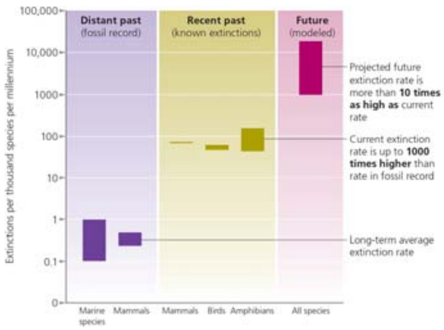
HUMAN CAUSED HABITAT LOSS DRIVES SPECIES TOWARD EXTINCTION



Increasing carbon dioxide leads to warming temperatures



IS THE STAGE SET FOR A SIXTH MASS EXTINCTION?



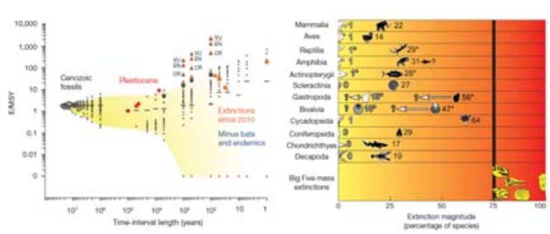
The current rate of extinction may equal or even exceed the rate of loss during the Permian Mass Extinction.

This statement reflects a growing concern with the rapid loss of biodiversity as a result of anthropogenic effects on the environment.

But, is it true?

Has the Earth's sixth mass extinction already arrived?

Anthony D. Barnosky[1,2,3], Nicholas Matzke[1], Susumu Tomiya[1,2,3], Guinevere O. U. Wogan[1,3], Brian Swartz[1,2], Tiago B. Quental[1,2]†, Charles Marshall[1,2], Jenny L. McGuire[1,2,3]†, Emily L. Lindsey[1,2], Kaitlin C. Maguire[1,2], Ben Mersey[1,4] & Elizabeth A. Ferrer[1,2]



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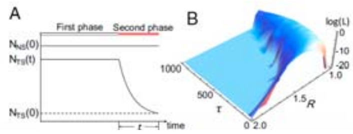
Large numbers of vertebrates began rapid population decline in the late 19th century

The current rate of species extinction is ~1,000 times the background rate of extinction and is attributable to human impact, ecological and demographic fluctuations, and inbreeding due to small population sizes. The rate and the initiation date of rapid population decline (RPD) can provide important clues about the driving forces of population decline in threatened species, but they are generally unknown. We analyzed the genetic diversity data in 2,764 vertebrate species. Our population genetics modeling suggests that in many threatened vertebrate species the RPD on average began in the late 19th century, and the mean current size of threatened vertebrates is only 5% of their ancestral size. We estimated a ~25% population decline every 10 y in threatened vertebrate species.

- **Accelerated losses of biodiversity are a hallmark of the current era. Large declines of population size have been widely observed and currently 22,176 species are threatened by extinction.**



Haipeng Li, Jinggong Xiang-Yu, Guangyi Dai, Zhili Gu, Chen Ming, Zongfeng Yang, Oliver A. Ryder, Wen-Hsiung Li, Yun-Xin Fu, and Ya-Ping Zhang

www.pnas.org/cgi/doi/10.1073/pnas.1616804113

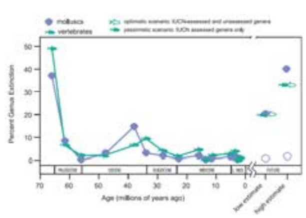
PNAS Early Edition

EXTINCTION

Ecological selectivity of the emerging mass extinction in the oceans

Jonathan L. Payne, Andrew M. Bush, Noel A. Heim, Matthew L. Knope, Douglas J. McCauley

To better predict the ecological and evolutionary effects of the emerging biodiversity crisis in the modern oceans, we compared the association between extinction threat and ecological traits in modern marine animals to associations observed during past extinction events using a database of 2497 marine vertebrate and mollusc genera. **We find that extinction threat in the modern oceans is strongly associated with large body size, whereas past extinction events were either nonselective or preferentially removed smaller-bodied taxa.** Pelagic animals were victimized more than benthic animals during previous mass extinctions but are not preferentially threatened in the modern ocean. The differential importance of large-bodied animals to ecosystem function portends greater future ecological disruption than that caused by similar levels of taxonomic loss in past mass extinction events.



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