

The Simple Economics of Mass Extinctions

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According to UN environment programme:

- One million of the world's estimated 8 million species of plants and animals are threatened with extinction
- Close to 90% of the world's marine fish stocks are fully exploited, overexploited or depleted.
- Agricultural expansion is said to account for 70% of the projected loss of terrestrial biodiversity.

Published: June 1, 2012

OPINION

Are We in the Midst Of a Sixth Mass Extinction?

A Tally of Life Under Threat

The International Union for Conservation of Nature has evaluated 52,205 species, depicted here, for their ability to survive. [Related Article »](#)

Each symbol represents 100 species assessed:



Mass Extinctions Are Accelerating, Scientists Report

Five hundred species are likely to become extinct over the next two decades, according to a new study.



SkYROCKETING Extinctions Put Humans at Risk

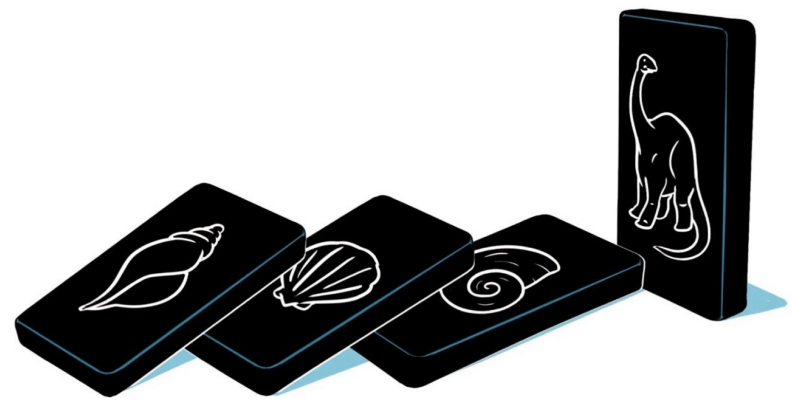
By Anna North



OBSERVATORY

Earlier Mass Extinction for Most of Marine Life

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Warning on Mass Extinction of Sea Life: 'An Oh My God Moment'

A new study finds that if fossil fuel emissions continue apace, the oceans could experience a mass extinction by 2300. There is still time to avoid it.

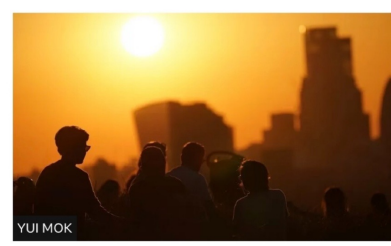


Dolphins feeding off the east coast of South Africa. Chris & Monique Fallows/Nature Picture Library, via Alamy

Climate change: More studies needed on possibility of human extinction

1 August 2022

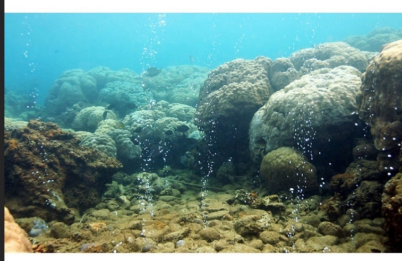
COP26



Catastrophic climate change outcomes, including human extinction, are not being taken seriously enough by scientists, a new study says.

The authors say that the consequences of more extreme warming - still on the cards if no action is taken - are "dangerously underexplored".

Life in the Sea Found Its Fate in a Paroxysm of Extinction

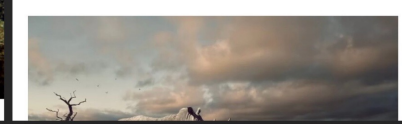


IN DANGER Corals are the most vulnerable creatures in

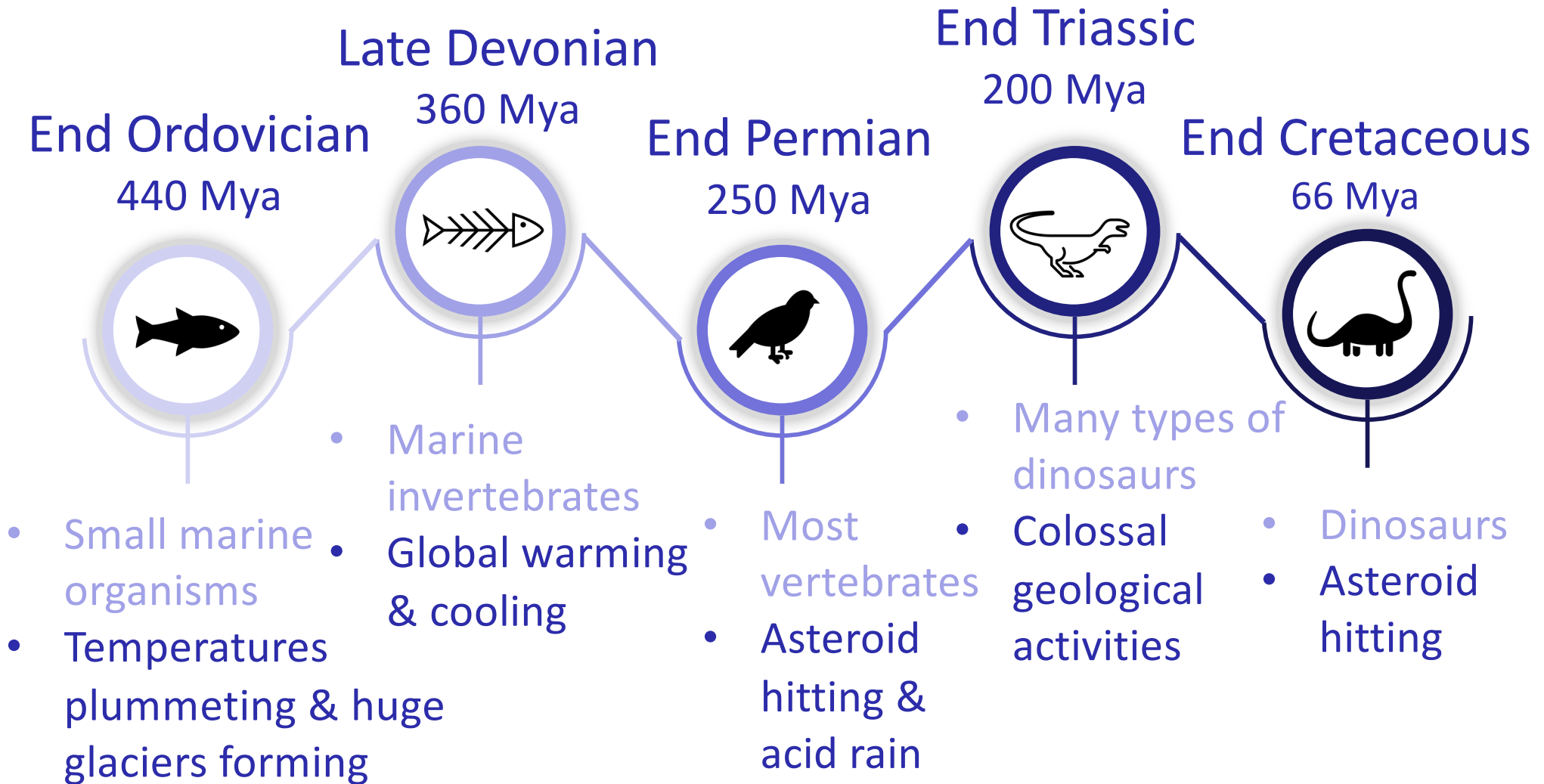
Biodiversity: What is a mass extinction and are we causing one?

9 December 2022

Climate change



Big Five Mass Extinctions



Physical Scientists predicting a Mass Extinction

- Barnosky et al. (2011), Nature:
“Has the world’s sixth mass extinction already arrived”
- Ceballos et al. (2015), Science Advances
“Accelerated modern human induced species losses: Entering the sixth mass extinction”
- Ceballos et al. (2020), PNAS
“Vertebrates on the brink as indicators of biological annihilation and the sixth mass extinction”

Why?

- Passive Habitat loss created by pollution and climate change.
- Active Habitat loss created by deliberate conversion of forests, wetlands, natural areas for commercial use.
- Overharvesting for human consumption

Four Questions to Answer

- How might Economists think about Mass Extinctions?
- Could the driving force be Habitat loss?
- Could the driving force be Overharvesting?
- Where does economics tell us to look for early signs of a Mass Extinction.

Method

- Revisit a case of near extinction caused by Overharvesting – North American Buffalo
- Introduce a new case of impending extinction caused by Habitat Loss – Killer Whales
- Put these forces together in a many species model to understand the ingredients for a Mass Extinction.

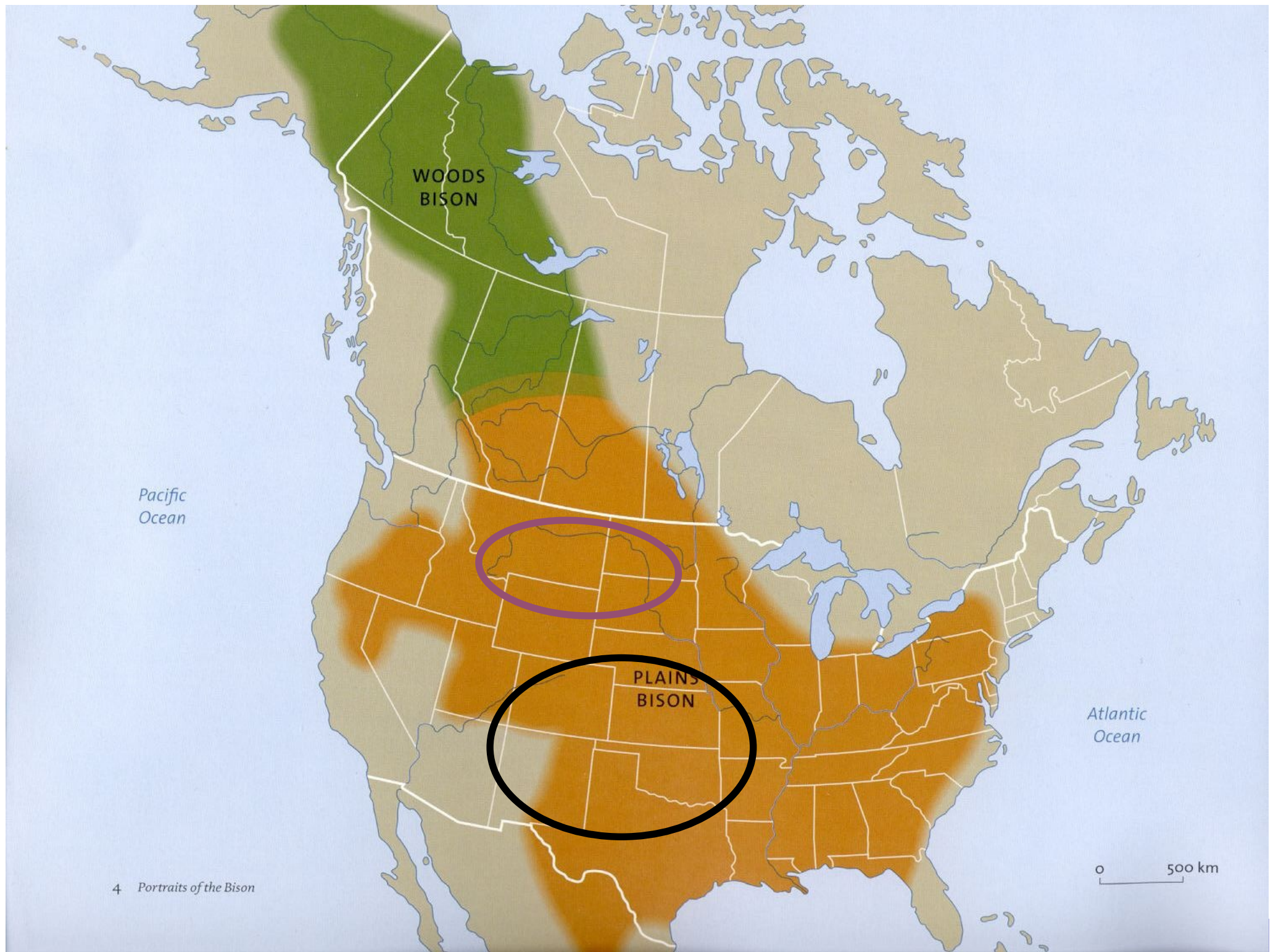
Overharvesting

Buffalo



“Buffalo hunt: International trade and the virtual extinction of the North American bison.”

American Economic Review (2011), M. Scott Taylor



Buffalo History

- Pre-European contact population of somewhere between 25 - 30 million animals.
- Habitat destruction and subsistence hunting slowly removed the populations east of the Mississippi by approximately the 1830s.
- By the 1860s, buffalo only on the Great Plains. West of the the 98th meridian, East of the Rockies. By 1865: 10-15 million buffalo left.

- Completion of Union Pacific Railroad in 1867 divided the herd into small Northern and large Southern herds.
- Slaughter on the “Great Plains”. Southern herd eliminated from 1871-1879. Northern herd eliminated from 1881-1883.
- In a little more than 10 years, population fell from perhaps 10 million to 100.



Glenbow Archives NA-354-30



Three Main Suspects

- The Army came, wanted the bison dead to “civilize” the Indians, they facilitated hunting, and buffalo numbers fell.
- The Railroads came, they created a market for their meat, robes and hides, they facilitated hunting, and buffalo numbers fell.
- New rifles came, allowing hunters to shoot from 600 yards away and kill 100 buffalo in a “stand”.

What needs to be Explained?

- Why was the slaughter a slaughter?

Tanning innovation

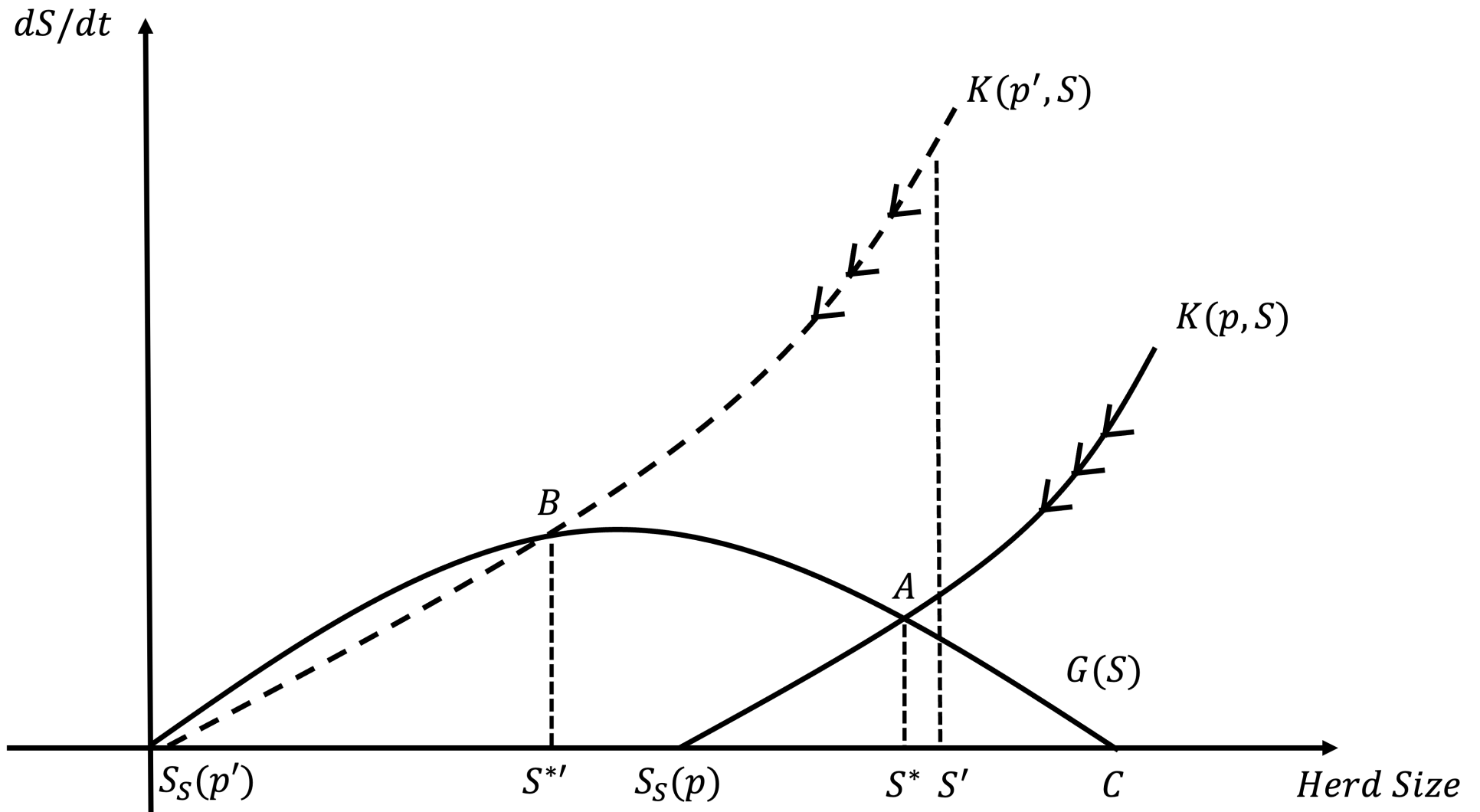
- Why didn't prices adjust to limit the slaughter?

US was small on world markets

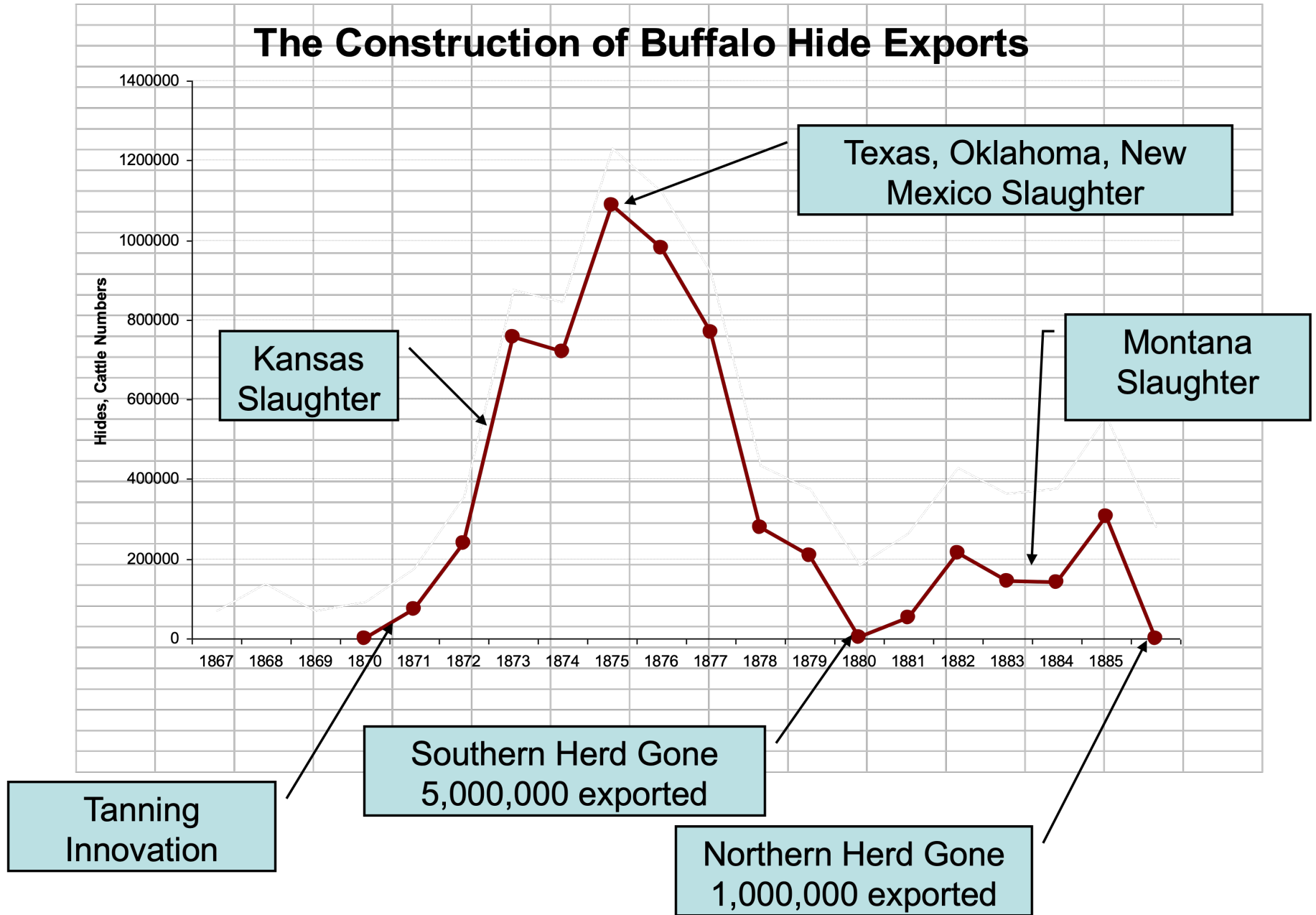
- Where did all the buffalo products go?

France, Germany & the U.K.

How it Happened



The Construction of Buffalo Hide Exports



Who killed the Buffalo?

- Tanning Innovation created in Europe
- Robust demand comes from Europe
- Are Europeans responsible for the most shameful event in US Environmental history?

Habitat Loss



Killer Whales

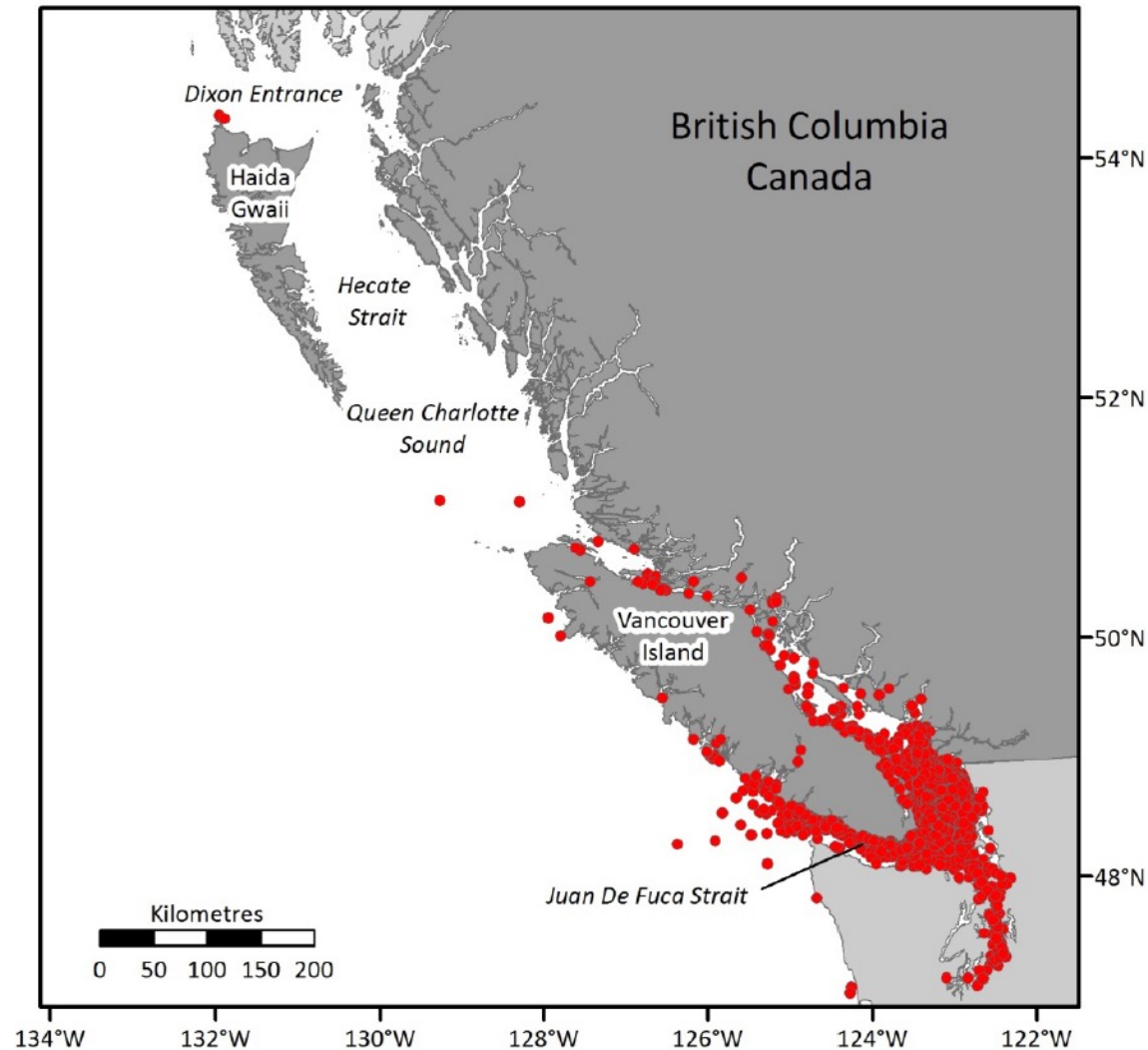
“International Trade, Noise Pollution, and Killer Whales”

*WP 31390. National Bureau of Economic Research, 2023.
M. Scott Taylor & Fruzsina Mayer*

History

- July 16th, 1964: A small killer whale was captured. The display industry started.
- Early 1970s: Live capture was regulated and then banned by 1980.
- Late 1990s: KW were protected by both Canadian and US governments.
- Early 2000s: KW were listed as Species at Risk (Canada) or Endangered species (US). The SRKW is endangered; the NRKW is listed as threatened.
- Today: SRKW has perhaps 74 whales, the NRKW 330.

SRKW Sightings

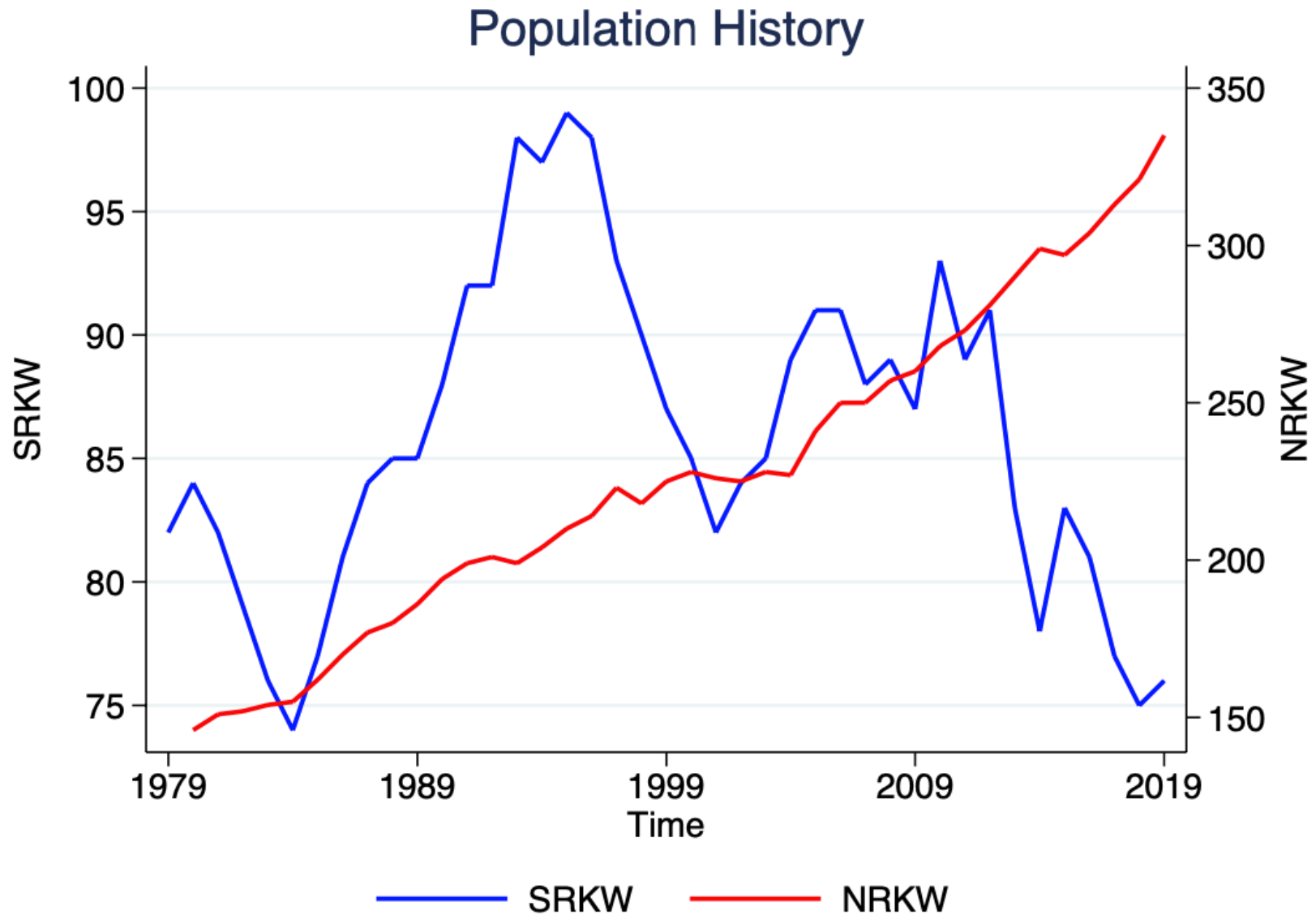


Distribution of sightings and encounters with Southern Resident Killer Whales.
Source: Figure 2. in Ford et al. (2017)

The Problem with the Southern Residents

- The Southern Resident population has been on a long downward trend since the mid to late 1990s.
- The current population size is about where it was in the mid 1970s when the live capture industry was still active.
- Its age and sex composition is worrisome.

#7. The SRKW Population Decline is Unique



Three Main Suspects

- A lack of prey, sometimes linked to declining Salmon returns on the Columbia and Fraser Rivers and dams on its tributary the Snake River.
- Vessel disturbances from whale watching and large Commercial Vessels.
- PCBs and other long-lived contaminants leaching into the marine environment and then magnified by bioaccumulation.

What needs to be Explained?

- Why after the SRKW were protected from capture, has their population plummeted?

Noise Pollution from Commercial Vessels

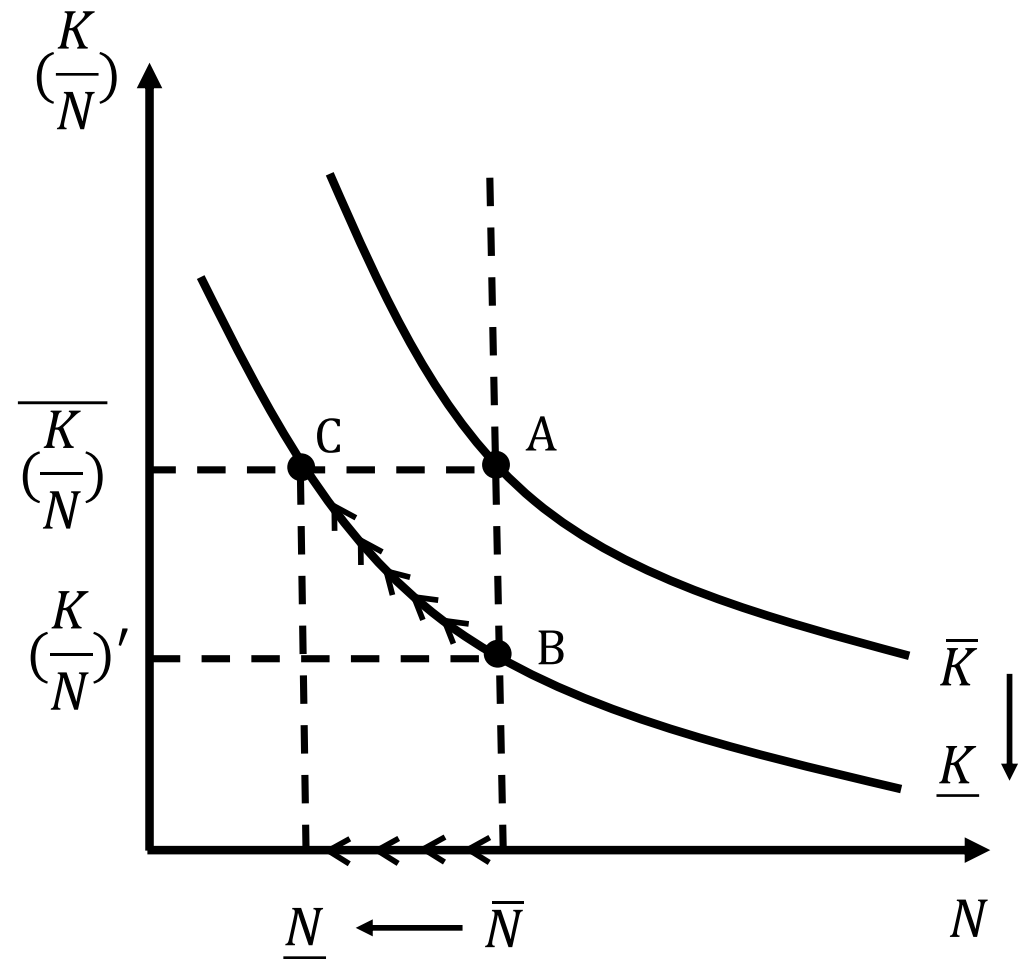
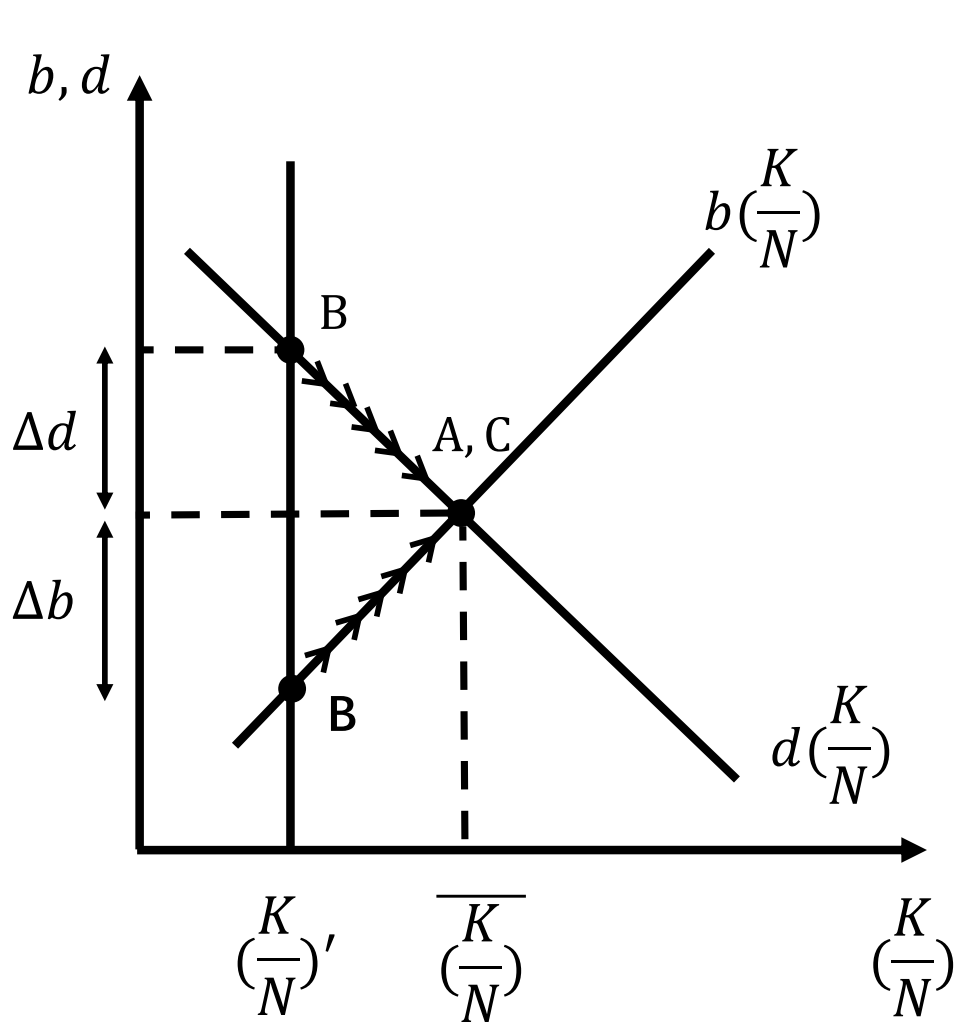
- Why did it occur post 2000s?

Trade with Asia exploded, while the composition of vessels shifted to very noisy container ships.

- What about Salmon or PCBs?

Salmon Abundance is cyclical; PCB levels are not limiting other KW populations.

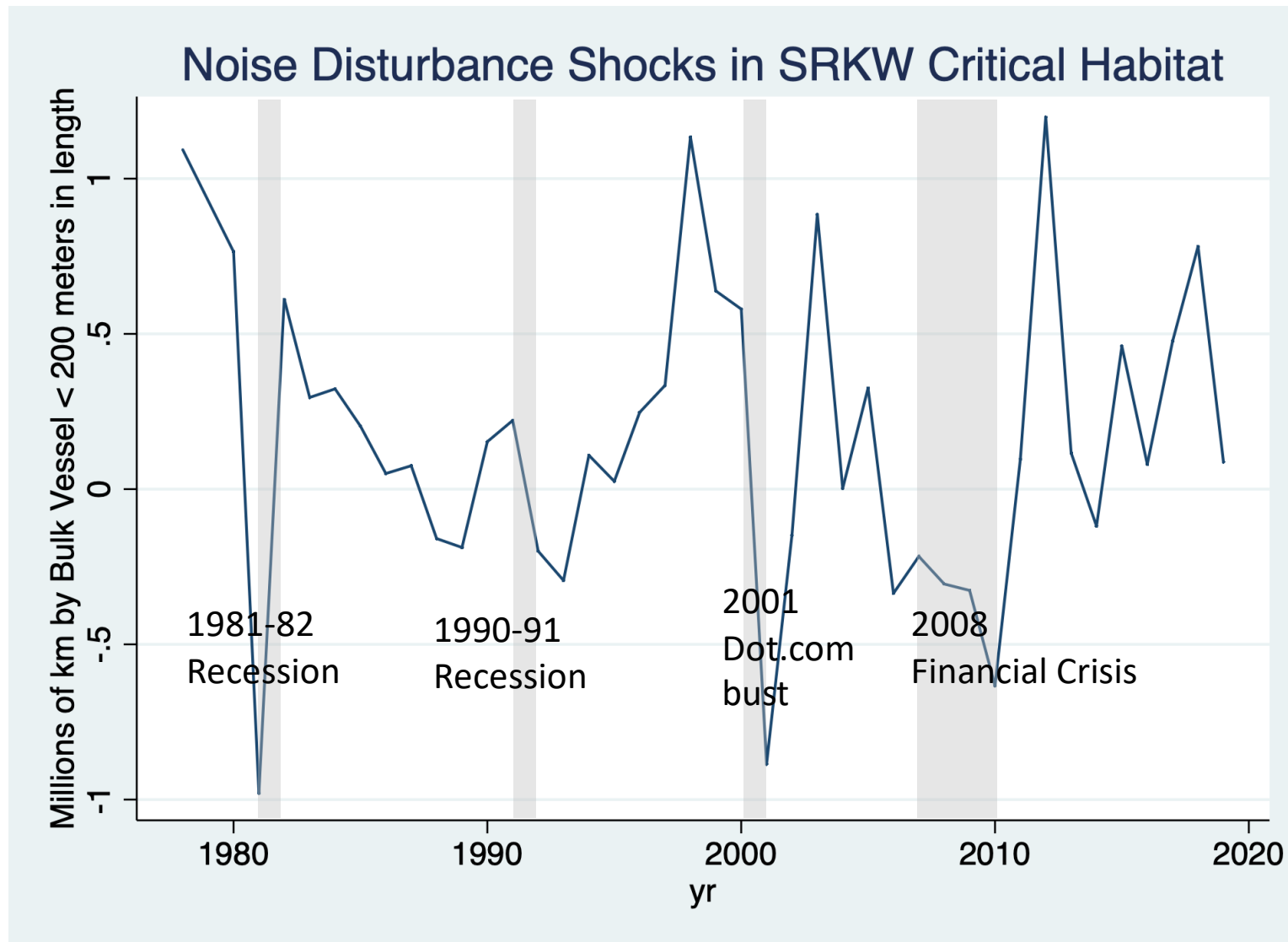
How could Noise Pollution from Vessels lower KW populations?



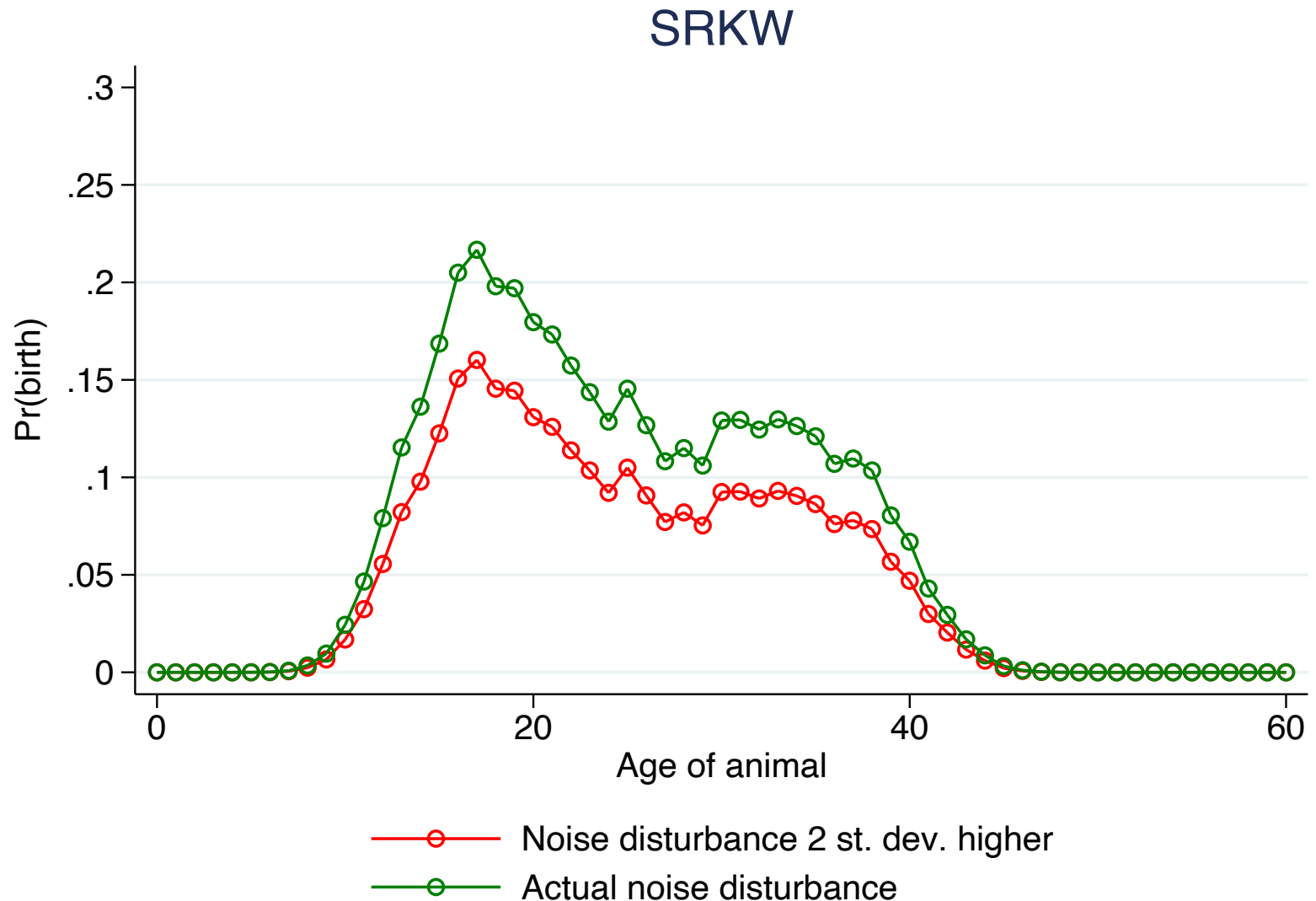
Quasi-experimental Research Design

- Compare the fertility and mortality, of otherwise identical Killer whales, who are exposed to greater or lesser amounts of noise pollution.
- Condition on large set of demographic, prey and competition variables. Ensures like-to-like comparisons.
- Use “pollution shocks” to eliminate avoidance and fixed effects for sorting.

Noise Disturbance Shocks in SRKW Critical Habitat

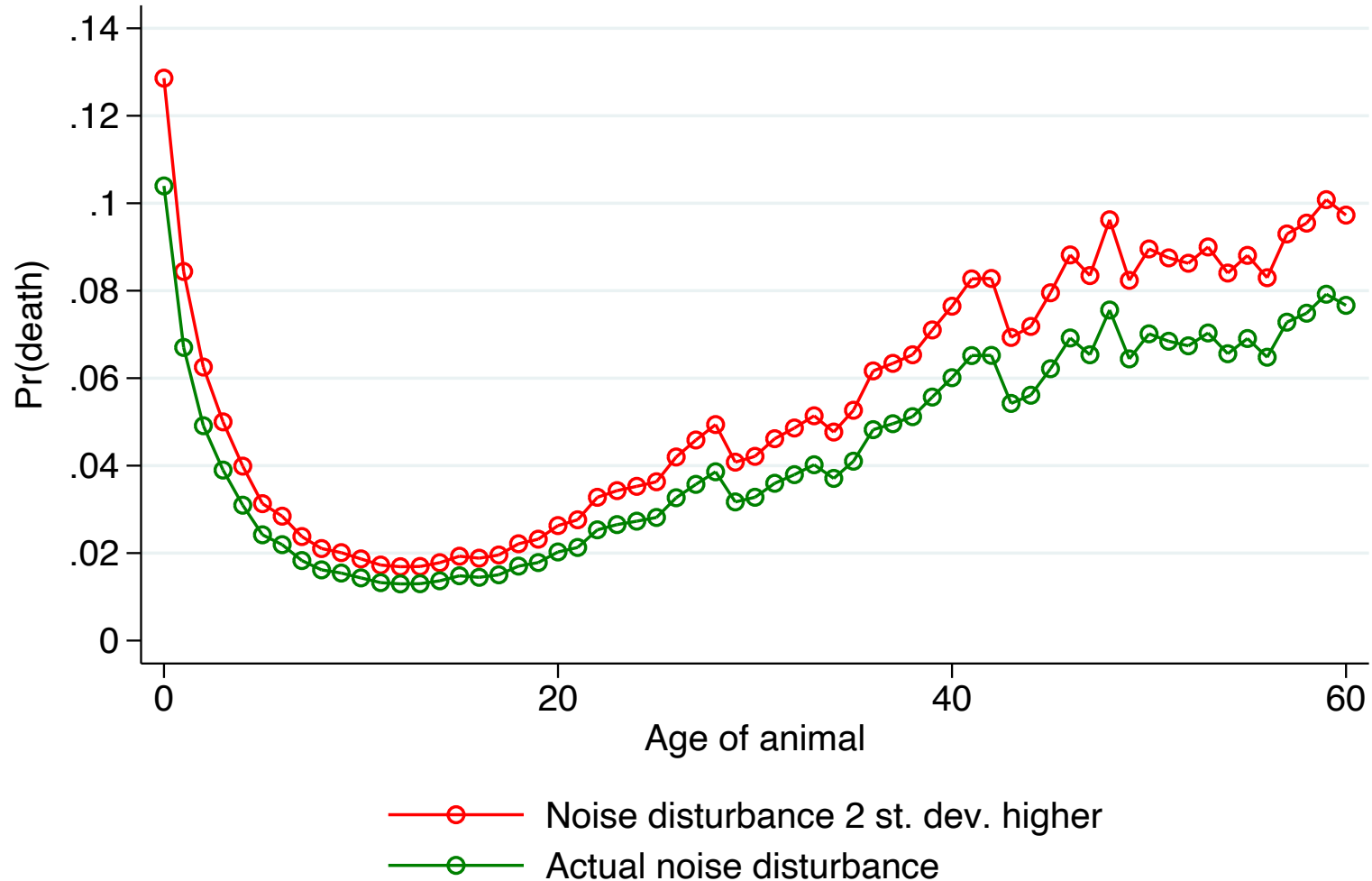


Fertility Profile: Avg Year vs Noisy Year



Mortality Profile: Avg Year vs Noisy Year

SRKW

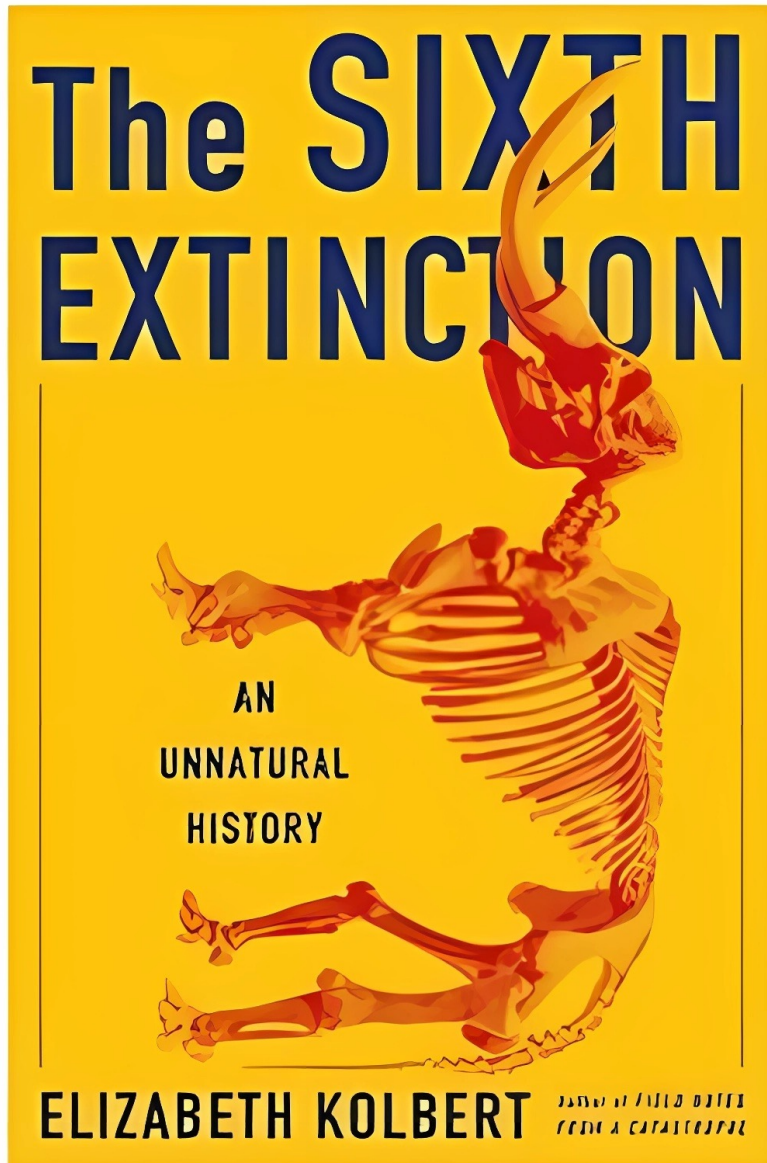


Conclusions

- Vessel noise pollution shocks measured by disturbance, lowers births and raises deaths.
- Effects vary across vessel class and size. Largest container ships have very significant impacts on both births and deaths.
- Given the magnitude of the impacts, no feasible amount of salmon restoration is going to bring the SRKW back if vessel traffic is left unchecked.

Mass Extinction

A Simple Model of Mass Extinction

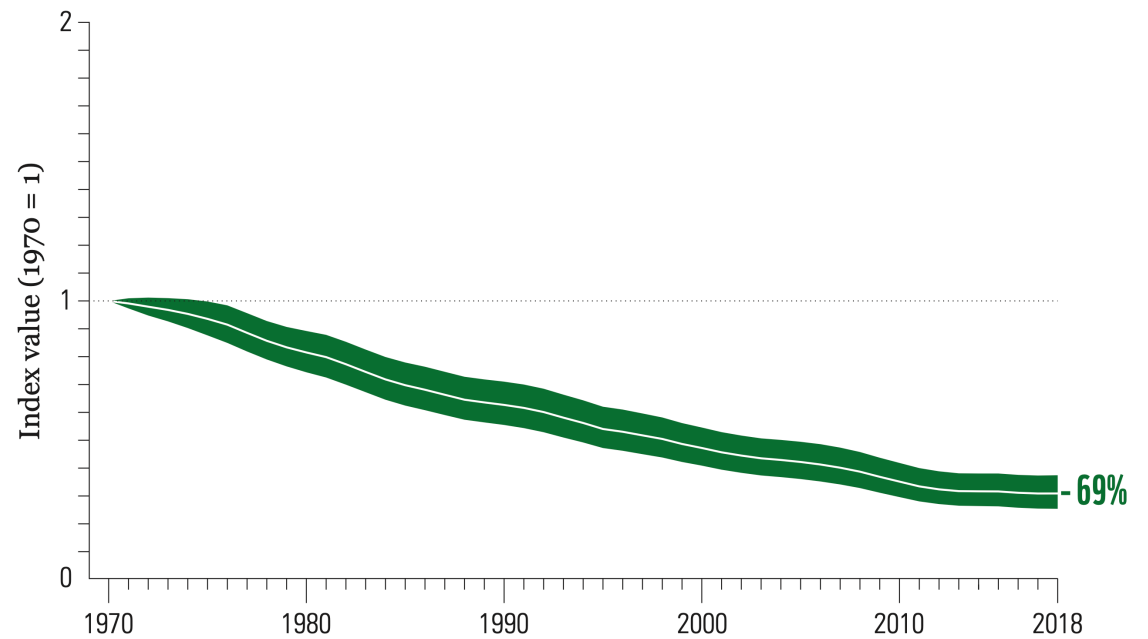


“The Economics of Extinctions”

In Preparation for the Journal of Economic Perspectives (2023). M. Scott Taylor & Rolf Weder

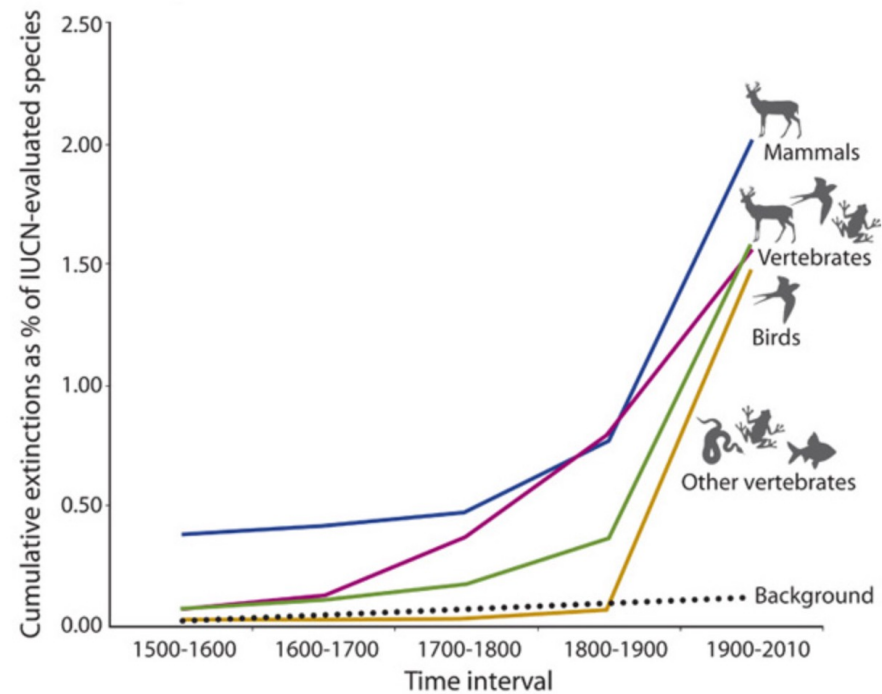
What needs to be Explained?

Aggregate
measures of
Biodiversity
are Declining



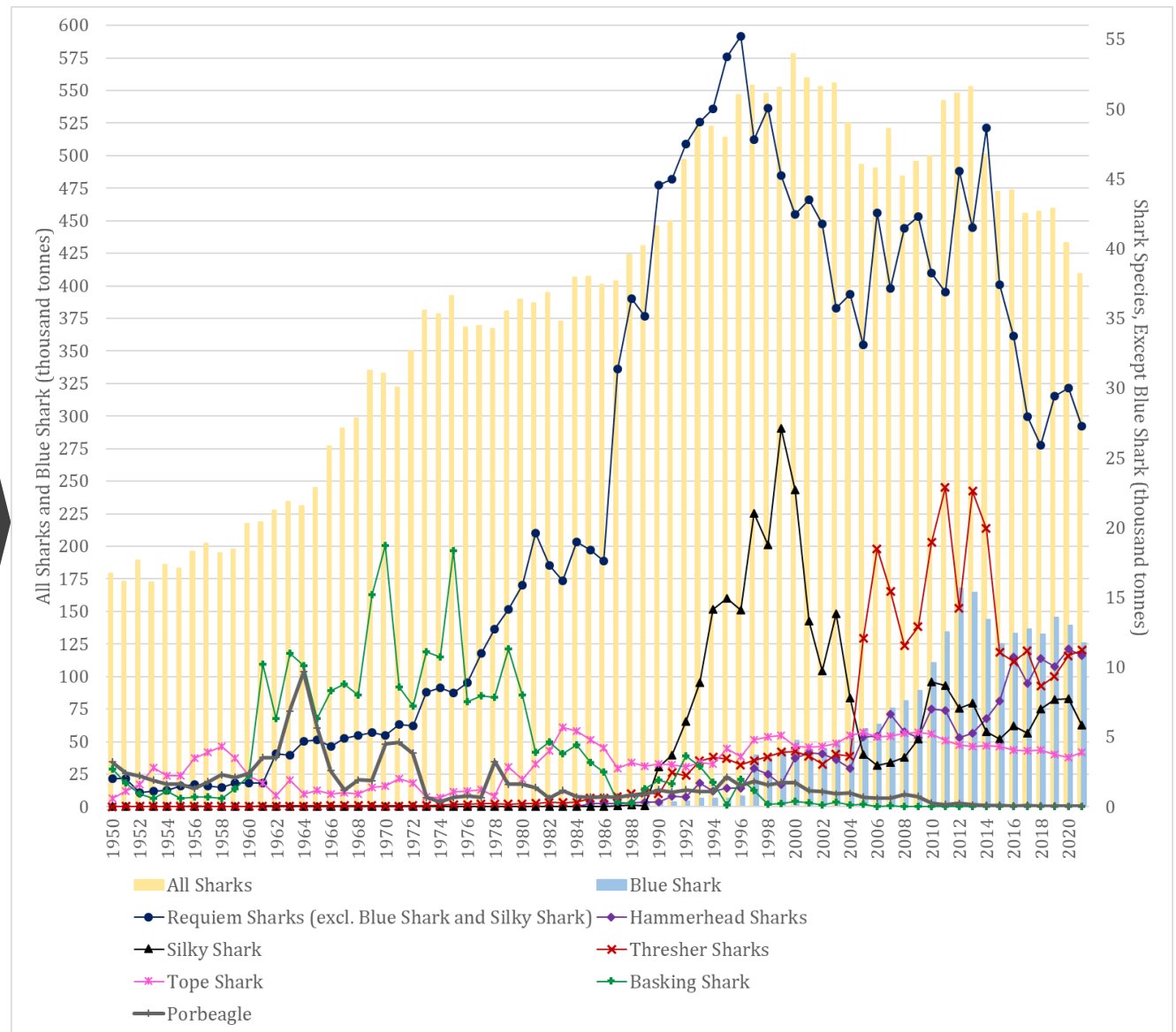
Global Living Planet Index

Rapidly Increasing Rates of Extinction



Cumulative vertebrate species recorded as extinct or extinct in the wild by the IUCN (2012). Graphs show the percentage of the number of species evaluated among mammals (5513; 100% of those described), birds (10,425; 100%), reptiles (4414; 44%), amphibians (6414; 88%), fishes (12,457; 38%), and all vertebrates combined (39,223; 59%). Dashed black curve represents the number of extinctions expected under a constant standard background rate of 2 E/MSY. Conservative estimate. Image and caption courtesy of Ceballos et al (2015)

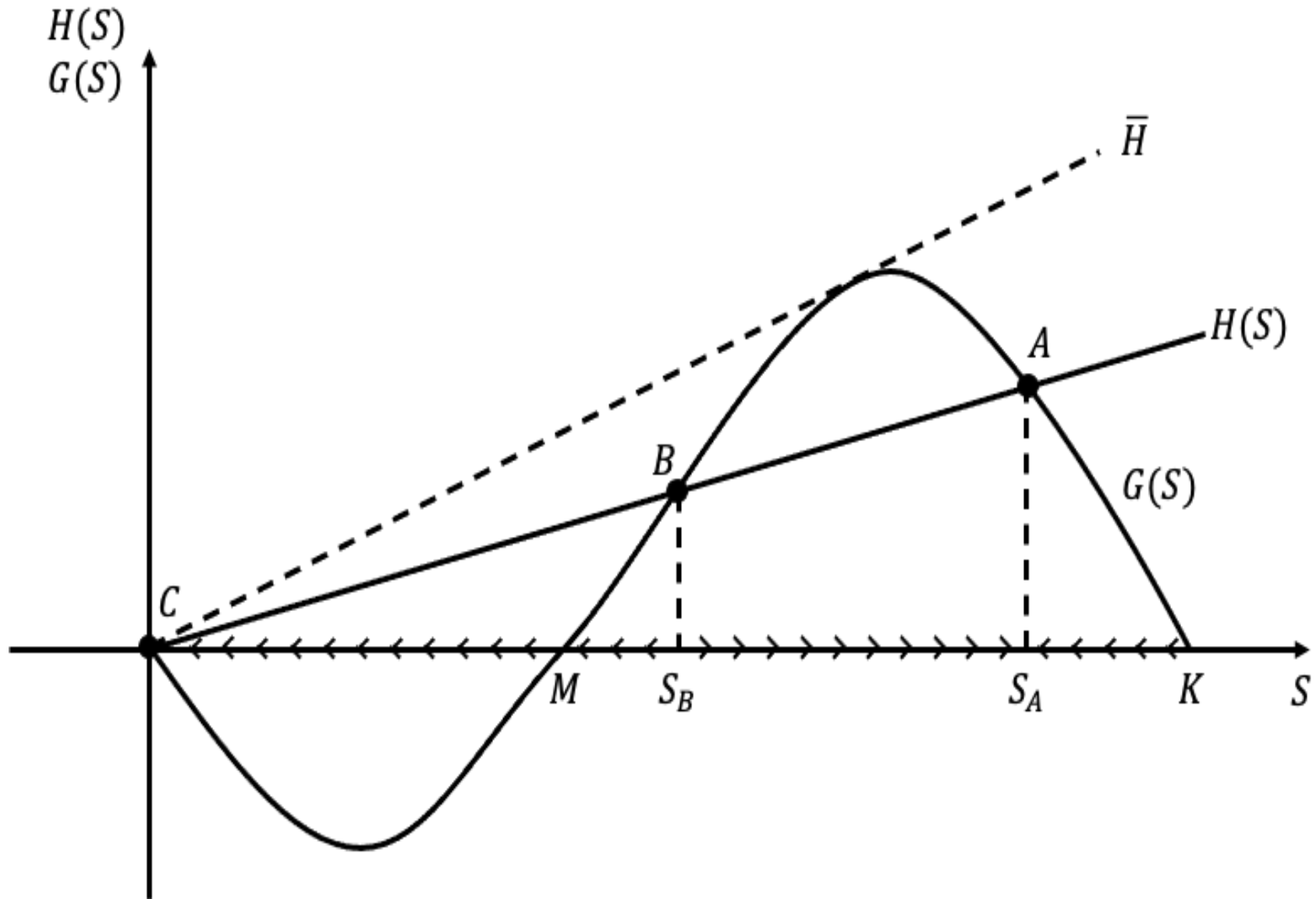
Aggregate Harvests Hide Serial Depletion



Assumptions

- Every species has a minimum viable population.
- Multiple species are connected via demand, supply side, or both.
- There are no asteroids, aliens, run away climate change, or cataclysmic events.

One Species & 3-2-1 Extinction

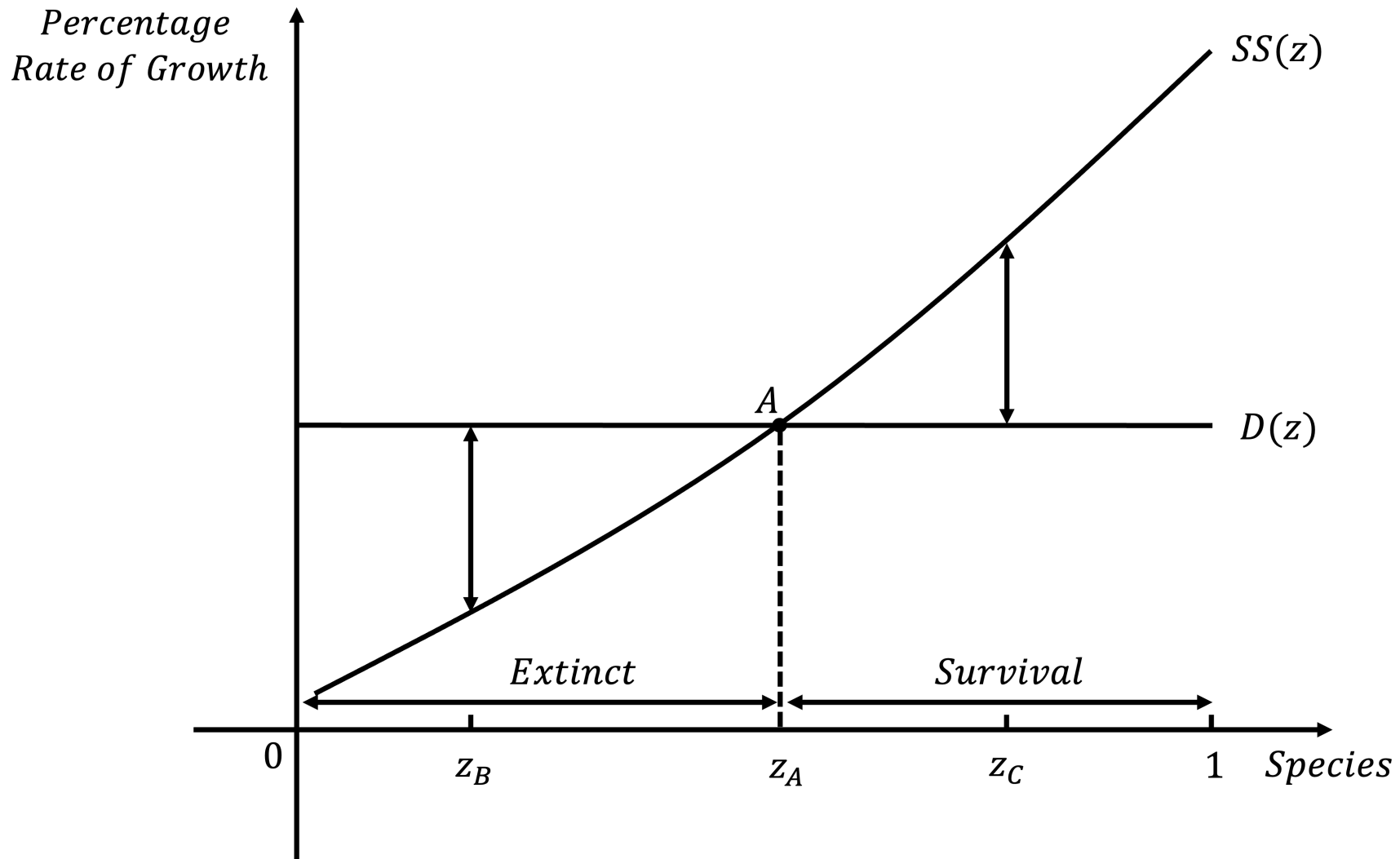


Extinction Condition

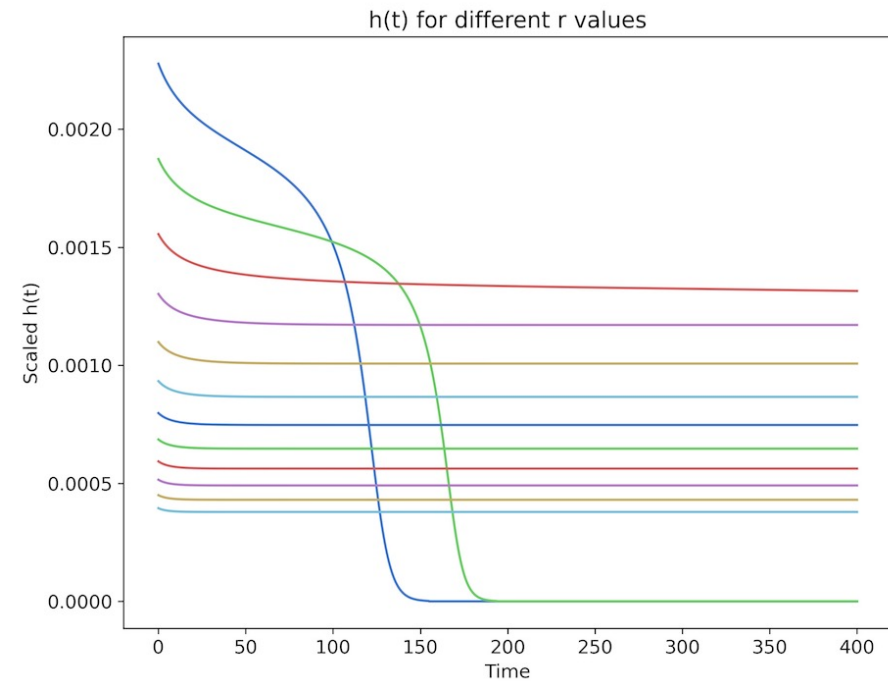
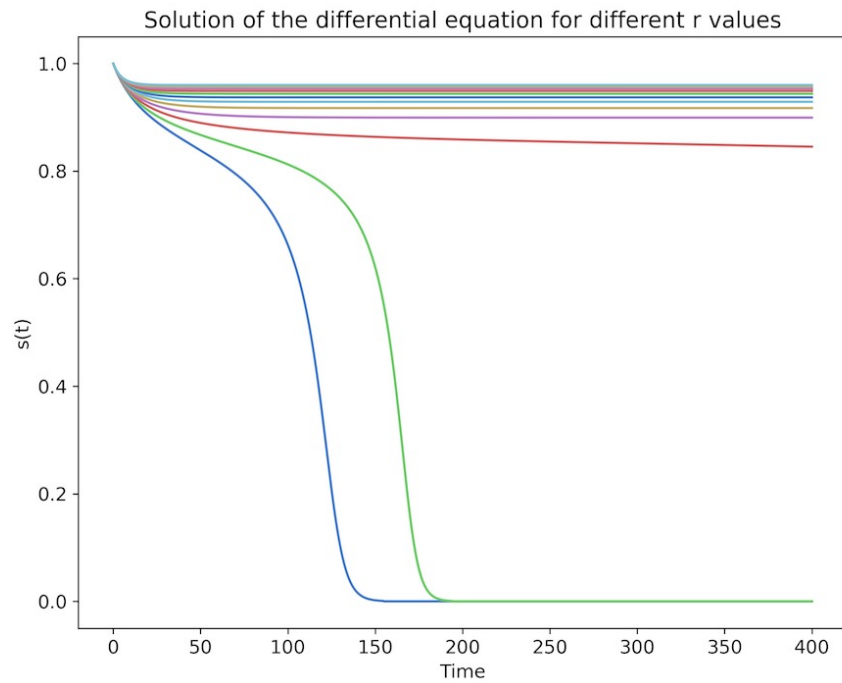
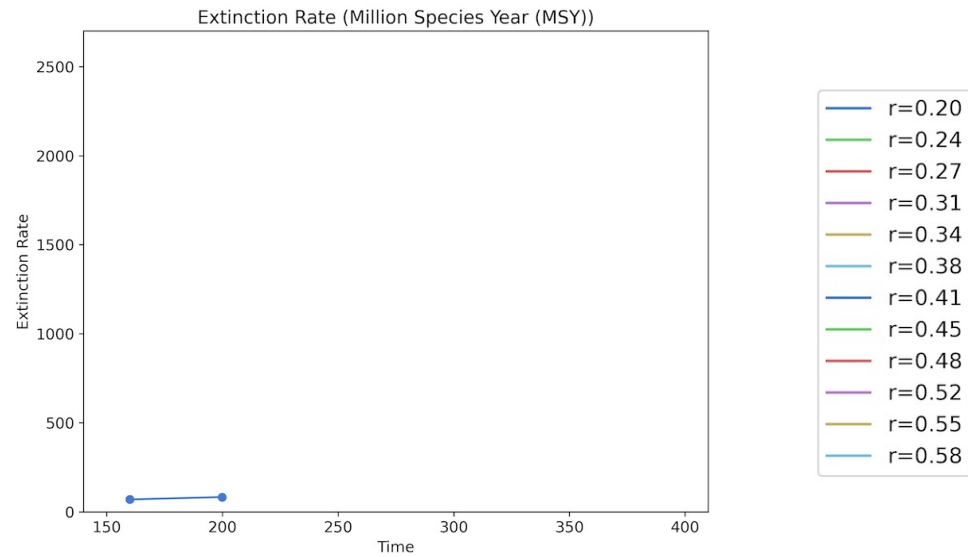
- Assume Demand is spread uniformly across species labelled by z which is in $[0,1]$.
- Assume species differ in rate of reproduction, $r(z)$ but share a common vulnerability $v = M/K$.
- Then a species goes extinct if:

$$D(z): \beta L \varphi > \frac{r (1 - v)^2}{\alpha 4v} : SS(z)$$

The Steady State Demand and Supply of Extinction



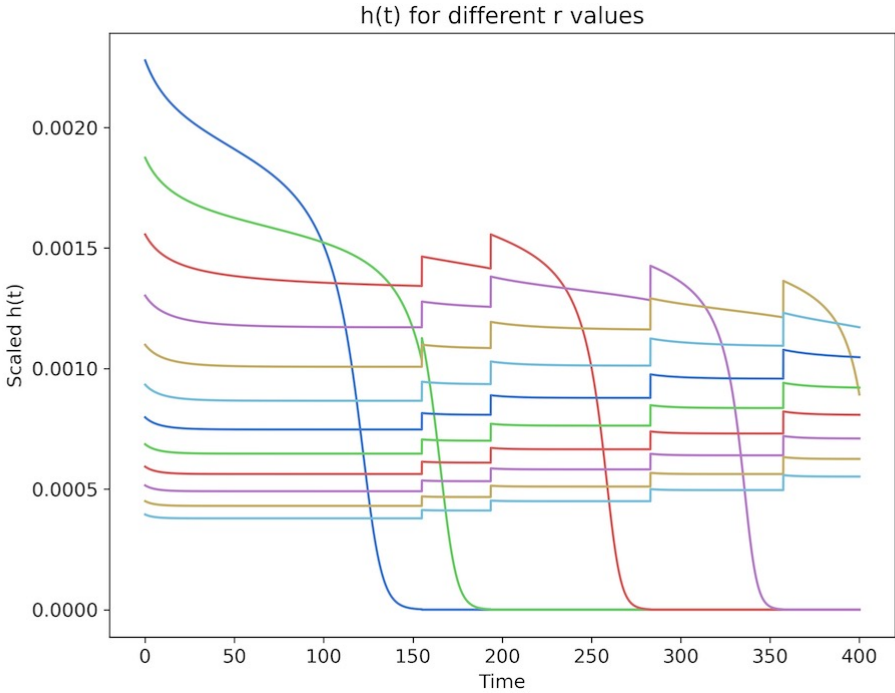
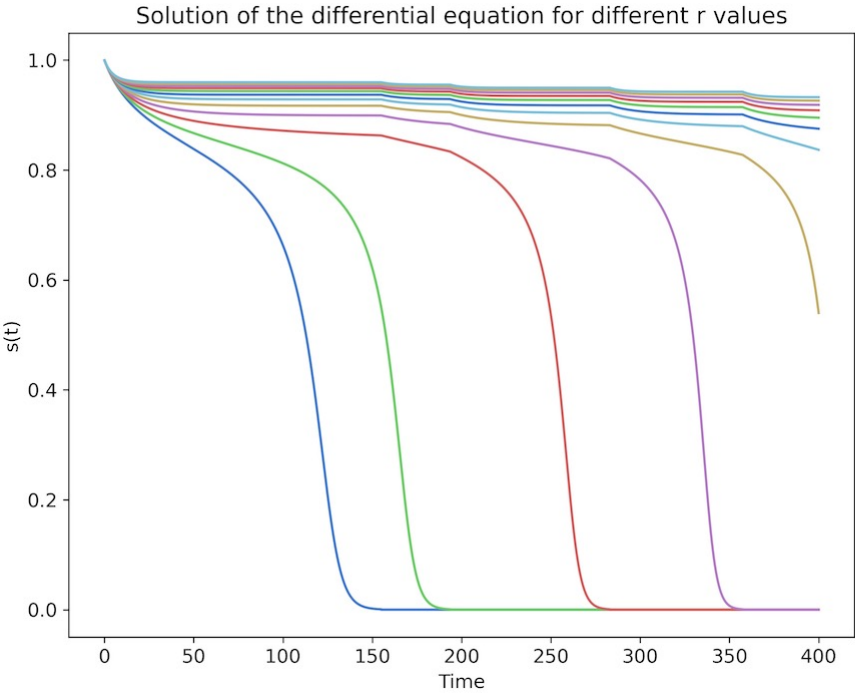
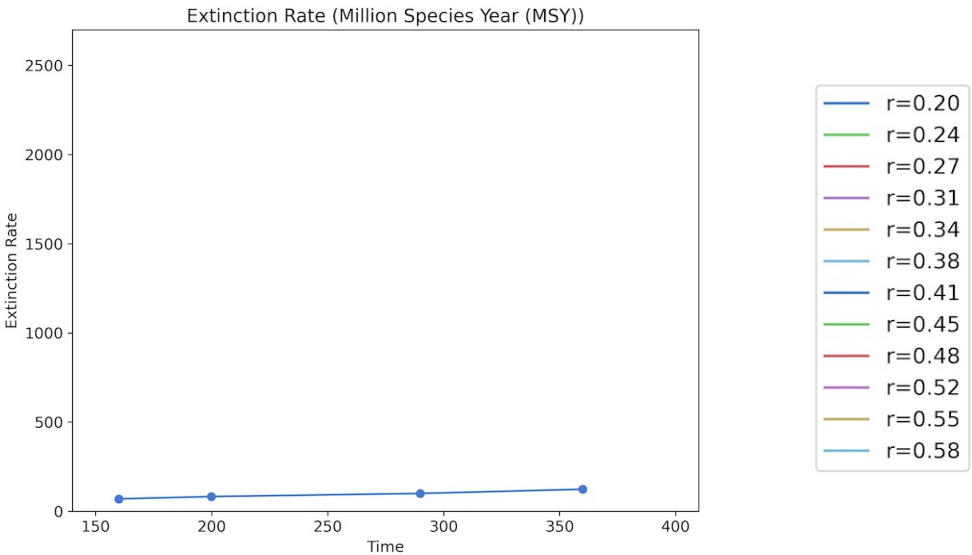
Diffuse Demand & Habitat Intact



Add Substitutability in Demand

- Where does demand go, when a species goes extinct?
- Assume demand shifts to the remaining species.
- Result: Serial depletion with Aggregate Harvests hardly declining.

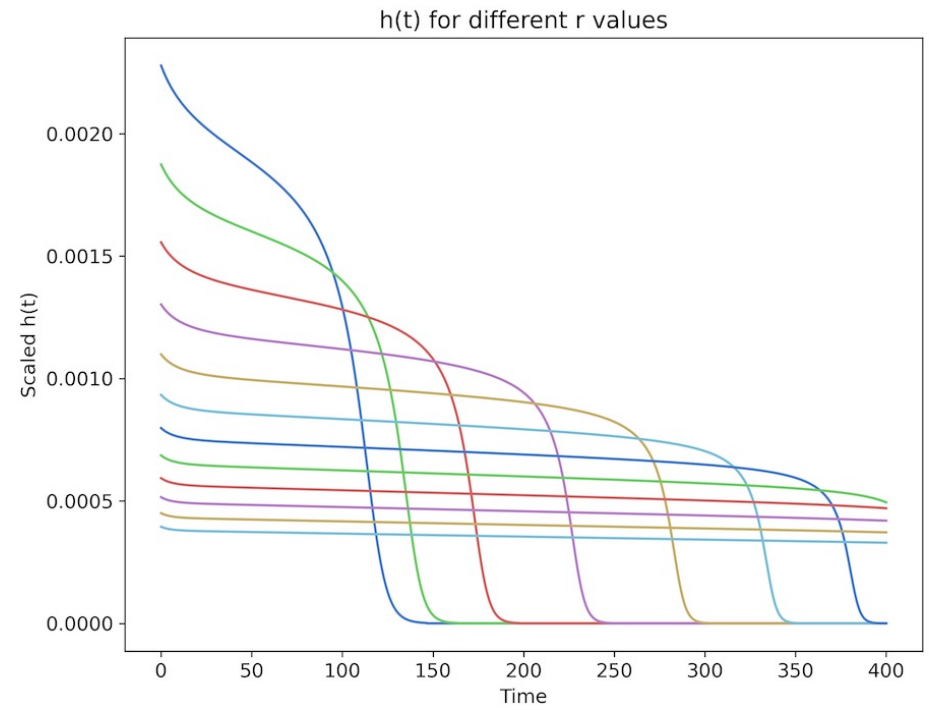
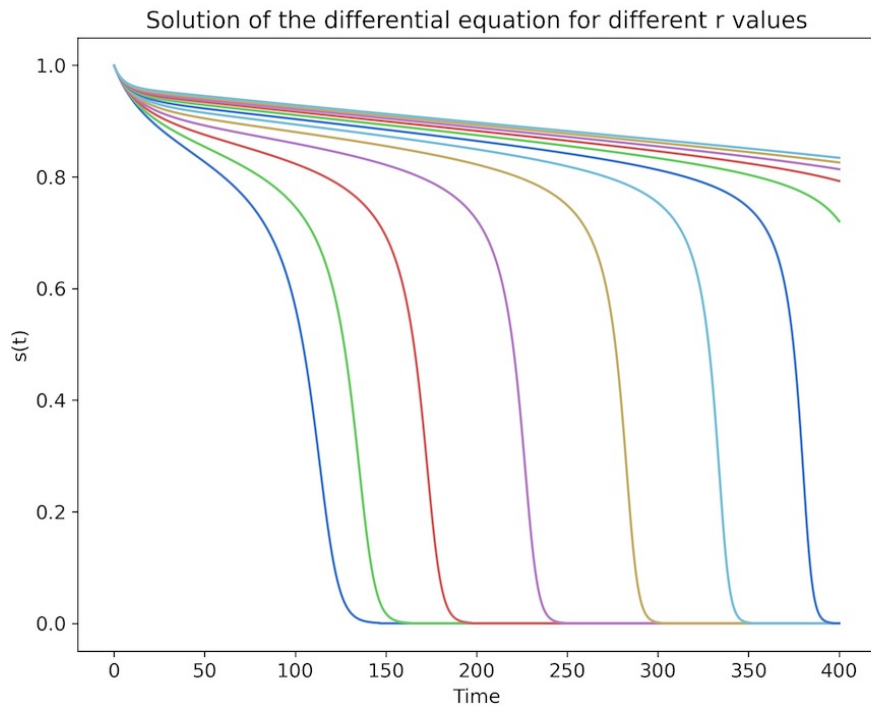
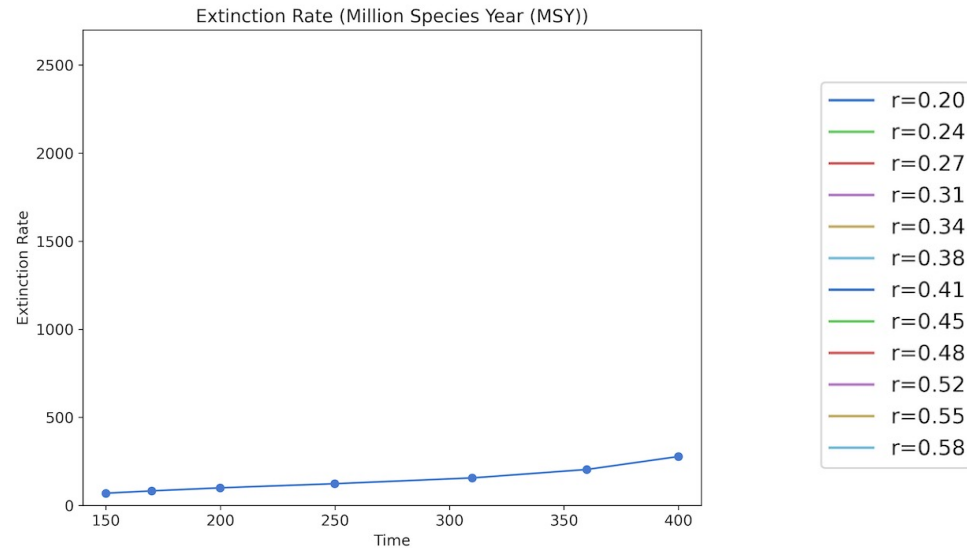
Concentrated Demand & Habitat Intact



Add Complementarity in Supply

- What about habitat loss from climate change?
- Assume very slow climate change lowers the carrying capacity of nature, raises vulnerability.
- Result: Sequential extinction with slowly declining populations and harvests.

Diffuse Demand & Gradual Habitat Loss

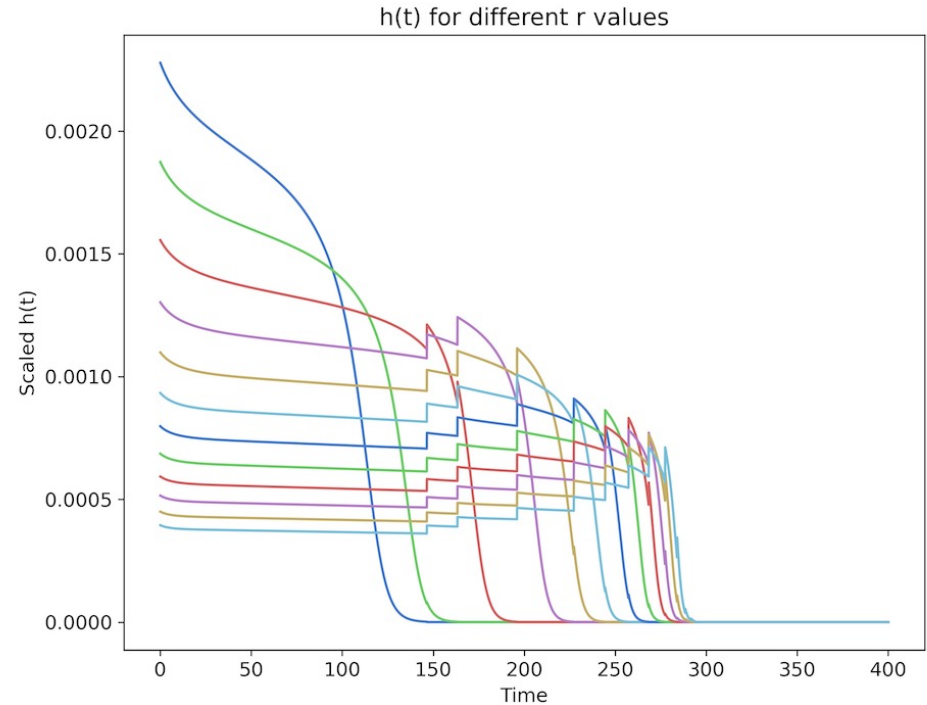
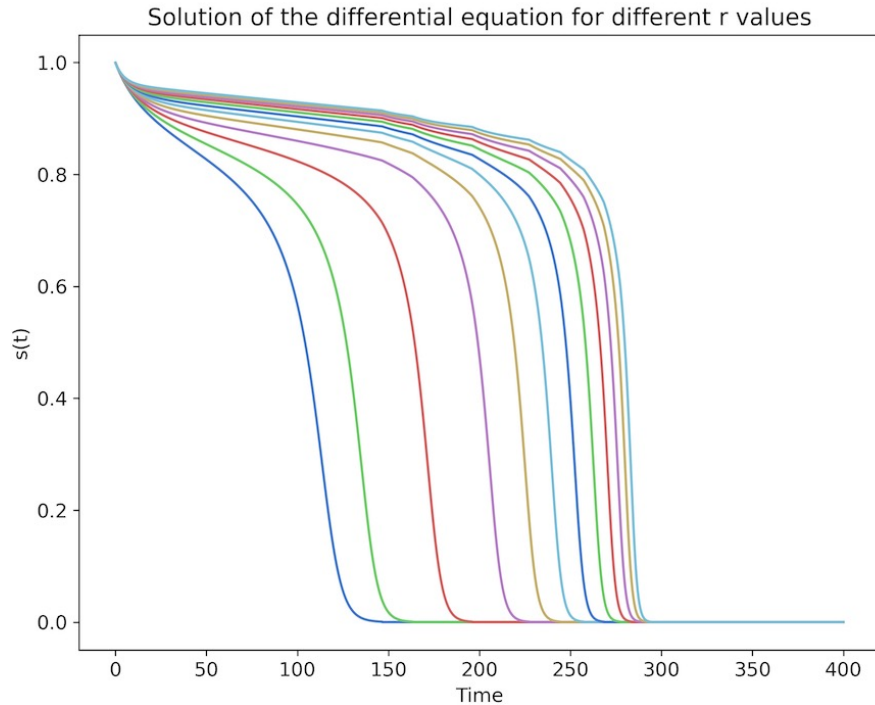
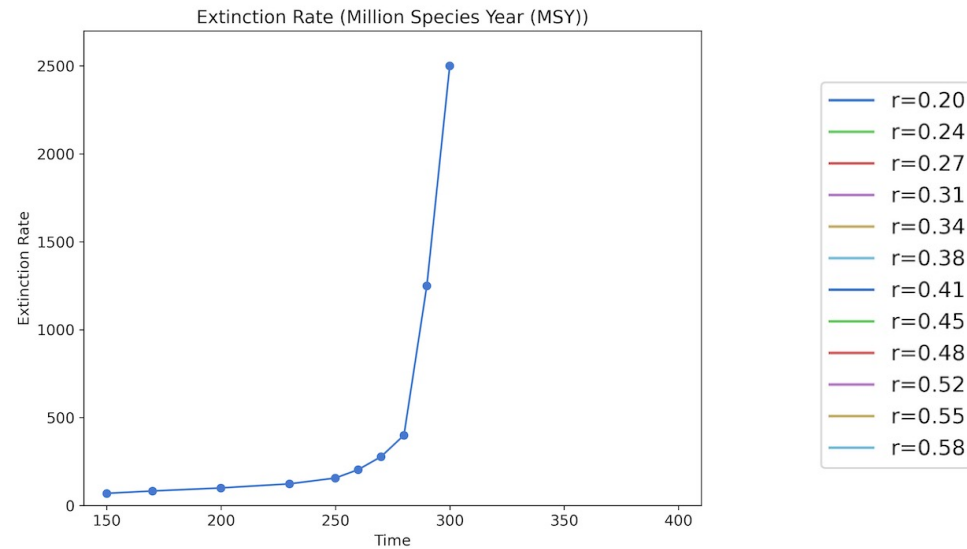


Habitat Loss & Overharvesting

Via

Demand And Supply side Links

Concentrated Demand & Graduate Habitat Loss



Why?

- Any extinction caused by habitat loss, leads to the concentration of demand worsening overharvesting.
- Any extinction caused by overharvesting, shifts demand to remaining species making the impact of their habitat loss more important.
- To an economist - they are complements.

Who is responsible ?

- Overharvesting from oceanic and land resources?

Homo Sapiens

- Climate change that is ongoing?

Homo Sapiens

- Who is the only species on the planet capable of altering this future?

Homo Sapiens

Conclusion

- UN Biodiversity Conference (COP 15) in Montréal 2022 ended with landmark biodiversity agreement through to 2030, including:
 - Designate at least 30% of global land and sea as protected areas
 - Restoration of 30% of terrestrial and marine ecosystems
 - Mobilizing at least \$200 billion per year from public and private sources for biodiversity

Let's hope countries live up to their pledges –
the physical scientists may be right.

Thank you



Convention on Biological Diversity

- The Convention on Biological Diversity (CBD) is an international treaty adopted in 1992 and signed by 196 countries
- Aims to promote the conservation and sustainable use of biological diversity

Convention on Biological Diversity

3 Main Objectives

1. The conservation of biological diversity
2. The sustainable use of the components of biological diversity
3. The fair and equitable sharing of the benefits arising out of the utilization of genetic resources