What Does the Quaternary Fossil Record Tell Us about Marine Extinctions?

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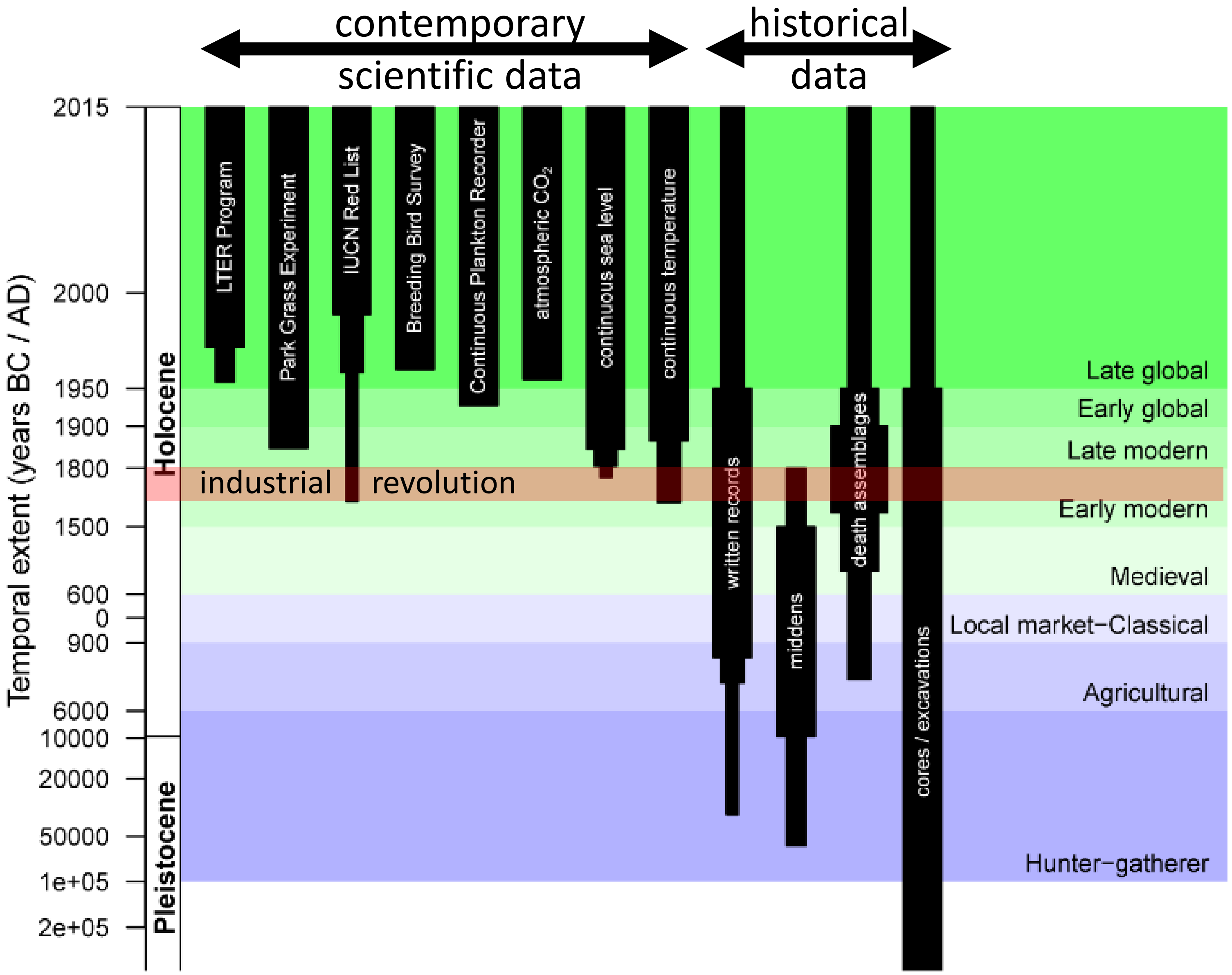
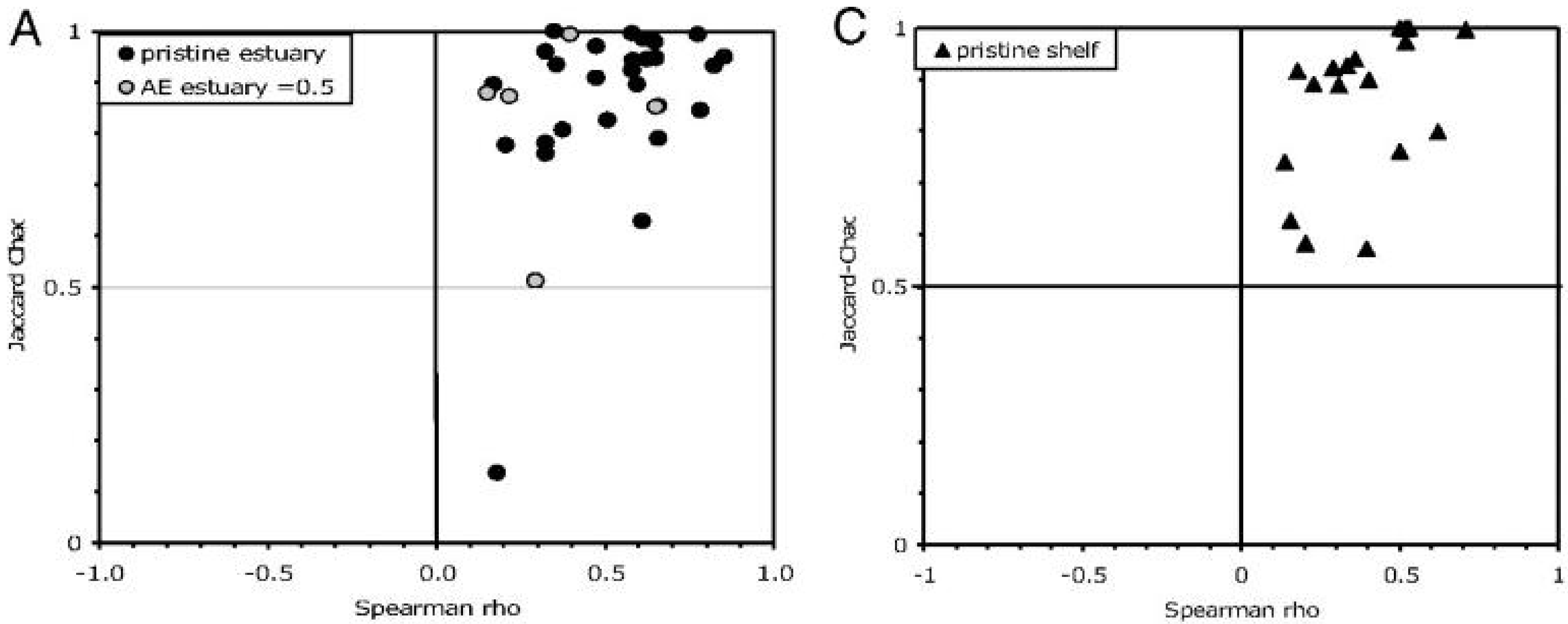
Historical Value of Conservation Paleobiology



Kosnik and Kowalewski 2016, *Biology Letters*

But How Good is The Fossil Record?



Kidwell, 2007, *PNAS*

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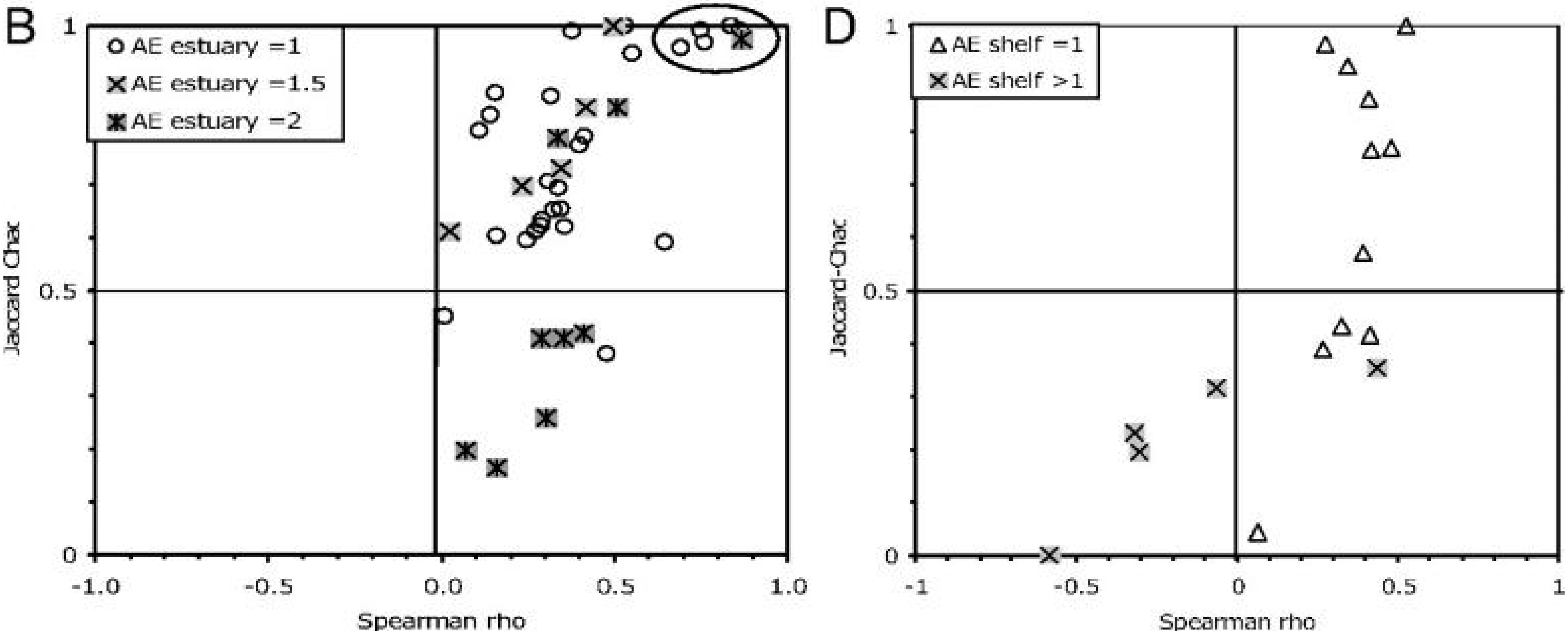

Kidwell, 2007, *PNAS*

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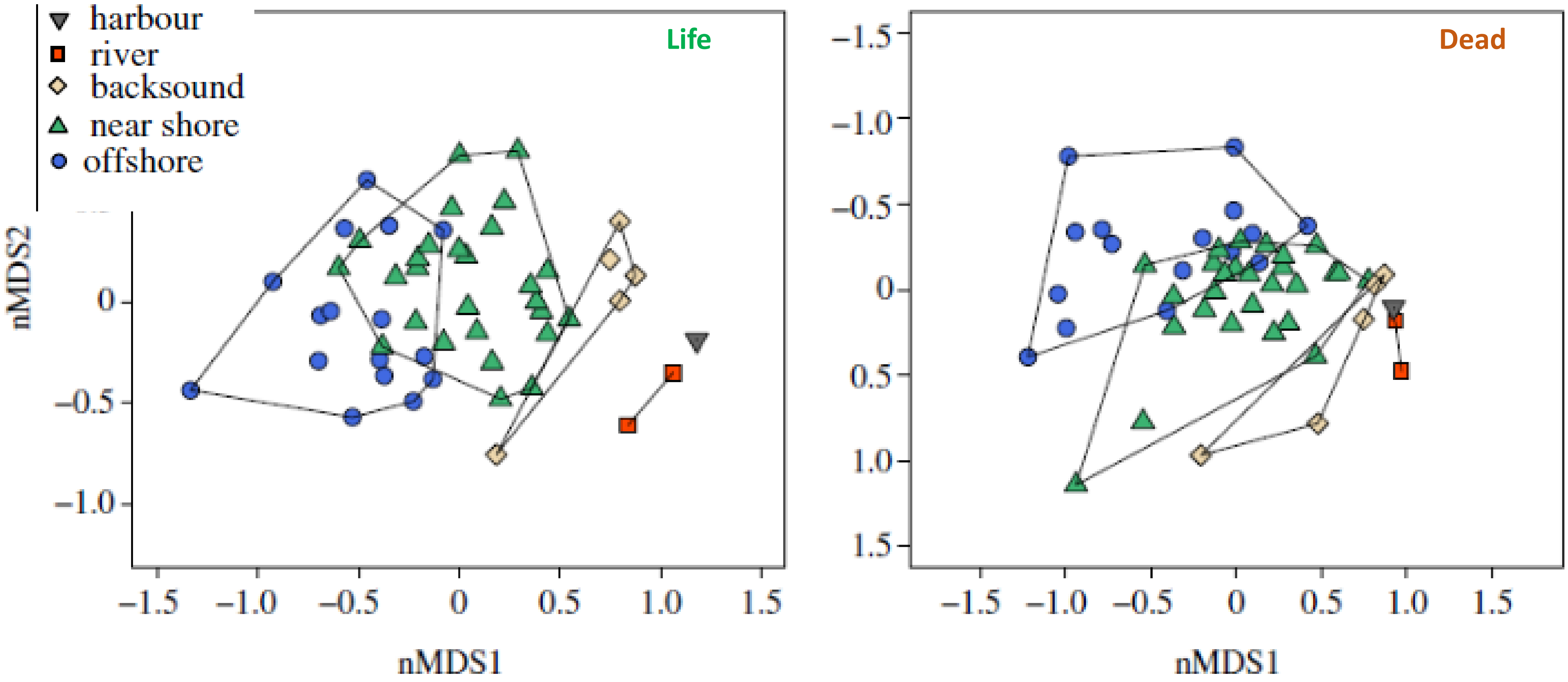


Tyler and Kowalewski, *Proc. Royal Soc. B,* 2017

Time-averaging

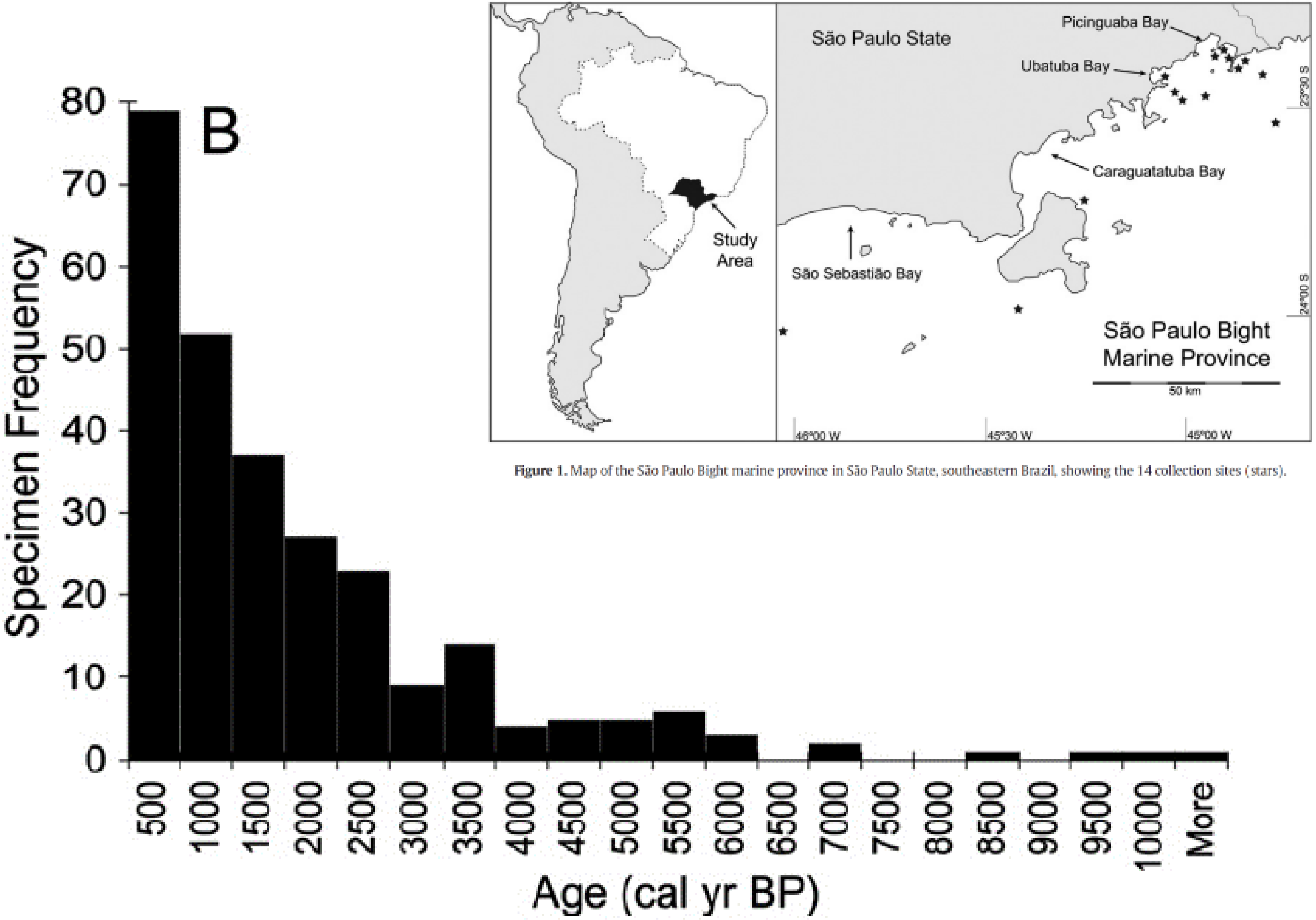


Figure 1. Map of the São Paulo Bight marine province in São Paulo State, southeastern Brazil, showing the 14 collection sites (stars).

Dexter et al. 2014, Quaternary Research

Humans Impact the Fossil Record of Anthropogenic Changes

Somewhat analogous to the Heisenberg Uncertainty Principle, the very same human-driven processes that have been altering ecosystems also affect our ability to reconstruct these changes based on geohistorical data.

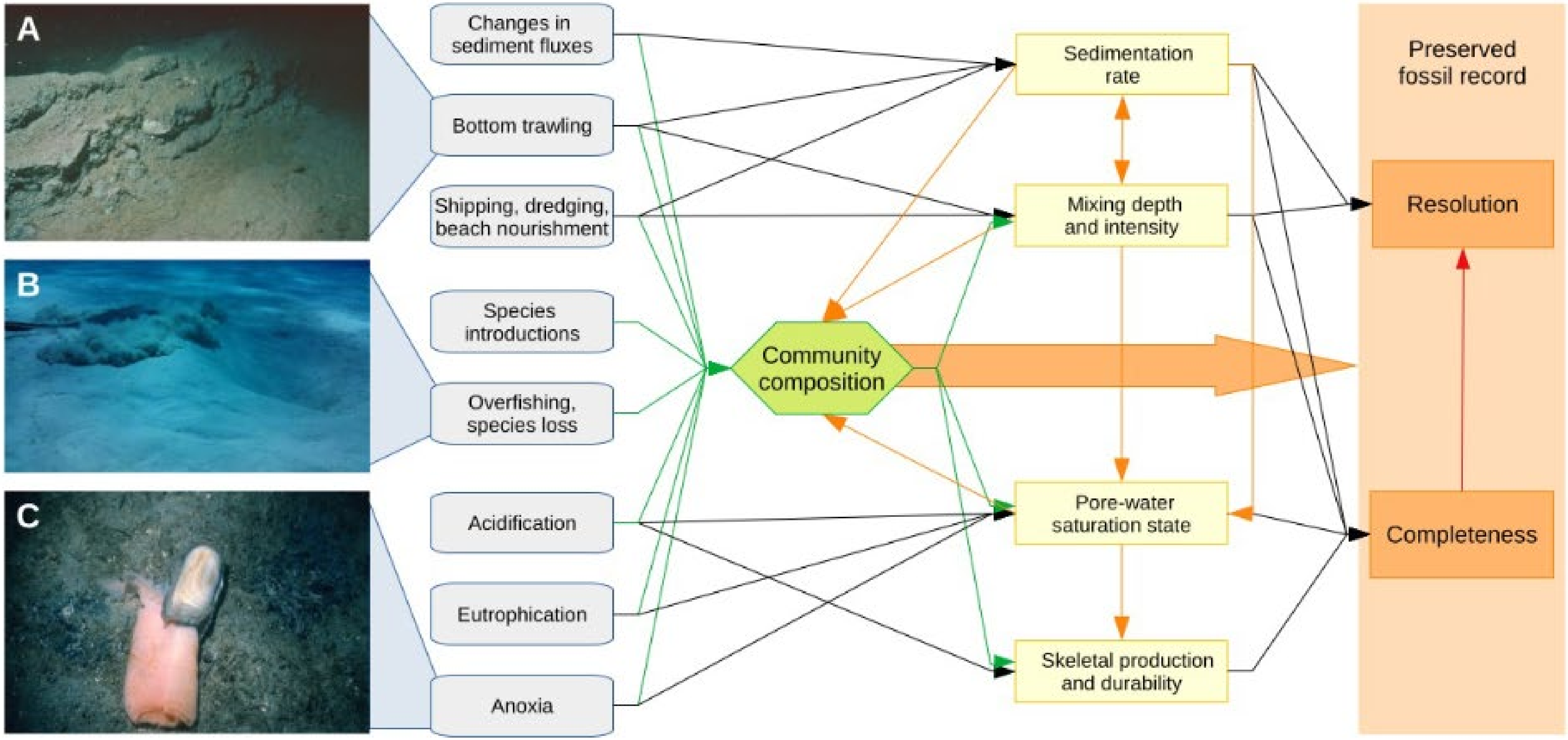


Figure 1. A conceptual framework for understanding how human impacts can affect the quality of the currently forming marine fossil record with examples of physical (A), biological (B) and geochemical (C) disturbances to marine ecosystems. The four parameters controlling the

Nawrot et al., *Biogeosciences*, 2024

Extinctions

Extinction – A total disappearance of a species. Also referred to as "global extinction" (Estes et al., 1989).

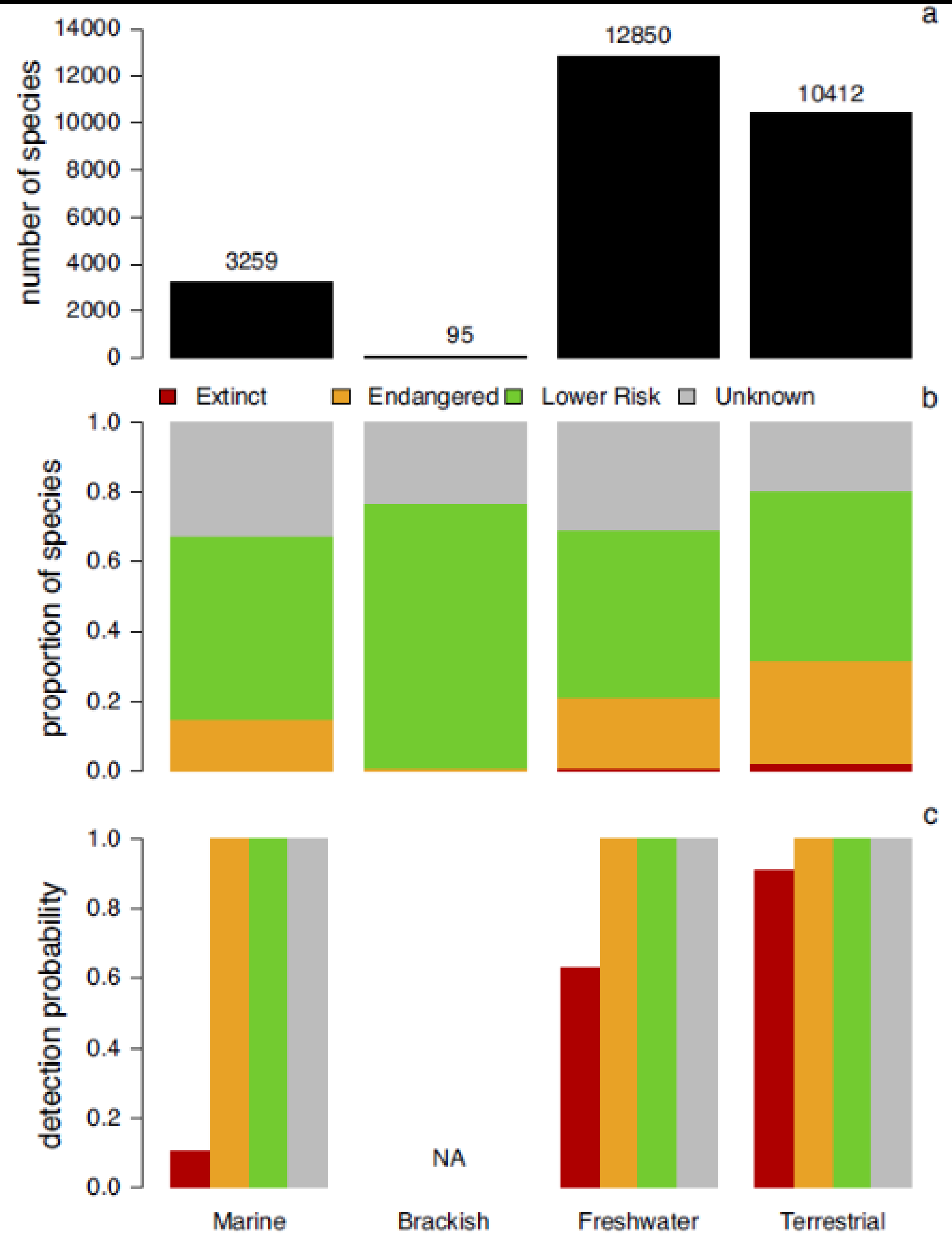
Extirpation – A local or regional disappearance of a species still occurring elsewhere ("**local extinction**" sensu Estes et al., 1989). Extirpations can lead to the fragmentation of geographic ranges and range contractions

Ecological Extinction – Ecological decline of a species that is still present but no longer plays a significant ecological function or interacts significantly with other species (McConkey and O'Farrill, 2015). Ecological extinction can be driven by "**decimation**", a dramatic decline in population density, in which case harvesting is no longer economically viable ("**commercial extinction**"; Carlton et al., 1999; McCauley et al., 2015). Ecological extinction can also be due to changes in **functional traits** of a species.

Extinction Debt – This conceptual addendum to the extinction terminology posits that biodiversity loss lags anthropogenic environmental pressures (e.g., Tilman et al., 1994).

Modified from:
Kowalewski et al., 2023,
Cambridge Prisms: Extinction

Extinctions in Marine Realm (IUCN "Red List")



Kowalewski et al., 2023, *Cambridge Prisms: Extinction*

Extinctions in Marine Realm (IUCN "Red List")

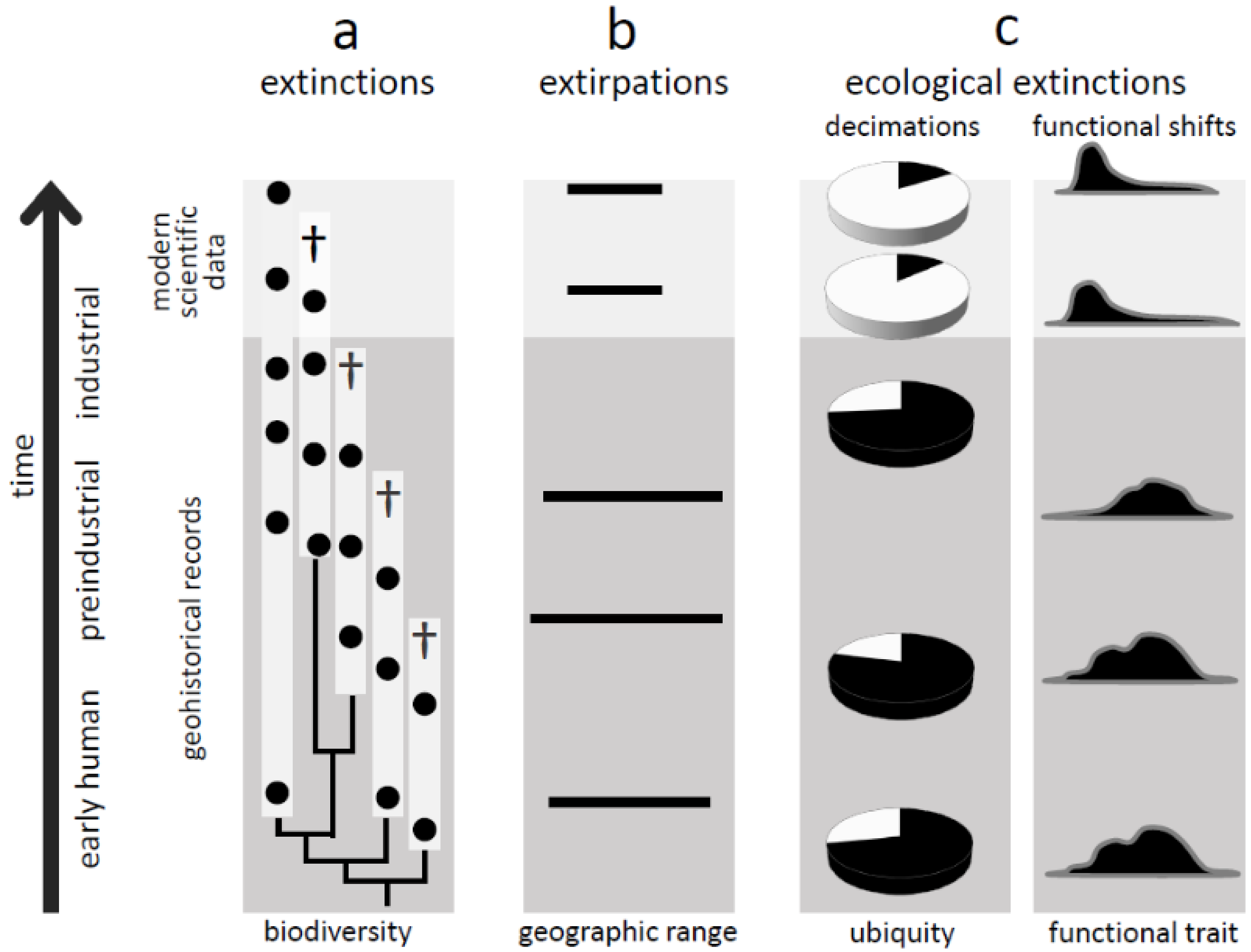
Table 1. The list of marine species currently classified as 'extinct' according to the IUCN Red List (IUCN, 2023b)

Species	Class	Common name
Vanvoorstia bennettiana	Floridoephyceae	Seaweed
Neomonachus tropicalis	Mammalia	Caribbean Monk Seal
Zalophus japonicus	Mammalia	Japanese Sea Lion
Hydrodamalis gigas	Mammalia	Steller's Sea Cow
Neovison macrodon	Mammalia	Sea Mink
Camptorhynchus labradorius	Aves	Labrador Duck
Prosobonia cancellata	Aves	Christmas Sandpiper
Bulweria bifax	Aves	Small Saint
Urile perspicillatus	Aves	Spectacled Cormorant
Zapornia monasa	Aves	Kosrae Crake
Pterodroma rupinarum	Aves	Large Saint Helena Petrel
Haematopus meadewaldoi	Aves	Canarian Oystercatcher
Pinguinus impennis	Aves	Great Auk
Mergus australis	Aves	Merganser
Prototroctes oxyrhynchus	Actinopterygii	New Zealand Grayling
Psephurus gladius	Actinopterygii	Chinese Paddlefish
Collisella edmitchelli[a]	Gastropoda	Limpet
Lottia alveus	Gastropoda	Eelgrass Limpet
Omphalotropis plicosa	Gastropoda	—
Littoraria flammea	Gastropoda	Periwinkle

[a]*Lottia edmitchelli* is currently recognised as the valid name for this limpet species.

Kowalewski et al., 2023, *Cambridge Prisms: Extinction*

Extinctions – Conservation Paleobiology Perspective



Kowalewski et al., 2023, *Cambridge Prisms: Extinction*

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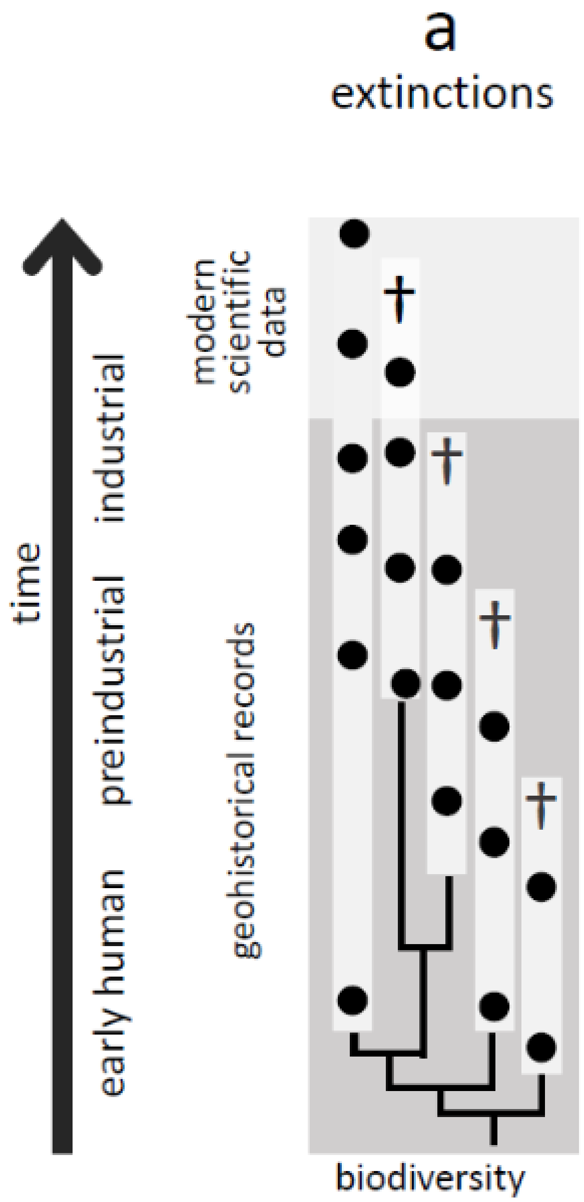

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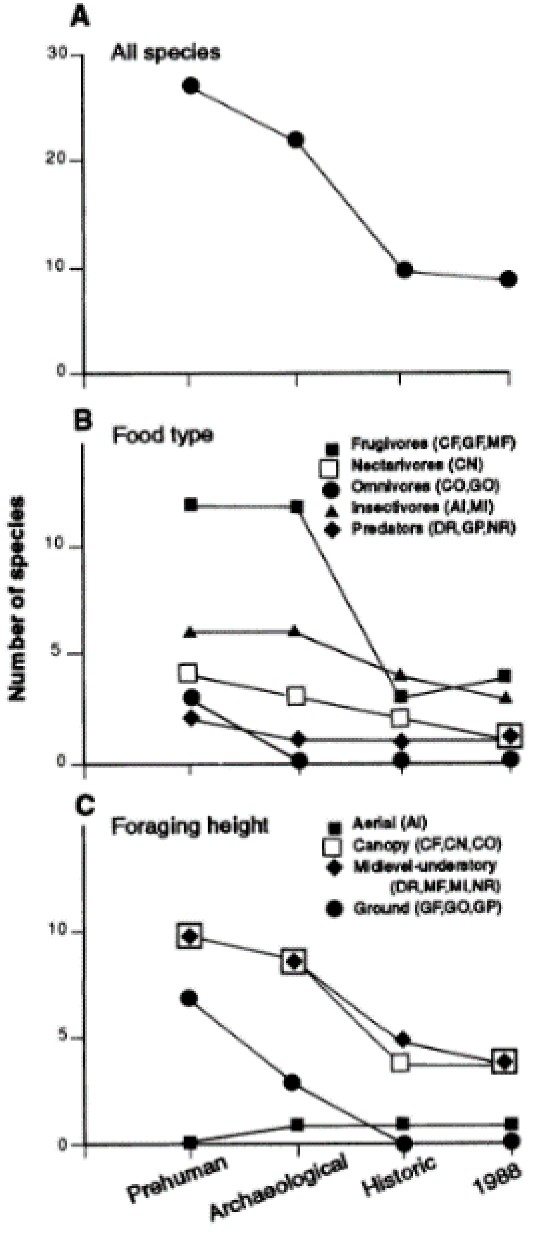


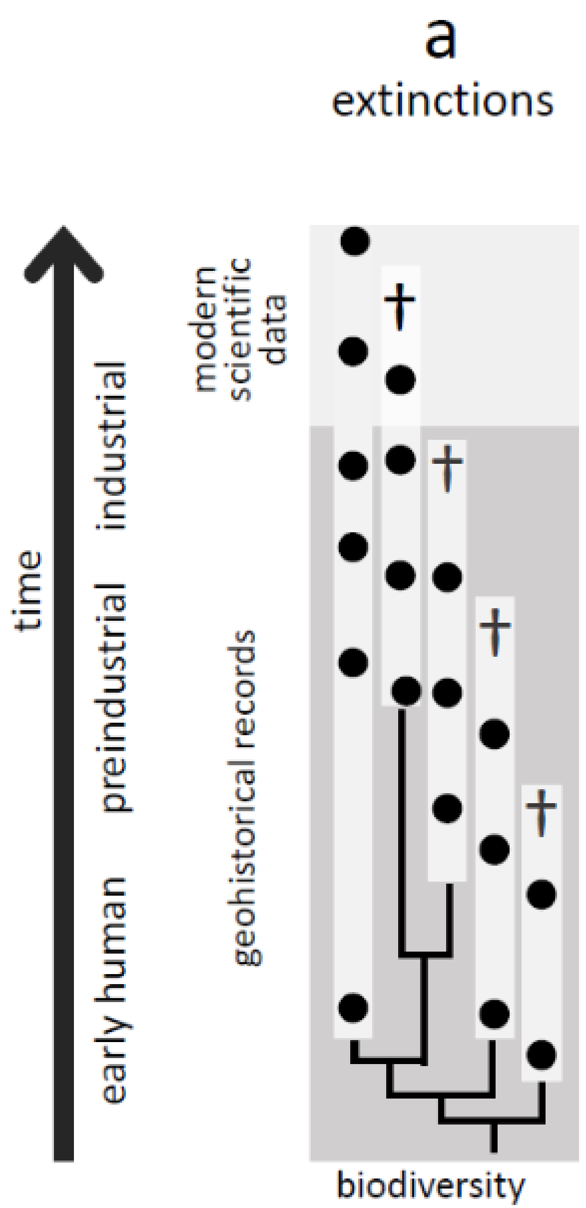
Steadman 1995, *Science*

Prehistoric Extinctions of Pacific Island Birds: Biodiversity Meets Zooarchaeology

David W. Steadman

“On tropical Pacific islands, a human-caused "biodiversity crisis" began thousands of years ago and has nearly run its course. Bones identified from archaeological sites show that most species of land birds and populations of seabirds on those islands were exterminated by prehistoric human activities. The loss of birdlife in the tropical Pacific may exceed 2000 species (a majority of which were species of flightless rails) and thus represents a 20 percent worldwide reduction in the number of species of birds. The current global extinction crisis therefore has historic precedent”
{*Science* 1995}

Extinctions – Conservation Paleobiology Perspective



Empty shells: A hidden record of Holocene extinctions?

- Empty shells of mollusks, a major source of biodiversity data, are routinely included in taxonomic studies and biodiversity surveys. Most of the new bivalve species named between 2000 and 2009 were described from empty shells (Mikkelsen 2011)
- During 25 years of research in New Caledonia, as many as 73% of 1,409 turrid gastropod species were only documented by empty shells, and 34% were known from a single specimen (Bouchet et al., 2009).
- Dead-only species of benthic foraminifers may represent ~5% out of the ~2,140 documented species (Murray, 2007) .
- The present-day estimates of geographic or bathymetric ranges often include skeletal remains, including mollusks (Dijkstra and Maestrati, 2010), brachiopods (Bitner and Logan, 2016) and bryozoans (Di Martino and Rosso, 2021).

Are all species known from empty shells still around or are they extinct or extirpated? This question is difficult to resolve because the prevalence of “empty shell species” may reflect a long tail of rare species or the yet unacknowledged record of hidden extinctions.

Modified from: Kowalewski et al., 2023, *Cambridge Prisms: Extinction*

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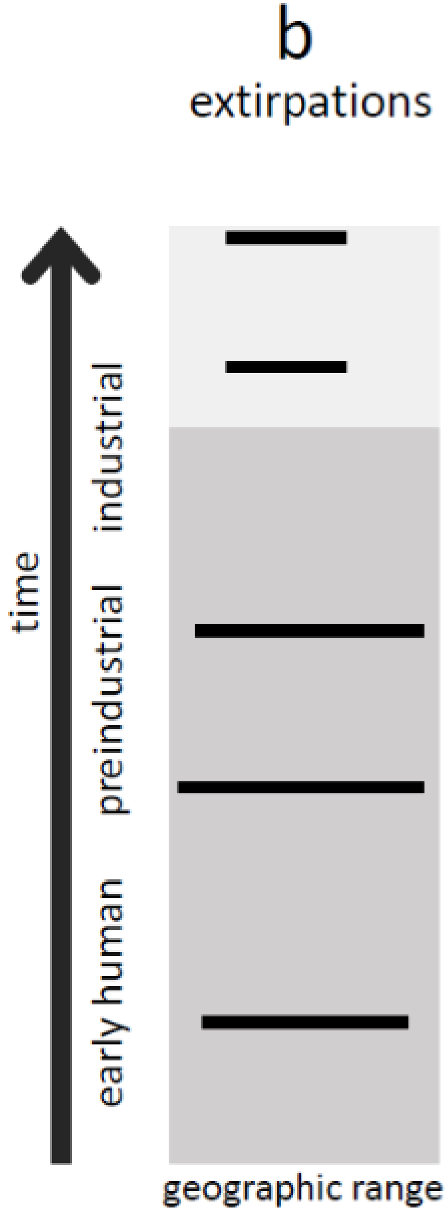

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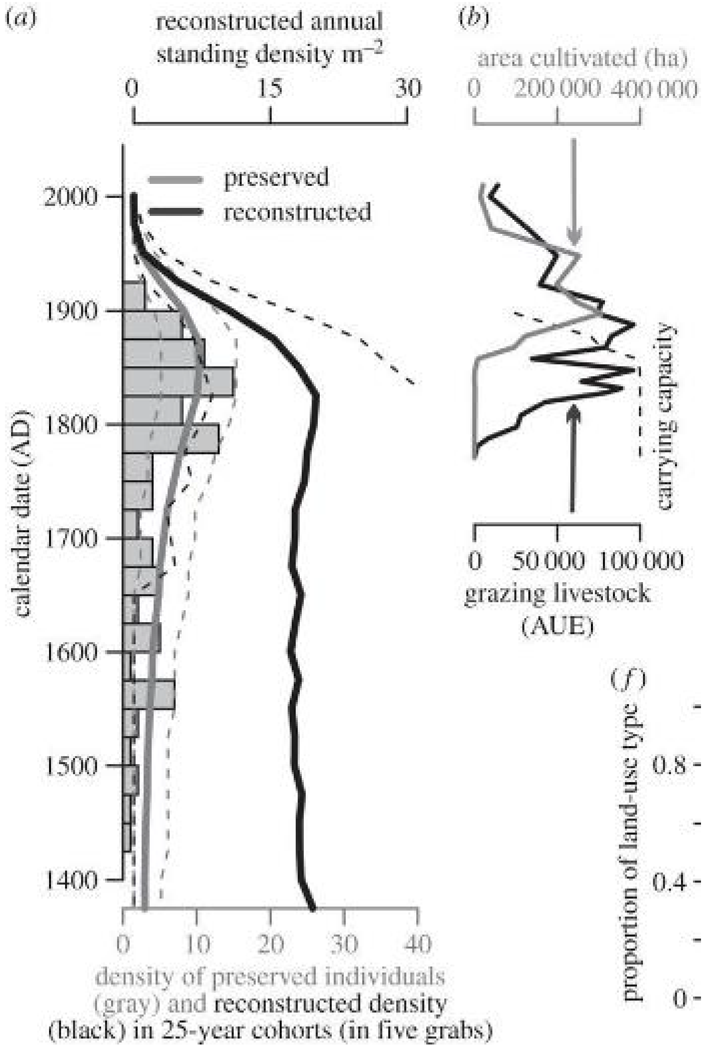


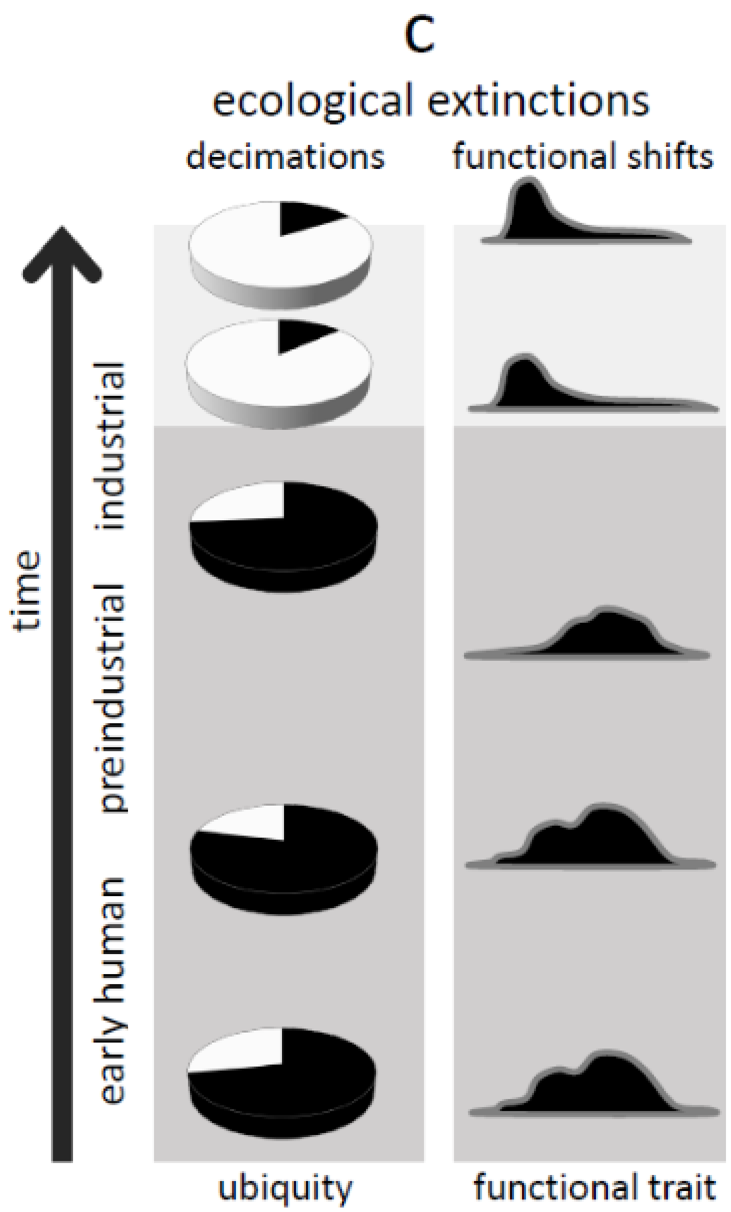
Tomašových and Kidwell, 2017, *Proc. Royal Soc. B*, 2017

Geohistorical data can also aid in assessing the potential role of humans in driving extirpation events

- Ancient DNA and radiocarbon dating revealed that Atlantic grey whale declined in the mid-Holocene long before the onset of intensive commercial whaling. This decline was likely due to Holocene climate changes (Alter et al., 2015).
- Historical records (archaeological middens, death assemblages, and sediment cores) indicate that oyster reefs underwent extirpation in the late 19th and 20th centuries in many temperate regions: Australia (Ford and Hamer, 2016), Tasmania (Edgar and Samson, 2004), Scotland (Thurstan et al., 2013) and the Adriatic Sea (Gallmetzer et al., 2019).
- Death assemblages revealed that scallops and brachiopods were abundant on the California shelf in the late Holocene but went locally extinct due to the nineteenth-century increase in sedimentation and turbidity triggered by agricultural land use (Tomašových and Kidwell, 2017).

Modified from: Kowalewski et al., 2023, *Cambridge Prisms: Extinction*

Extinctions – Conservation Paleobiology Perspective

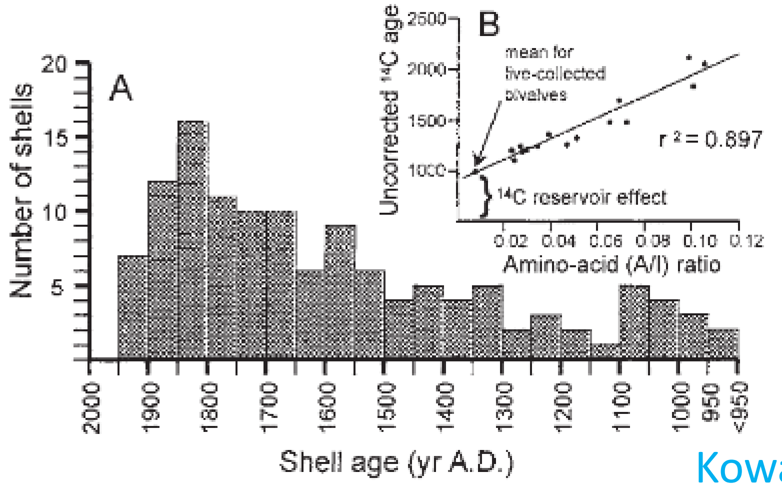


Geohistorical data can aid in assessing the past declines in populations (decimations)

- Field surveys and ^{14}C dating of shells in the Colorado River Delta indicated that the population density averaged at least 50 mollusks per m^2 in the last millennium. The modern intertidal zone average 3 mollusks per m^2 (Kowalewski et al., 2000).

- In the Chesapeake Bay, the density of live oysters in the Pleistocene was an order of magnitude higher than in modern oyster populations. The Pleistocene estimates notably exceeded the threshold density of 50 oysters per m^2 used in Chesapeake Bay as a benchmark for a fully recovered population (Lockwood and Mann, 2019)

- The denticle accumulation rates standardized for reef accretion rates suggested that sharks were over three times more numerous before humans began using marine resources in Caribbean Panama (Dillon et al., 2021).



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Kowalewski et al. 2000, *Geology*

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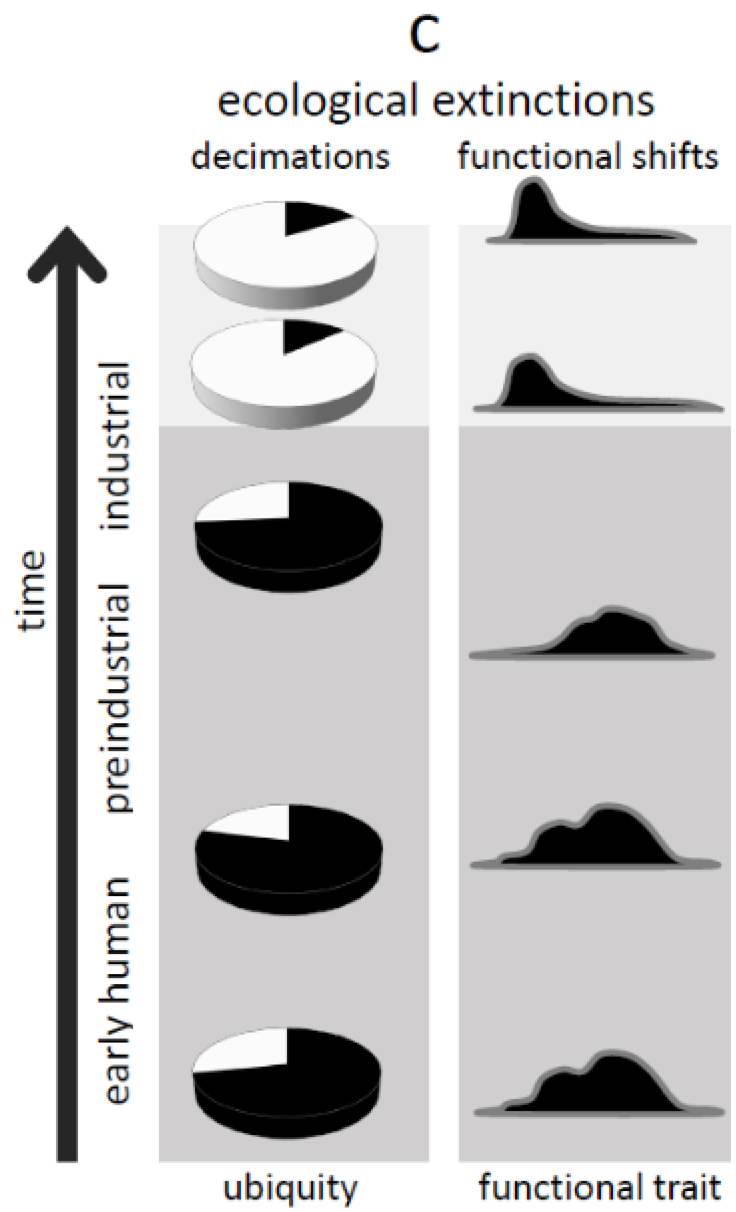
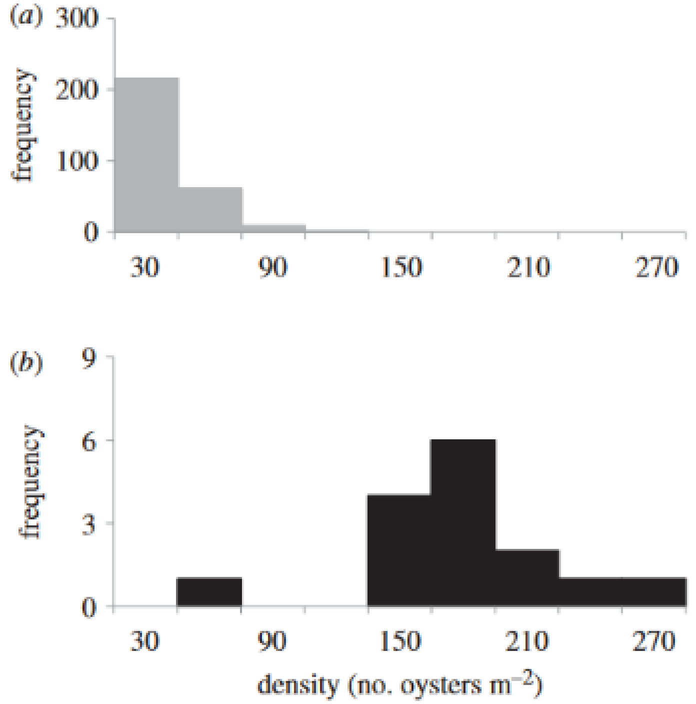
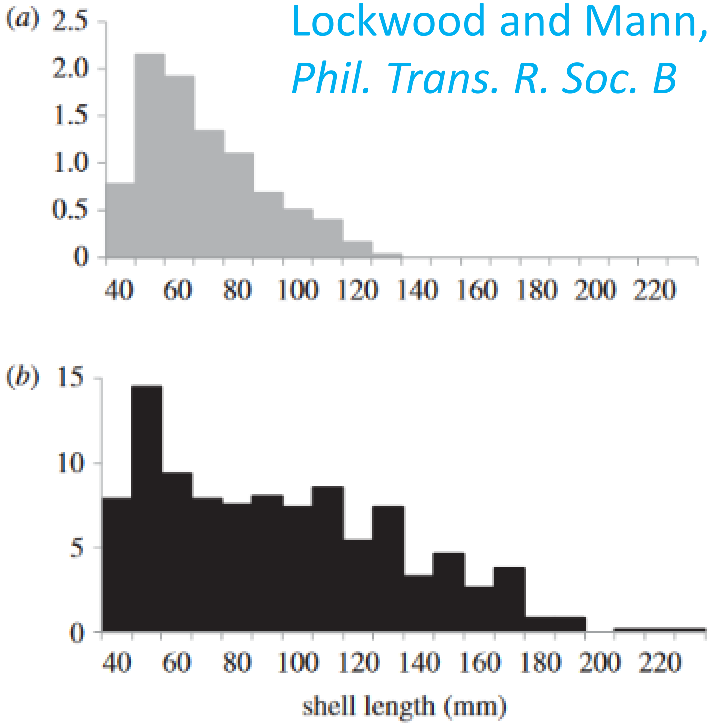


Geohistorical data can assessing the past functional losses

- The Pleistocene fossil record in the Chesapeake Bay indicates that past oyster populations included a higher proportion of large individuals. The largest size classes exceed the largest live oysters observed today (Lockwood and Mann, 2019).
- Pleistocene oyster estimates suggest that filtration rates were an order of magnitude higher in the Pleistocene than today – a direct estimate of the decline in ecosystem services due to shifts in functional traits.





Lockwood and Mann, 2019, *Phil. Trans. R. Soc. B*

Extinctions – Conservation Paleobiology Perspective

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- Despite various limitations that underlie conservation palaeobiology strategies, geohistorical archives represent a wealth of data that can play an important role in assessing extinctions, extirpations, ecological extinctions, extinction debts and extinction threats.

Conservation Paleobiology Network

Applying Historical Data to Aid Conservation and Management of Nature

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