Anthropogenic processes alter the completeness and resolution of the marine fossil record

Rafał Nawrot[1], Martin Zuschin[1], Adam Tomašových[2], Michał Kowalewski[3] and Daniele Scarponi[4]

[1]Department of Palaeontology, University of Vienna, Austria
[2]Earth Science Institute, Slovak Academy of Sciences, Slovakia
[3]Florida Museum of Natural History, Gainesville, FL, USA
[4]Dipartimento BiGeA, University of Bologna, Italy

Contact: rafal.nawrot@univie.ac.at

Human impacts alter their own fossil record

The youngest fossil record and sedimentary archives (geohistorical records) represent an indispensable source of data on ecosystem states and climate variability before the onset of ecological monitoring and instrumental records. Geohistorical data allow reconstructing long-term human impacts on marine ecosystems and are thus increasingly incorporated into conservation decisions.

However, human transformation of marine communities and habitats also alters sedimentary and biological processes controlling the formation of fossil archives recording these changes. In other words, **humans affect not only *what* is preserved but also *how* it is preserved.**

How humas affect the quality of the fossil record?

Diverse physical, geochemical, and biological **human-induced disturbances** can modify sedimentation rates, depth and intensity of sediment mixing, pore water saturation state, and preservation potential of skeletal remains – the parameters controlling the completeness and spatiotemporal resolution of the fossil record.

The novel anthropogenic processes include changes in sediment fluxes due to the alteration of alluvial and coastal landscapes, seabed disturbance by bottom trawling and ship traffic, ocean acidification and deoxygenation, removal of native species, and introduction of invasive ecosystem engineers.

Interpreting the fossil record in the Anthropocene

The complex, interactive effects of humans on both marine ecosystem processes and the quality of the fossil archives recording them affect our ability to track the history of human impacts based on geohistorical data.

On the one hand, human-induced changes in the nature of the fossil record can indicate historical shifts in ecosystem functioning because key ecosystem processes affected by human impacts, such as bioturbation and remineralization of organic matter, also control the burial and preservation of skeletal remains.

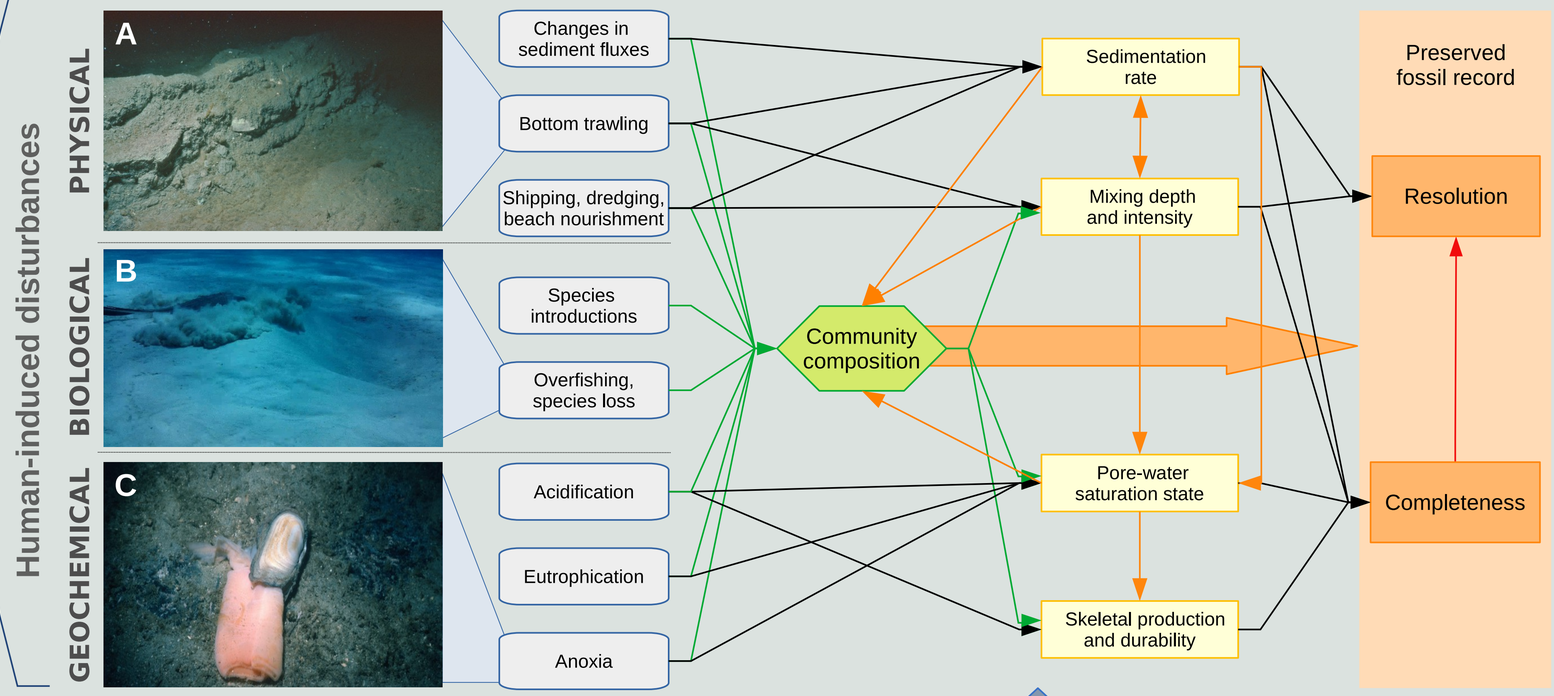
On the other hand, **systematic changes in the quality of the fossil record** resulting from human impacts represent a challenge for reconstructing past ecosystems and climate states based on data from sediment cores and other geohistorical records. The biases arising from human-induced shifts in the completeness and resolution of the fossil record can be minimized by:

1) integrating ecological, taphonomic, sedimentological, geochemical, and stratigraphic data;
2) estimating temporal mixing and stratigraphic disorder using novel geochronological methods;
3) applying numerical simulations that jointly model ecological dynamics and preservational processes.

Conclusions

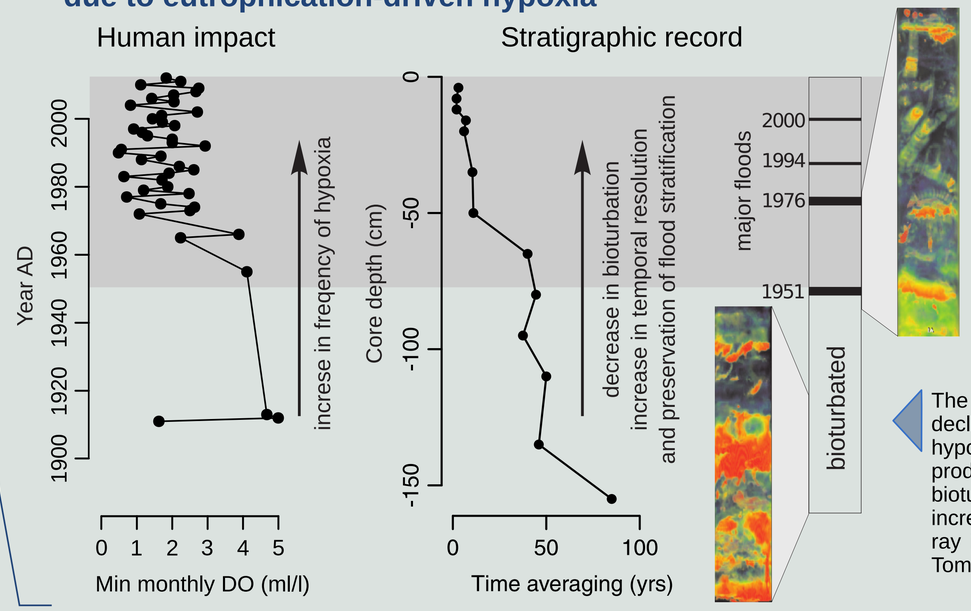
Humans have become a major force transforming the nature of marine sedimentary and fossil records in the Anthropocene. Conservation paleobiology, historical ecology, marine geology and paleoclimatic studies thus need to consider the effects of the novel anthropogenic processes. Understanding feedback between human alteration of ecosystem processes and their preservation in the fossil record is crucial for correctly interpreting geohistorical archives of the ongoing anthropogenic transformation of the coastal ocean.

Conceptual framework



The four parameters controlling the completeness and resolution of the fossil record (yellow fields) can be affected by human impacts either directly (black arrows) or indirectly through changes in community composition (green arrows), and are linked by complex feedback loops (orange arrows). Examples of human impacts: A) Seabed disturbance caused by trawling, Gulf of Trieste, Adriatic Sea. B) Foraging ray causing intensive bioturbation, San Salvador, Bahamas; proliferation of durophagous rays was triggered by a decline in shark abundance due to overfishing. C) Emergence of a deep infaunal bivalve during a benthic mass mortality event triggered by seasonal hypoxia, Gulf of Trieste, Adriatic Sea. Images by M. Stachowitsch (A, C) and M. Kowalewski (B).

Example: increase in stratigraphic resolution due to eutrophication-driven hypoxia



The 20th-century eutrophication of the northern Adriatic Sea led to decline in dissolved oxygen (DO) concentrations and loss of hypoxia-sensitive infauna. In the stratigraphic record of the Po prodelta this regime shift is expressed by upcore decrease in bioturbation, reduced time averaging of molluscan assemblage and increase in the preservation of thin silty layers (denser layers in x-ray images of the core) correspond to decadal floods. Data from Tomašových et al. 2018 (*Paleobiology* 44, 575–602)