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Fisheries

A global IUCN Red List assessment of abalones at risk in a changing climate

21 January 2025

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Of 21 abalone species fished commercially for human consumption, 15 are classified as threatened

Using IUCN Red List methodology, this study assessed the extinction risk to all 54 species of abalone (genus *Haliotis*). Of the 21 fished commercially for human consumption either now and/or in the past, 15 (71.43 percent) of the species are classified as threatened and identified as critically endangered, endangered or vulnerable. Photo of greenlip abalones (*Haliotis laevigata*) by Peter Southwood (CC BY-SA 3.0, https://creativecommons.org/licenses/by-sa/3.0, via Wikimedia Commons).

Given the combined impacts of human exploitation and a changing climate, the risk of marine extinctions is now universally accepted within policy arenas with overexploitation as the principal driver. As human populations increase, overfishing, both legal and illegal, is affecting the abundance and productivity of marine taxa. **Deficiency of data** (https://doi.org/10.3389/fmars.2021.606932), that would otherwise flag population change, can result in overfishing even of common species and rare species frequently lack data on abundance.

The effects of overfishing are exacerbated by a variety of human-mediated environmental stressors, most notably elevated levels of carbon dioxide. Its increases resulting from the combustion of fossil fuels, both intensifies ocean warming and leads to ocean acidification, where excess carbon dioxide combines with seawater and if unchecked, can **impede calcification** (https://doi.org/10.1098/rspb.2010.2404) in mollusks and other marine invertebrates.

Approximately 46,000 marine **mollusk species** (https://hal.science/hal-02165705/) have been recorded with possibly a further 150,000 waiting to be identified and described, many from the deep seas.

Despite their importance to biodiversity, the marine food web and as a fishery resource, their conservation status is barely known. Mollusca is the phylum most impacted by extinction with more than 300 species listed by the **IUCN Red List** (https://pmc.ncbi.nlm.nih.gov/articles/PMC11666003/) – the International Union for Conservation of Nature Red List of Threatened Species is an inventory of the global conservation status and extinction risk of biological species – as having become extinct and

although marine species may be **less prone to extinction** (https://doi.org/10.1111/j.1523-1739.2009.01245.x) than terrestrial or freshwater species, the true number may be considerably more than this.

However, despite their ubiquity, the IUCN Red List of Threatened Species, the world's leading database on species' extinction risk, includes just 1886 assessments of marine mollusks.

To place this in context, 74 percent of all fishes, 85 percent of reptiles, 90 percent of mammals, 92 percent of amphibians, and 100 percent of birds have been **assessed** (http://www.iucnredlist.org/resources/summary-statistics).

This article – **summarized** (https://creativecommons.org/licenses/by/4.0/) from the **original publication** (https://doi.org/10.1371/journal.pone.0309384) (Peters, H. et al. 2024. Abalones at risk: A global Red List assessment of Haliotis in a changing climate. *PLoS ONE* 19(12): e0309384) – assessed the current status and extinction risk of all 54 abalone species globally using the IUCN Red List criteria, to provide data in support of conservation measures for those species at the greatest risk of extinction over the short to medium term, and to inform climate smart restoration planning and action.

Study setup

The IUCN Red List is the world's leading resource for describing the global conservation status of animals, plants and fungi, and uses a standard methodology to classify species into one of nine categories supported by a codified set of criteria (Table 1). Using IUCN Red List methodology, we assessed the extinction risk to all 54 species of abalone (genus *Haliotis*). Before developing the database for our global abalone assessment, we referenced the **World Register of Marine Species** (http://www.marinespecies.org) to create a taxonomic list of these species, which were then ran through the Species Information System (SIS), the online assessment tool of the IUCN Red List of Threatened Species that acts both as a repository for the data and as a 'calculator' to determine the categories and criteria that are central to establishing the level of threat.

PETERS, Abalone, Table 1

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Category	Code	Test
Extinct	EX	There is no reasonable doubt that the last individual has died measured over a time fra appropriate to the taxon's life cycle and life form
Extinct in the wild	EW	The taxon is known only to survive in cultivation, in captivity or as a naturalized populatic well outside the past range

Critically endangered	CR	The taxon meets any of the criteria A to E for Critically Endangered, and it is therefore considered to be facing an extremely high risk of extinction in the wild
Endangered	EN	As CR but considered to be facing a very high risk of extinction in the wild
Vulnerable	VU	As CR but considered to be facing a high risk of extinction in the wild
Near threatened	NT	The taxon has been evaluated against the criteria but does not qualify for CR, EN or VU, b close to qualifying for or is likely to qualify for a threatened category in the near futur
Least concern	LC	The taxon has been evaluated against the criteria and does not qualify for CR, EN, VU or Widespread and abundant taxa are included in this category
Data deficient	DD	There is inadequate information to make a direct, or indirect, assessment of the taxon's r extinction based on its distribution and/or population status
Not evaluated	NE	The taxon has not yet been evaluated against the criteria

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Table 1: Categories and criteria used to establish the threat level for 54 species of abalone.

For detailed information on the study design, development of the database used, and data analyses, refer to the original publication.

Results and discussion

Abalones can generally be classified into two groups – those that are (or have been) fished commercially and those that are generally not exploited owing to their small size. Although lacking data, some of the small non-commercial species may also be taken incidentally as food, but this would be through gleaning by local subsistence fishers and likely to have only a marginal effect on populations, unlike organized fisheries including recreational abalone fishing. Furthermore, while poaching has had a catastrophic impact on some commercial fisheries it is likely negligible on unexploited species.

A digital distribution map accompanies each IUCN Red List species assessment generated in this study. To improve visualization on a global scale, maps were standardized using a base map for nearshore coastal species that extends to either the 200-meter depth or 100 km from shore. Fig. 1 shows the global distribution of a) all species (n = 54), b) commercially fished species (n = 21) (note, some species may not be fished across their entire distribution, especially where local regulations may include a size limit, or gear restrictions e.g., no SCUBA), and c) threatened species only (n = 20).

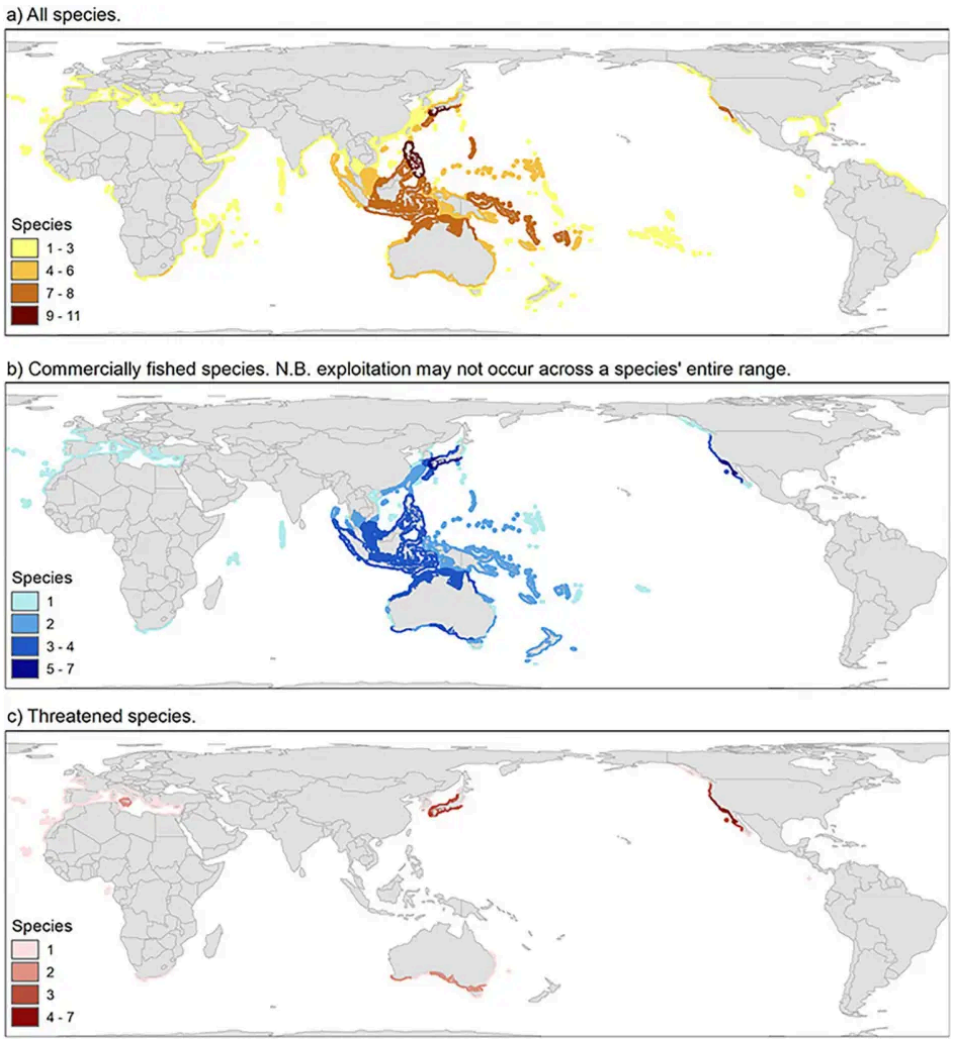

Fig. 1: Global distribution of abalone spp. (a) all species, (b) species commercially fished, and (c) species threatened with extinction – Critically Endangered (CR), Endangered (EN) or Vulnerable (VU). Basemap (i.e. country layer only) sourced from Natural Earth (http://naturalearthdata.com/).

Twenty-one of all abalone species (38.89 percent) are (or have been) commercially fished and/or are recognized targets of recreational fishers, of which 15 (71.43 percent) are categorized as threatened with one further species categorized as Near Threatened (NT). Of the 33 unexploited species, only five (15.15 percent) are categorized as threatened with a further two as NT. Fig. 2 graphically illustrates that of those species with a sufficiency of data, i.e. not categorized Data Deficient, commercially exploited abalones are over four times more likely to face extinction than unexploited species.

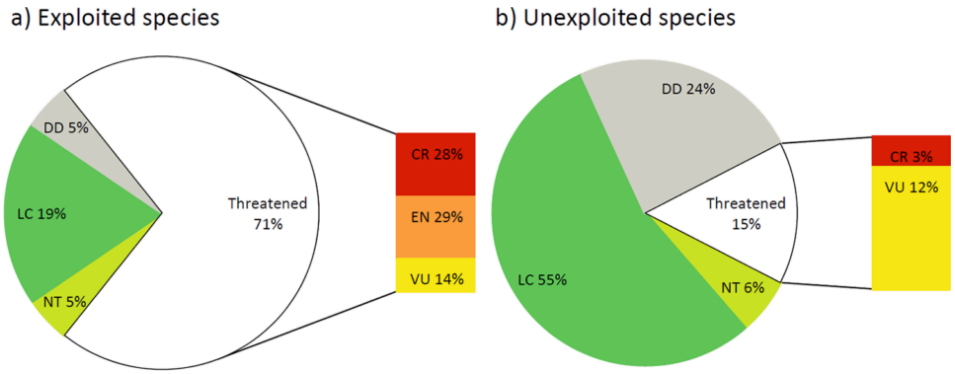

Fig. 2: Abalone species assessed globally analyzed by category. CR: Critically Endangered; EN: Endangered; VU: Vulnerable, NT: Near Threatened, LC: Least Concern, DD: Data Deficient, and showing the impact of commercial exploitation. Adapted from the original.

Our analysis clearly shows that abalone species exposed to fishing have a reduced resilience and a significantly greater chance of extinction compared to those that are unexploited. The few unexploited species assessed as threatened are generally characterized by occurring within a highly restricted range where marine heat waves (MHWs) and loss of habitat could drive an extinction event.

Although overfishing for abalones can be observed through a historical lens, the impact is felt to this day on fisheries around the world where widespread stock declines have left remaining populations more vulnerable to a **suite of stressors** (https://doi.org/10.3389/fclim.2022.908708). Most fisheries nowadays are subject to management controls ranging from total closure to enforcement of quotas, mandatory data loggers and the banning of SCUBA. Management measures that restrict catch provide greater protection of minimum abalone densities necessary for successful fertilization. These include bag and size limits, permanent marine protected areas (MPAs) to protect identifiable populations and prohibition of SCUBA for deep stock conservation, rather than seasonal closures, which simply shift catch effort to later seasons.

Monitoring stocks using fishery independent surveys provides baselines estimates for comparisons following major environmental events. Ideally, this should include kelp and algal cover, as well as competitors such as sea urchins, and also predators that can, when out of balance, severely impact abalones. Pre-impact data can also inform managers of the causes of any subsequent population decline, including identification of harmful algal blooms that also devastate farmed abalones.

Of the 54 species of abalone assessed globally, 20 (37.04 percent) are threatened with extinction, i.e., categorized as Critically Endangered (CR), Endangered (EN) or Vulnerable (VU), with a further three species categorized Near Threatened (NT). Fig. 3 shows the number of species of each category by oceanic region.

Fig. 3: Numbers of abalone species by category code analyzed by oceanic region. Adapted from the original.

Although wild abalone fisheries have declined in most regions globally, with estimated 1970s landings of 20,000 tons reduced to 4,500 tons by 2020/21, the commercial loss has been more than replaced by an upscaling in aquaculture, where total global production in 2010 of 65,344 tons had, by 2020/21, reached 243,506 tons. While this partnership between aquaculture and wild fisheries can appear promising, especially in the face of climate driven stressors, greater support and funding by foundations and governments is still needed. Despite this exponential increase in abalone aquaculture, the decline in wild populations persists while success in reversing it can only be described as modest with current levels of support.

Even with sustainable fisheries, failures in policing and enforcement can rapidly reverse gains where there is aggressive and widespread poaching, especially from organized criminal gangs. It may be the case that effective visible protection of large wild abalone assemblages will be more successful and less costly than relying on restocking with aquaculture produced abalones. Recent work has demonstrated the importance of sustainable fishing, conservative fishing quotas and periodic fishery closures. While protecting larger females within MPAs that can serve as **climate refugia** (https://doi.org/10.1002/ecs2.4002), bolstering resilience to climate stressors will require close collaboration between fishers, fishery managers and scientists.

“Abalone, against all odds: How one French shellfish producer learned to survive (https://www.globalseafood.org/advocate/abalone-against-all-odds-how-one-french-shellfish-producer-learned-to-survive/)”

Elevated sea-surface temperatures are giving rise to a multiplicity of immediate threats through loss of algae and habitat, expansion of pathogens and transition of marine ecosystems. Evidence shows that over future decades, abalones, common with most, if not all calcareous marine taxa, will become

increasingly vulnerable to such changes in ocean chemistry. In addition to the impact on calcification, fertilization, **embryonic larval development and settlement** (https://doi.org/10.3390/biology2020651) may all be compromised, allowing for less surplus productivity for fisheries.

We know the environment for abalones will, in the future, be warmer and less oxygenated as MHWs are **predicted to increase in frequency** (https://doi.org/10.3389/fmars.2019.00499), intensity and duration. Anomalous heating at the ocean surface is driven by changing climate and further influenced by El Niño-Southern Oscillation (ENSO). ENSO events result in the **episodic warming and cooling** (https://www.nature.com/articles/d41586-019-02196-1) of the tropical Pacific, and although this effect is centered on the eastern Pacific, its influence can be observed across the whole of the Pacific, Atlantic and Indian Oceans. Unless the combustion of fossil fuels that is driving temperature and acidification is arrested, the long-term future of abalones together with all other marine mollusks remains uncertain.

Perspectives

This study assessed the current status and extinction risk of all 54 abalone species globally using IUCN Red List criteria, exploring each species' distribution, current and projected threats from exploitation, poaching, environmental stress and ecological disruption. The goal is to provide data in support of conservation measures for those species at the greatest risk of extinction over the short to medium term to inform climate smart restoration planning and action.

Results indicate the need to use all tools available, including restoration aquaculture, reductions in fishing pressure, marine protected areas, favorable microclimates, and genetically more resilient families to support abalones given that we know how vulnerable these mollusks are to climate stressors. They are truly oceanic "canaries in the coalmine."

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