

Rethinking Atoll Futures: Local Resilience to Global Challenges



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Winning article

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The narrative of atoll futures within planetary boundary sciences is not one of inevitable loss but of adaptive capacity, sustained resilience, and empowered local stewardship.

The transgression of planetary boundaries has far-reaching consequences for ecosystems and biodiversity worldwide. To broadly communicate these threats in a public discourse, powerful symbols have been championed to evoke a tangible understanding for the real-





world impacts of a changing climate and biosphere. Just as the polar bear became the emblematic symbol for a warming climate and melting pole caps, the low-lying islands of atolls have come to symbolize rising sea-levels and their existential threats to coastal communities, animals, and plants. Undeniably, atolls are the forefront of climate change impacts.



Figure 1: Atoll Islands. Photo by Sebastian Steibl.

However, the recurrent usage of atoll islands as icons for climate change-induced sea-level rise has manifested in an overly fatalistic narrative, promoting the idea that these unique tropical island ecosystems are inevitably and irrevocably destined to drown under rising seas. This surrendering perception of atolls not only disempowers local and Indigenous island communities by marginalizing them as no more than bystander 'canaries-in-the-gold-mine' of climate change but also risks overlooking nascent opportunities that have recently arisen from advances in atoll geoscience, ecology, and conservation.

The motivation behind our article was to develop a transformative framework for atoll futures beyond this binary of loss and surrender. Our aim was to encourage a rethinking of atolls within the broader context of planetary boundary science, management, and policymaking. To achieve this, we brought together a diverse author team spanning researchers from different Earth science disciplines, applied atoll conservationists, land managers, and Indigenous scholars. We synthesized existing literature, integrated Indigenous perspectives from atoll





inhabitants, and identified critical knowledge gaps towards a pathway for nature-based solutions and local restorative action on atolls.

Atoll islands are widely perceived as inevitably lost to rising sea levels due to their low elevation. This characterization, however, rests on a key misconception: that atoll islands are static, inert landforms. In fact, atolls are entirely biogenic structures, physical features of the environment created by living organisms, and are both dynamic and adaptive. Their very formation and persistence rely on a continual process of natural accretion (growth in layers) and dynamic adjustments, whereby sediments generated by the surrounding coral reefs accumulate over time and are being continually reworked, effectively and dynamically altering the islands' size, elevation, and location. Naturally functioning and intact atoll ecosystems can vertically accrete at rates commensurate with sea-level rise. Primarily through impairing these natural processes do atolls become unable to keep pace with sea-level rise. Therefore, we argue, it is not the atoll islands' low elevation per se that is creating their vulnerability to climate change, but instead the accelerated undermining of the atolls' natural growth processes when planetary boundaries are being transgressed. While some factors act on a global scale (e.g., ocean acidification and global warming), it is local-scale impacts (land system change, change in biosphere integrity) that tip the scales from atoll persistence to collapse.



Figure 2: Local-scale impacts from land system change, from changes in the biosphere integrity, and modifications of the biogeochemical flows on atolls that all result in undermining the structural integrity and natural growth processes of the islands themselves. Figure taken from our research article (Steibl et al. 2024).





The implications of these insights are twofold. First, they suggest that there is a suite of overlooked, locally implementable measures that can protect and restore the natural growth processes of atoll islands. We do not dispute that global climate change must urgently be attended to, but our article puts the spotlight on a critically overlooked dimension. Unlike global climate change, mitigating local-scale impacts can immediately be achieved through local policymaking, therefore acting as a backstop until global impacts from greenhouse gas emissions are meaningfully addressed. We argue that a transboundary perspective, which considers the intimate connections between geosphere and biosphere processes, is central to identifying such opportunities. The atoll, when viewed as an integrated land-sea system, can be conceptualized as comprising three interconnected compartments. The first is the coral reef, which functions as the 'sediment factory' that supplies island-building material. The second is the land-ocean interface, which acts as the 'conveyor belt' for transporting sediments from the reef to the land. The third is the atoll island itself, which serves as a site for active sediment accumulation and binding. Each of these compartments is subject to degradation from local impacts, such as changes in land use, alterations in biosphere integrity, and disruptions to biogeochemical flows (Figure 2). Protective measures aimed at these compartments can reinforce the overall accretion processes that underpin atoll island growth and stability. Furthermore, we identified a set of ecological restoration interventions that hold the potential to actively leverage resilience locally, which could be incorporated into and covered by climate finance for atoll nations.

A new, just approach to atoll futures and management necessitates the inclusion of Indigenous knowledge systems. Although the holistic understanding of atoll dynamisms and integrated land-ocean systems has only recently begun to gain traction within Western scientific paradigms, local and Indigenous atoll communities have long recognized, adapted to, and managed these dynamics. Indigenous perspectives offer valuable insights into the long-term interactions between atoll ecosystems and the environmental processes that sustain them. By incorporating these traditional ecological knowledge systems into the framework of planetary boundary science, researchers and policymakers can enrich their understanding of atoll resilience and more effectively guide decision-making and land-use planning. This integration is not merely a matter of academic interest. It represents a critical step towards ensuring that the narrative surrounding atoll futures is inclusive and empowering. The prevailing discourse, which often frames atoll inhabitants as passive victims of rising sea levels, risks marginalizing the very communities that have historically stewarded these ecosystems. Reorienting the narrative to highlight both the adaptive capacities of atoll systems and the agency of their native inhabitants fosters a more balanced and proactive approach to climate resilience, returning the ownership of the narrative on atoll futures to the people and nations that inhabit these islands.





In summary, the resilience of atoll ecosystems in the face of planetary-boundary transgressions hinges on a nuanced understanding of both global and local dynamics. While the global drivers of climate change remain pressing concerns, local-scale impacts offer immediate avenues for intervention. Through targeted ecological restoration and supportive local policy measures, it may be possible to bolster the natural processes that enable atolls to adapt to rising sea levels. By identifying pathways towards local resilience against the global challenges that atolls face, we can contribute to a future in which atoll islands are not merely seen as passive indicators of environmental decline but as active participants in a broader, more resilient planetary system.

In developing and adopting this transformative framework, researchers, policymakers, and community leaders alike are encouraged to view atolls through a lens that emphasizes both vulnerability and resilience. It is through this balanced perspective that innovative, place-based solutions can be identified, ensuring that the narrative of atoll futures within planetary boundary sciences is not one of inevitable loss but of adaptive capacity, sustained resilience, and empowered local stewardship.



Figure 3: The full author team. From top left to bottom right: Sebastian Steibl, Paul S. Kench, Hillary S. Young, Alex S. Wegmann, Nick D. Holmes, Nancy Bunbury, Teurumereariki Hinano Teavai-Murphy, Frank Murphy, Neil Davies, James C. Russell.