Planning at multiple scales for healthy corals and communities

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Coral underwater near Half Moon Caye island, a natural monument of Belize in the Lighthouse Reef Atoll. Credit: Antonio Busiello, (WWF)

Governments in the Mesoamerican Reef region are exploring the use of nature-based solutions to strengthen coral health and societal benefits for

coastal communities. A new study led by Stanford researchers in collaboration with scientists from the World Wildlife Fund, the Healthy Reefs Initiative, and others from the Smart Coasts project quantified the outcomes of different watershed interventions to support coral health at regional versus national scales, and identified target areas that could improve both ecosystem and societal benefits nationally and across the region.

The work has been published in *Nature Sustainability*.

The nature-based approaches evaluated as key watershed (e.g., drainage area) interventions include ecosystem restoration or protection, and sustainable agriculture. Yet determining which areas to target for these interventions requires understanding the complex relationships between terrestrial and marine ecosystems, also known as "land-sea linkages," their benefits to people, and the spatial scale being considered.

This work pushed the boundaries of how scientists analyze biophysical and ecological relationships, using cutting-edge optimization models (for the first time in a coastal context) of how to maximize benefits—and to whom—while meeting spatial or resource constraints.

"To restore nature—in this case, a large barrier reef—international collaborative actions at a large scale are what will really help," said Jade Delevaux, the study's lead author and senior fellow at Stanford's Natural Capital Project.

"At the same time, if you want to support coastal communities' resilience by protecting properties and infrastructure along the coast or tourism-based livelihoods—you're probably making decisions on a smaller scale."

The research focused on illuminating some of these trade-offs for decision-makers and seeking places where there might be win-wins for

the environment and people.

Land-sea connections

Healthy coral reefs provide essential economic, social, and environmental benefits to the communities that depend on them. These include coastal protection from storms, climate regulation, nature-driven tourism, and fisheries that feed communities.

While marine ecosystems can be affected by human activities in the ocean, like dredging or aquaculture, or natural hazards such as hurricanes, they are also affected by the health of upstream terrestrial ecosystems. Intensified deforestation in mangroves and tropical forests is a key factor, as it worsens pollution and carbon emissions on land. It also leads to sediment runoff from loss of their root systems, which harms downstream coastal water quality and consequently coral reef health.

The coastal and marine ecosystems of the Mesoamerican Reef stretch over 1,000 kilometers, establishing it as the largest transboundary barrier reef system in the Northern Hemisphere. Belize, Guatemala, and Honduras, three countries in the region, significantly affect the reef through human activities that impact the coastal watersheds. Yet these watersheds don't always align with political boundaries, complicating policy interventions.

"It would be hard to justify, even scientifically, asking Guatemala or Honduras to finance watershed interventions if most of the benefits are accrued by the people in Belize," said Delevaux. "That's when we asked the question: if you were to manage watersheds with an eye towards supporting both people and climate resilience, would you target the same areas as you would if you were solely focused on coral reef health?"

Mapping benefits across scales

To answer that question, researchers and local partners identified target areas where three key watershed interventions could be implemented: restoration of agricultural land to native forest; protection of existing forest; and sustainable agriculture—converting conventional agriculture and ranching to agroforestry and silvopasture.

"It was amazing to see the level of coordination and collaboration happening while covering such a large geographic area. The communities' knowledge, needs, and questions really influenced the science through the many workshops, participatory mapping exercises, and capacity trainings we held to gather the information for these analyses," said Delevaux. "I'd say that part of the work was really inspiring, because you see how it's going to be used firsthand."

Then, using InVESTecosystem services models, Delevaux and colleagues quantified the effects of different interventions in different target areas on coral health through sediment retention. They found that the most important target areas for coastal communities—where interventions would maximize societal benefits like tourism, fisheries, and coastal protection—changed depending on whether they prioritized a regional- versus national-scale scale approach.

Sediment retention and coral health improve the most in models prioritizing regional interventions that target larger, transnational watersheds. A national emphasis on smaller, non-transboundary watersheds lined by reefs provides more localized societal benefits.

"At the regional scale, across countries, we found we have the best opportunities for making investments in watersheds that are going to help reduce sedimentation and increase coral health across the region," said Katie Arkema, senior fellow at the Natural Capital Project and

senior scientist at the Pacific Northwest National Lab, with a joint appointment at the School of Marine Environmental Affairs at the University of Washington.

"At the national scale, we can make investments that are going to really specifically benefit the coastal communities in that country through those societal ecosystem service benefits," said Arkema.

While the study results show trade-offs between regional coral health and country-level societal benefits, there were also some interventions that prioritized similar target areas in both.

"These spatially explicit results are empowering for both local and regional managers. A donor or investor might be interested in improving reef health in a specific reef area or Marine Protected Area and could use these results to target the watersheds that yield maximum improvement in their focal area. A national government could determine the best set of interventions and watersheds that maximize both social and ecological benefits," said Melanie McField, co-author, founder, and director of the Healthy Reefs for Healthy People Initiative.

"The model can also quantify the regional reef and social benefit to cooperative work in the major watersheds, supporting potential large-scale multi-national conservation efforts."

Co-creating for the future

Researchers co-designed the study with local partners, including Healthy Reefs for Healthy People, and locally based affiliates of the World Wildlife Fund.

In Honduras, the results of the study are helping to guide investments in watershed restoration through replanting mangrove forests to minimize

sediment runoff.

For Belizeans in Placencia, these results add to almost two decades of support for mangrove-forward development between the Natural Capital Project, WWF, Belize Coastal Zone Management Authority and Institute (CZMAI), and others. Delevaux also continues to work with communities in Placencia, Belize through an NSF project to find equitable nature-based solutions like mangrove restoration and conservation at the local level.

"It can be useful to emphasize for decision-makers that we do have some quantitative models and tools that can help support the kinds of decisions they have to make on where to direct funds. [Our research] can help provide insights into how the decisions that they make today might influence what happens in the future," said Arkema.

More information: Jade M. S. Delevaux et al, Social–ecological benefits of land–sea planning at multiple scales in Mesoamerica, *Nature Sustainability* (2024). DOI: 10.1038/s41893-024-01325-7

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