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Perspective: Analyzing susceptibility of coastal MPAs to catastrophic land-based events

Editor's note: Rafael Magris is an environmental analyst at the Brazilian national agency for biodiversity conservation – ICMBio. He is lead author on the new study "A modelling approach to assess the impact of land mining on marine biodiversity: Assessment in coastal catchments experiencing catastrophic events (SW Brazil)", which is described in this essay.

By Rafael Magris

In November 2015, 39 million cubic meters of metal-contaminated slurry polluted riverine and coastal waters in southwestern Brazil when a tailings dam failure occurred in a headwater of the Doce River catchment. (A tailings dam is used to store wastes from mining operations.) The plume of contaminated sediment ultimately reached several sensitive marine habitats including coral reefs, seagrass meadows, and habitats formed by coralline crustose algae. Much of the sediment accumulated in two marine protected areas – Santa Cruz Wildlife Refuge and Costa das Algas Environmental Protection Area.

Marine protected areas by themselves are generally ineffective at reducing land-based disturbances: this is because an MPA's jurisdiction normally ends at its boundary line. Therefore broader management approaches like integrated coastal zone management should be used to help account for threats that originate in one realm (terrestrial) but affect another (marine).

However, analyses of the impacts of terrestrial threats on marine areas tend to focus on diffuse sources of pollution such as nutrient runoff from agriculture, use of pesticides in forestry plantations, and resulting phytoplankton blooms. No one to my knowledge has specifically addressed the risk effects of *catastrophic* events on downstream marine systems, such as those associated with the sudden collapse of tailings dams.

A new modeling approach

In this new study, my research team provides a modeling approach to predict the cumulative impact of past and ongoing sediment disturbances related to a tailings dam failure, using the Doce River as our case. We examined a range of coastal ecosystems that differed in their ability to tolerate these stressors. We applied a hydrological model that built on sediment transport estimates following a tailings dam spill event, and acknowledged that disturbances were temporally dynamic. Then we coupled estimated sediment loads discharged by the river with hydrodynamic models to simulate the dispersal of pollutants in the sea.

We determined that the Doce River exported 74 million tons of sediment after the tailings dam accident. In contrast, normal sediment export would have been just 2.5 million tons over the same period. By tracking the accumulation of sediment on the sea, we could estimate the footprint of the accident, spreading over nearshore habitats such as coral reefs on the Abrolhos Bank, the most biodiversity-rich area in the South Atlantic Ocean. We also found that primary producers were particularly sensitive to sediment concentration increases (e.g., crustose coralline algae forming rhodolith beds, as well as seagrasses) and were thus heavily impacted.

Although we focused our approach on the Doce River catchment, the approach is flexible and can be applied to diverse potential catastrophes with occurrences that are episodic in both time and space (e.g., landslide hazards, coastal cliff failure). It is also applicable to all types of ecosystems beyond those addressed in our case. Integrating modeling like this will allow MPAs to refine their vulnerability assessments in a more complete way, and detect trends in ecosystem integrity over time.

It should be noted that just three years after the Doce River dam collapse, another tailings dam burst in the same region of Brazil. In the latest case the watershed is more heavily fragmented, so sediment will deposit more gradually than the Doce collapse along the river's course due to the presence of hydroelectric power plants and reservoirs. With the ongoing push for economic development, tailings dam failures like these are becoming a more common threat to aquatic ecosystems.

For more information:

Rafael Magris, James Cook University. Email: rafael.magris@my.jcu.edu.au

For a video animation showing a model of the spread of the Doce River sediment plume after the 2015 accident, click here.