

# Protecting Red Sea coral reefs from desalination risks<sup>1</sup>



Source: Helena Villela, KAUST, with permission.

Note: Healthy coral ecosystem in the Red Sea.

## Freshwater scarcity is driving desalination, but brine discharge threatens coral reef health

Roughly 2 billion people lack access to fresh, safe water, and water scarcity is increasing. As the demand for fresh water grows, the largely arid nations bordering the Red Sea, notably Saudi Arabia and Egypt, are investing in desalination as a potential solution. However, the brine discharges from desalination plants threaten the health of the Red Sea's coral reef system — one of the largest and most biodiverse in the world. The consequences of exposure to the brine, which is known to have high salinity and contaminants, range from minor disruption for some wildlife communities to death for others.<sup>3</sup>

Although increased salinity is known to be harmful, the effects of desalination discharge on coral reef health and the implications for planning and management are not well understood. As a first step in addressing this knowledge gap, KAUST researchers and international and local partners (Red Sea Global) examined the effects of increasing salinity on two representative Red Sea coral species: *Acropora* sp. (see photos below) and *Stylophora pistillata*.

### The bottom line

- A study conducted by KAUST<sup>2</sup> researchers, international collaborators, and local stakeholders argues for science-informed planning and management to reduce the risk of desalination discharge poses to the health of Red Sea coral reefs.
- To help safeguard the reefs from damage, the authors recommend maintaining exposure to brine discharge below a threshold of 10% above ambient salinity.
- The results of this research show that even moderate levels of excess salinity can impact coral health, while higher levels can be lethal.
- The study is a critical first step toward comprehensively assessing the risks posed by desalination discharge to all species of coral and other marine life.



## Science-informed planning and management can help mitigate risks of brine discharges

The study recommends maintaining brine exposure at a threshold of less than 10% above ambient salinity levels to avoid stressing coral and improve its survival.

Meeting that goal will require better planning and management, supported by a better understanding of the relationship between discharge from desalination plants and coral reef health. The study identifies needs for additional hydrodynamic modeling to ensure that coral reef ecosystems are not exposed to salinity levels exceeding biologically tolerable limits.

### Investigate dynamics of discharge plumes and habitat interactions

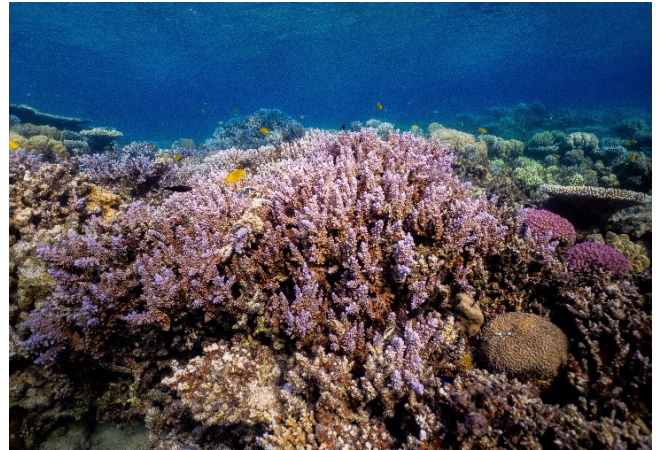
The study argues for “ecologically relevant” work that can help bridge the divide between the laboratory and real-world conditions. To understand the effects of longer exposures to brine, the study calls for models that capture how plumes of briny discharge disperse in coastal waters, how quickly the discharge dilutes, how long harmful exposures last in local oceanographic environments, and how well coral can tolerate or adapt to fluctuations in salinity. Thus, the study suggests implementing a long-term in-situ monitoring program for studying the impact of brine discharge.

### Expand scope of research

The study provides baseline data and a framework, which the authors suggest extending to research on other brine contaminants, coral species, and reef organisms. Increased salinity is only one of many potential stressors found in brine. Desalination plant discharges can contain other contaminants, including trace metals, residual chemicals, and nutrients, that can harm reef organisms additively and interactively. Other species of coral and marine life may also be vulnerable to the discharge components.

### Use results to inform plant design and manage outflows

Integrating the insights from this research into environmental impact statements and management strategies will help protect coral reefs. For example, learning more about how local coral species tolerate salinity fluctuation can help determine ecologically safe placements for discharge pipelines. Moreover, some models suggest that a shallower discharge angle of 30-45 degrees may enhance dilution and offshore transport of brine in coastal waters with slopes.



**Source:** Helena Villela, KAUST, with permission.

**Note:** Healthy *Acropora* colony.

## Research demonstrates sensitivity of coral reefs to heightened salinity

The study's recommendations are based on the results of a controlled experiment that tested the physiological and biochemical responses of *Acropora* sp. and *S. pistillata* to increasing salinity in a laboratory. Both species were exposed to salinity levels at 5%, 10%, 22.5%, 43%, and 75% above ambient salinity, defined as the concentration of salt typically found in water in their natural habitats, which averages 40 parts per thousand in the Red Sea.

At levels above 5% and 10% added salinity, the species' health began to decline. The physiological manifestations included bleaching, tissue loss, and polyp retraction, which impedes the ability of coral to grow.<sup>3</sup> Consistent with those harms, basic biochemical functions, such as chlorophyll retention and photosynthesis activity, declined.



**Source:** Helena Villela, KAUST, with permission.

**Note:** Details of healthy *Acropora* polyps.



**Source:** Morgan Bennett-Smith, KAUST, with permission.

**Note:** Dead *Acropora* colony.

Although both species showed signs of stress as salinity levels rose, *S. pistillata* was more sensitive than *Acropora* sp. Lethal effects began to appear at 13.8% increased salinity for the former and at 19.6% for the latter. The results also varied with rate and time:

- Rapid increases in salinity levels, at 43% and 75% above ambient levels, resulted in coral mortality within two days.
- Fifty percent of *S. pistillata* specimens exposed to salinity that is 22.5% above the ambient level died by the end of the seven-day study period.

Taken together, the results of the study suggest setting a threshold for added salinity at no more than 10% above ambient salinity levels, which is largely consistent with the findings of prior research.

## Summing up

The study shows that Red Sea coral is sensitive to increased salinity and thus vulnerable to damage from desalination plant discharge. The study recommends that brine exposure be maintained at levels no higher than 10% above ambient salinity to minimize health effects and long-term reef degradation.

Even moderate rises in salinity, if not well managed, can harm coral reefs near plant discharge sites. By pinpointing the effect of salinity, this study offers an essential first step in understanding the role of this stressor in coral reef health and establishing a risk-assessment framework for evaluating both the environmental impacts of brine discharges and the implications for planning and management.

The study also suggests extending the framework to research on other brine contaminants, coral species, and reef organisms. Doing so would allow scientists to capture more completely the effects of desalination discharges on the Red Sea's reef ecosystems.



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1. This policy brief summarizes findings from Micaela S.S. Justo, Laura Beenham, João Cúrdia, Marta Canha, Fern Lyne, Rita Bartossek, Carla Leite, Edwin Palmer, Edward Oldmeadow, Rosa Freitas, Michael L. Beruman, and Susan Carvalho, "Effects of Salinity Stress on *Acropora sp.* and *Stylophora pistillata* in the Red Sea: A pre-construction risk assessment for desalination plants," *Desalination*, Volume 616, 2025, <https://doi.org/10.1016/j.desal.2025.119328>. All rights and any third-party permissions remain with the respective rightsholders.
2. King Abdullah University of Science and Technology (KAUST).
3. Coral polyps are tiny soft-bodied invertebrates related to sea anemones and jellyfish that are fundamental to building coral reefs. See Coral Reef Alliance at <https://coral.org/en/coral-reefs-101/coral-polyps/>.