Invasive species of coral boasts amazing capacity for regeneration

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Scientists investigate the factors that enable colonies of sun coral to multiply rapidly and drive out native species. An entire colony can regenerate from one tiny fragment. Credit: FAPESP

Detected for the first time in Brazil on the coast of the Southeast region in the late 1980s, when oil and gas prospecting began in the Campos Basin offshore of Rio de Janeiro, sun corals of the genus Tubastraea are now spreading very swiftly throughout the rocky shores and cliffs of Brazilian islands and are considered to be biological invaders.

Once biodiverse and multicolored, the reefs in Búzios Island—part of the municipality of Ilhabela, Sao Paulo State, also located at the Southeast—are now covered with orange stripes. In some places, no bare rock or other species of coral can be seen.

"The reefs around Búzios Island are in an irreparable condition," said Marcelo Kitahara, a professor in the Marine Science Department of the Federal University of São Paulo (DCMAR-UNIFESP) in Santos, Brazil. Kitahara heads a project supported by the Sao Paulo Research Foundation—FAPESP to study the phylogenomics of two species and the links between their evolution and climate change.

The genus Tubastraea comprises seven species, all native to the tropical waters of the Indian Ocean and Pacific. Only two, *T. coccinea* and *T. tagusensis*, are also found in the southwest Atlantic. Both are invasive species.

The first Brazilian sightings were recorded in the Campos Basin in the 1980s, followed by the discovery of colonies on reefs off the southern coast of Rio de Janeiro State in the 1990s. Since then, sun coral has been found across over 3,000 km of the Brazilian coastline, from Santa Catarina in the South to Ceará in the Northeast.

"Management action is still possible in some places, but this requires the complete manual removal of all colonies," Kitahara said. "If nothing is done to stop its advance, sun coral could potentially colonize the entire Brazilian coast."

A study showing the surprising capacity of sun coral to regenerate had its results published in the *Journal of Experimental Marine Biology and Ecology*. The lead author is Ph.D. student Bruna Louise Pereira Luz, a biologist affiliated with the Federal University of Paraná (UFPR) and currently in Australia studying sun coral at James Cook University, Townsville, near the Great Barrier Reef, under supervision of Kitahara.

"Sun coral colonies multiply at a great speed in areas such as these. We set out to understand how and why," said Kitahara. On one of the findings—only made possible through a lab-conducted experiment—they also revealed that sun coral regeneration process gets faster as water temperature increases.

Possible influence of Oil & Gas industry

The appearance of these invasive species just when oil and gas production began was not unique to Rio de Janeiro. The Gulf of Mexico also has vast offshore oilfields, and sun coral has been found on the Mexican coast since the early 2000s. There are even records of sun coral attached to the hulls of ships.

"We can't be totally sure that offshore oil drilling in the Campos Basin resulted in the invasion of our coast by sun coral, but all the evidence points to this conclusion," said the FAPESP project coordinator.

A coral reef is a limestone skeleton built by colonies of thousands of tiny animals called coral polyps. Most reef-building corals contain photosynthetic algae that live in their tissues. The corals and algae have a symbiotic relationship: the polyps provide the compounds required by the algae for photosynthesis, and the algae provide the polyps with nutrients. Other types, including sun coral, can grow and proliferate without algae.

"Because it has no algae, sun coral isn't confined to places with sunlight for photosynthesis. It typically occurs at depths of up to 20 meters, but sightings have been recorded at 110 meters. On rocky shores and underwater cliffs, polyps build huge numbers of colonies and cover 100% of the substrate," Kitahara explained.

During this process, they drive out the native coral, devastating ecological relations with the marine fauna that depend on or inhabit it.

Reorganization of stem cells

To investigate the mechanisms that enable sun coral to adapt so successfully and proliferate rapidly in various marine environments, the researchers collected a colony of *T. coccinea* and another of *T. tagusensis* from Búzios Island.

In the laboratory, the researchers removed from each colony 120 fragments composed of skeleton with living tissue but lacking mesenteries, mouths and tentacles. The samples of each species were then separated into two groups of 60, one with very small fragments (3.5-11 mm^2) and another with slightly larger fragments (11-53 mm^2). All 240 fragments were placed separately in containers with filtered seawater.

For each combination of species and fragment size, individuals were further separated into three groups of 20 fragments and maintained at a constant temperature of 24 °C (historically the average surface water temperature in the region), 27 °C (the average sea surface temperature in summer) or 30 °C (observed during heat waves).

Finally, the effects of the presence of food were tested by adding equal amounts (10 ml) of live zooplankton every other day to half of the containers.

The fragments were photographed on the first day of the experiment and when the mouth and complete polyp were first observed. Only 41 of the 240 fragments, or 17.1%, underwent tissue necrosis and death. The other 199 fragments (86.9%) regenerated. Of these, 21 (9% of the entire sample) displayed an alternative regeneration pattern, with the formation of two polyps instead of one.

Regardless of the species, coral fragment survival was affected only by temperature. The survival rate was highest at 24 °C. There was no difference between the fragments kept at 27 °C and those kept at 30 °C. Food supply and fragment size did not affect survival.

Regeneration was found to include the following stages. After initial tissue retraction, mouth rudiments became noticeable, sometimes two for a single fragment. Subsequent development consisted either of tissue reorganization around the mouth rudiments, leading to the formation of two small, distinct polyps, or the reabsorption of one of the rudiments, in which case significant tissue differentiation around the remaining mouth rudiment resulted in a larger polyp.

"We observed a very interesting phenomenon," Kitahara said. "From a cellular viewpoint, there was a reorganization of stem cells. The polyp in formation consumed tissue as a source of energy to prioritize the production of other body parts."

The results of the experiment generally indicated faster regeneration rates at higher temperatures. The fastest mouth regeneration for fragments without contact with food was 23 days at 24 °C or 18 days at 30 °C. However, fragments kept at 27 °C in contact with living zooplankton displayed 30% faster mouth development. This suggests optimal mouth development at the intermediate temperature (27 °C), provided there is contact with food.

Fragments of both species developed into complete polyps in approximately 25 days at 27 °C and 30 °C. Unfed individuals of the species *T. coccinea* took approximately 41 days to achieve polyp formation.

As Kitahara explained, the fact that sun coral regenerates faster at higher temperatures is highly germane to its invasive success. Most native corals on the Brazilian coast suffer bleaching when surface water temperatures rise.

"They lose color," said the FAPESP-funded researcher. "Warmer water interferes with the metabolism of their symbiont algae. Bleached coral survives only for a few days. If the temperature remains high, it dies. The bleaching or death of native coral opens up an opportunity for substrate invasion by sun coral."

The next steps in this line of research, according to Kitahara, will be to sequence sun coral's genome, on the molecular side, and, on the ecological side, to investigate the biological aspects of its invasion and how it affects native marine fauna.

The future does not appear promising for native corals on the Brazilian coast, in Kitahara's opinion. For sun coral, on the contrary, it appears to be bright. On one hand, global climate change and rising seawater temperatures help the invader, which regenerates faster in warmer water, while native corals risk dying. Not to mention the prospect of expanding oil production in Brazilian waters.

More information: B.L.P. Luz et al, A polyp from nothing: The extreme regeneration capacity of the Atlantic invasive sun corals Tubastraea coccinea and T. tagusensis (Anthozoa, Scleractinia), *Journal of Experimental Marine Biology and Ecology* (2018). DOI: 10.1016/j.jembe.2018.02.002

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