BIODIVERSITY
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WATCHING OUT FOR CORAL REEFS WITH FORAMS

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AGE: 15

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Lots of creatures live in coral reefs, including some tiny ones you might never have heard of. In this article, we will tell you about the importance of Foraminifera (also called forams), unicellular organisms with shells, that contribute to coral reefs in many ways. Just like corals, some forams living on the seafloor live closely together with microalgae. Some forams also thrive in similar environmental conditions (sunlight, temperature, salt) as corals. For this reason, forams can be used as reef "sensors", to keep track of the overall health of coral reefs. They can even help to detect poor environmental conditions that might harm coral growth in the future. In this article, we will look at a study of an Indonesian reef ecosystem in which the foram communities living on the seafloor were monitored between 1997 and 2018.

WHAT ARE LARGE BENTHIC FORAMINIFERA?

Coral reefs are the rainforests of the oceans. They harbor not only corals, but a wealth of other animals like sea urchins, sea cucumbers,

PLANKTONIC

Organism that lives in the water column.

BENTHIC

Organism that lives on the seafloor.

MICROALGAE

Microscopic algae consisting of a single cell.

sea feathers, sea stars, and turtles. Coral reefs also are home to many tiny creatures, like sea slugs, sea horses, shrimps, and a group you may not have heard of, called Foraminifera. Foraminifera (also called forams) are unicellular organisms with animal-like cells. Most forams have shells shaped like a cone, ball, star, coin, or swirl, while others have no shells. Forams are not limited to coral reefs. Some live floating in the ocean, known as **planktonic** forams. Others, known as **benthic** forams, live on the seafloor, from the deepest part of the ocean to the shoreline. Benthic forams are divided in two groups: small and large. The large benthic forams can range from 0.5 mm to 20 cm. They can grow to large sizes because they have a special relationship with **microalgae**. This relationship likely benefits both the microalgae and the forams. Microalgae use sunlight for photosynthesis to produce sugars, just like plants. The sugars provided by the microalgae give the foram energy to make its shell [1]. In exchange, the foram offers shelter and nutrients to the microalgae. However, scientists still do not fully understand this relationship and how it is affected by the surrounding environment, so they are still actively researching it.

COMMUNITY

Group of populations of two or more different species that occupy the same geographical area at the same time.

Large benthic forams and reef-building corals need similar temperatures, nutrients, and amounts of sunlight to thrive, because both rely on their relationship with microalgae. Foram communities change faster than corals because they are unicellular organisms and have a shorter life span. As environmental conditions change, some foram species will survive better than others, and changes can be seen in their **communities**. If environmental conditions are not good for coral growth, an effect can be seen in the foram community first. Early after the environment changes, corals might not yet show any signs of deteriorating health. This means that the number of species and quantity of large benthic foram species that form a community can be used to monitor the health of coral reefs [2].

CORAL TRIANGLE

The region of the Indo-Pacific grouping of the Philippines, Malaysia, Indonesia, Papua-New-Guinea, and Solomon Islands where the highest density of species present in coral reefs is found.

ABUNDANCE

Number of individuals for a given species.

A STUDY OF FORAMS IN THE SPERMONDE ARCHIPELAGO IN INDONESIA

To figure out for sure whether changes in large benthic foram communities can predict upcoming coral reef damage, researchers did a 20-year study (1997–2018) of large benthic foram communities in the Spermonde Archipelago, Sulawesi, Indonesia, located in the middle of the **Coral Triangle** [3]. They sampled the foram communities at 12 islands across the Spermonde Archipelago five times during the course of the study. A total of 26 large benthic foram species were identified by examining their shells with a microscope (Figure 1). Next, the forams were counted, to know how many shells of each species were in each sample (called the **abundance**). Samples were taken in two different reef habitats: the reef flat (very shallow, 1–2 m deep) and the reef slope (ranging from 1 to 30 m deep) (Figure 2). The researchers found that the foram community composition was very different between the reef flat and the reef slope. The **diversity** of foram species was higher (meaning there were more species) on the reef slope than on the reef flat. The diversity also depended on how far the island was from the mainland.

DIVERSITY

Quality of including different organisms in a group.

Figure 1

Figure 1

Eighteen of the most common foram species found on the reef slope and the reef flat habitats in Indonesia. The sizes of the forams vary between 0.5 and 5 mm in diameter, with *Neorotalia* being the smallest and *Parasorites*, *Marginopora vertebralis* and *Amphisorus* being the biggest. Images were not all taken at the same scale.

This study also showed that the composition of the large benthic foram communities changed from one year to another over the 20-year study period (Figure 2). Corals were more abundant in 1997, especially on the reef flat. At that time, the seafloor was dominated by some lentil-shaped forams (*Amphistegina*). The algal component on the seafloor increased greatly between 1997 and 2018, so did some star-shaped forams (*Neorotalia* and *Calcarina)*. Those

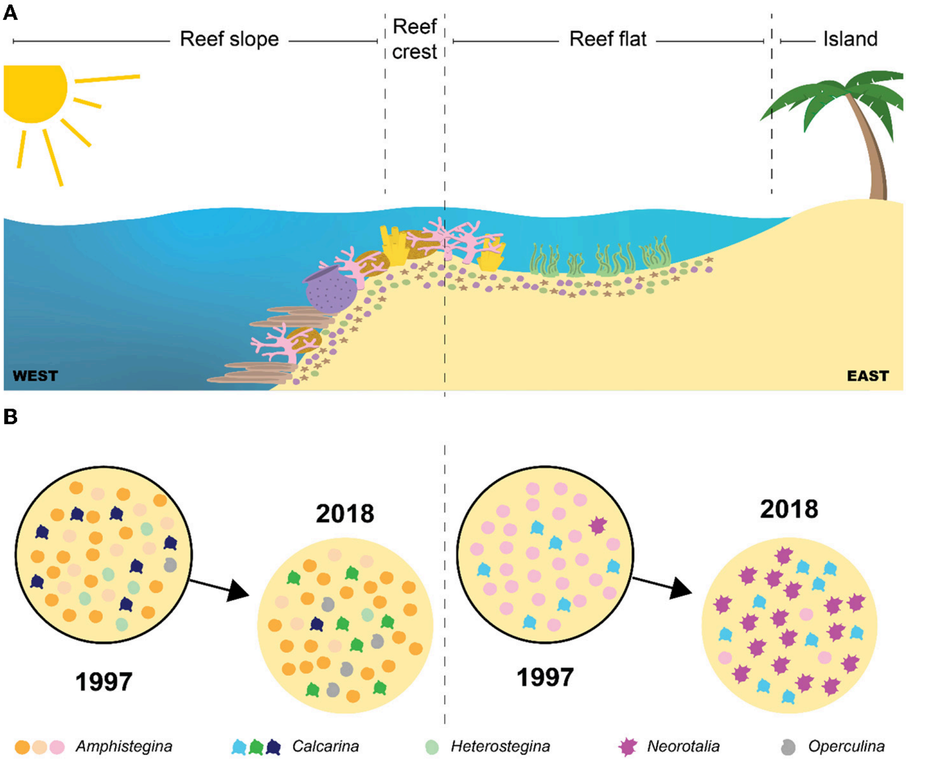

Figure 2

(A) A reef is divided in three zones: the reef flat, the reef crest and the reef slope (divided by dashed lines). A reef community consists of many organisms, including corals, sponges, fish, and forams. **(B)** Between 1997–2018, changes were seen in the composition of the foram community, especially on the reef flat where the number of star-shaped foram increased exponentially. Every foram species has its own shape and color. Figure adapted from Girard et al. [3].

star-shaped forams like to live in environments where algae also grow. Usually, when the environment is suited for algal growth, it is not for coral growth. The shift in the foram community over time therefore indicated a deterioration of the coral reef system in the Spermonde Archipelago.

The research showed us that many things can shape the composition of the foram communities: the type of material they grow on (called the **substrate**), island population, and distance from mainland, to name only a few [3, 4].

SUBSTRATE

A natural or artificial material that organisms can settle, grow, and live on or in.

MORE ALGAE GROWING IN THE SPERMONDE ARCHIPELAGO

Large benthic forams live on multiple substrates. Some thrive on the sand or algae. Others prefer coral rubble, made of dead pieces of coral skeleton. On coral rubble, there are lots of little cracks and holes to take refuge and settle in. Over the course of the 20-year study, the substrate in the Spermonde Archipelago changed (Figure 3). It started off in 1997 with more than 60% coral rubble, clean of algae. From 2012 on, more than 80% of the substrate became covered by small algae [3]. Despite the change in the substrate type over time, the amount of surface covered by living corals did not drastically decrease and even seems to have slightly increased in recent years [5].

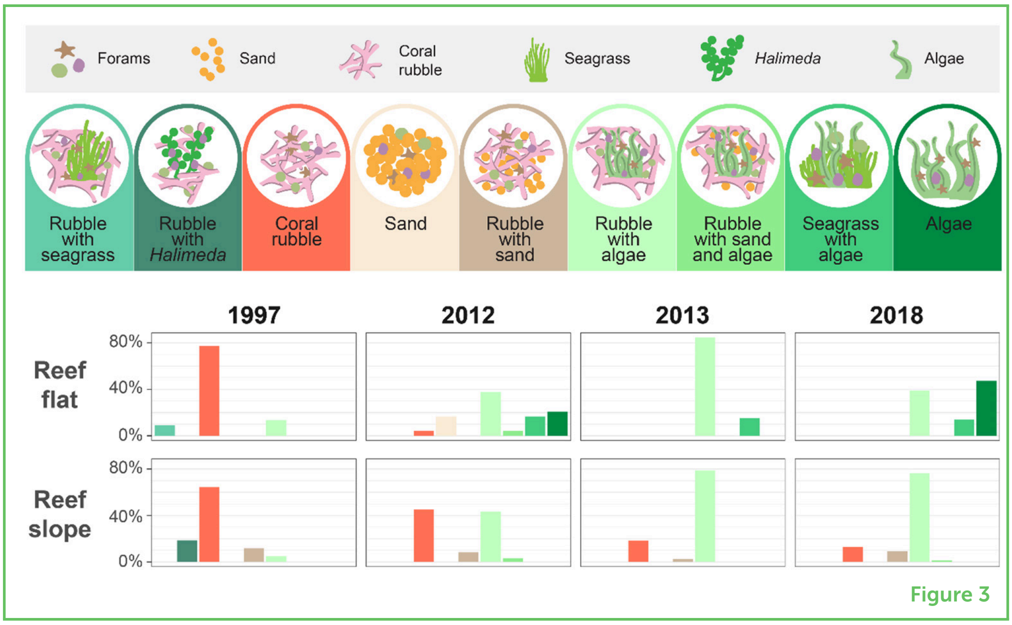

Figure 3

Changes in the substrate type on coral reefs between 1997 and 2018. The y axis shows the abundance of each type of substrate in the samples taken during the study. On the x axis, you can see the years when the samples were collected. With time, there is a decrease in the abundance of clean coral rubble (orange) and an increase in the abundance substrates with algae (various shades of green). This gives us the indication that the environment in the reef is more suited to algal growth, which might impact coral growth negatively. Figure adapted from Girard et al. [3].

Communities of algae are primarily shaped by how much they grow and how much they are eaten by herbivores (animals that feed on algae and plants). Algae grow faster when there are a lot of nutrients in the water, especially phosphorus and nitrogen. Algae also thrive when they get a lot of sunlight, like they do in shallow water [6]. The more people live on an island, the more pollution enters the water. Because pollution often contains phosphorus and nitrogen, the more pollution is in the water, the faster algae will grow—especially in the sunny, shallow parts of the reef. Pollution also decreases the number of fish eating the algae. Thus, the combination of faster growth and less algae being eaten results in more algae in the reef habitat. This sequence of events most likely changed the benthic habitats on the reef flat, which then affected the composition of large benthic foram communities. Indeed, many foram species seem to prefer a type of substrate [3].

Some foram species seemed to have strong preferences about which island they grew on, island's population, and where the island is located. The distribution of these forams is probably related to the water quality and amount of man-made pollution present in various areas of the Spermonde Archipelago. Scientists still do not fully understand the effects of substrate type and water quality on forams [3, 4].

FORAM MONITORING COULD HELP CORAL REEFS

Based on the study we just described, and previous studies from different regions of the world, we know that large benthic forams are very sensitive to both water quality and substrate type. Their community shifts can tell us about changes in environmental conditions that sensitive coral reefs are exposed to. Monitoring large benthic forams on a regular basis may help scientists to detect early stages of coral reef deterioration, as seen in the Coral Triangle and the Great Barrier Reef.

Coral reefs are hotspots of ocean biodiversity. Many human populations rely on reefs for food and tourist activities. When they are well managed, reefs can be sustainably used and preserved. Thus, it is very important to monitor the health of coral reefs. Closely monitoring communities of large benthic forams gives us a good estimate of coral reef health. Additionally, monitoring foram communities may also be used as a warning signal for early coral reef deterioration—hopefully in time to take action against whatever is damaging the reefs.

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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JUDE, AGE: 15

I am a big fan of both dogs and cats. I have trained my cat to walk on a lead so we can go for walks together in my spare time. I also love music and spend a lot of time playing my guitar. I enjoy reading about biochemistry (especially plant related) and one day would like to study the subject at university.

MARGARIDA, AGE: 15

My name is Margarida. I am 15 years old and I like reading, climbing, and writing. I love science, especially astrophysics and I have absolutely no idea what I want to do when I grow up. I also really like biology.

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Elsa is a Ph.D. student based at Naturalis Biodiversity Center and part of the 4D-REEF European research consortium studying the past, present, and future of turbid coral reef ecosystems. Her research focuses on the changes of forams community through space and time from the Spermonde Archipelago (Indonesia). She is also improving the identification of forams using DNA without the need of sorting the species from the sediment samples under a microscope. Her research contributes to the understanding of factors driving community changes in turbid reef systems. *elsa.girard@naturalis.nl

WILLEM RENEMA

Willem is a professor and researcher at University of Amsterdam and Naturalis Biodiversity Center as well as project leader of the 4D-REEF European research consortium. His research focuses on the evolution and ecology of large benthic forams, by studying the role of those forams in their environments. They are an important organisms participating to the production of sand in the reef, and were even more so in the past. He relies on a thorough understanding of their shell shape and genetic evolution, from both fossil and living forms.