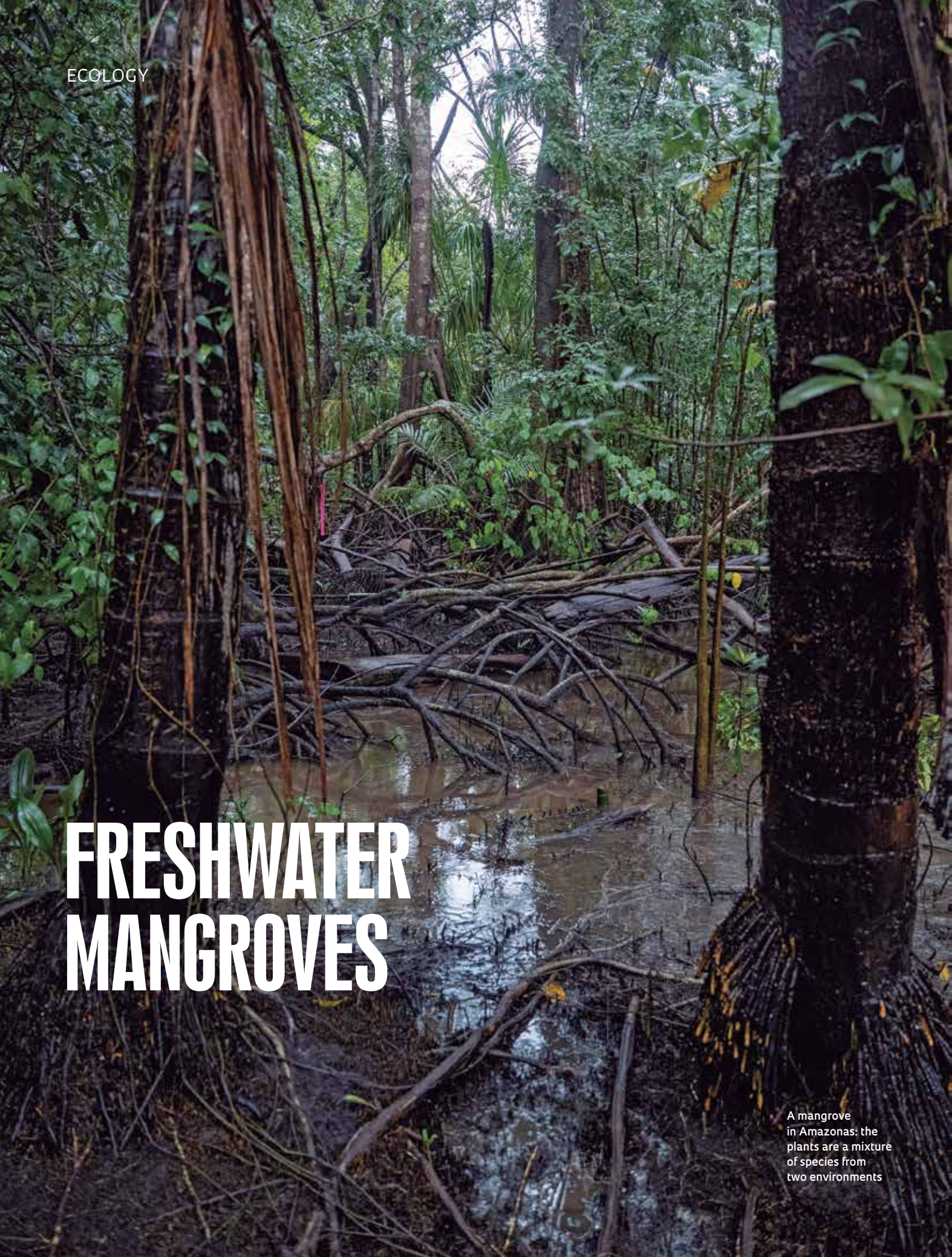
FRESHWATER MANGROVES



A mangrove in Amazonas: the plants are a mixture of species from two environments

A study explores this rare type of coastal ecosystem located at the mouth of the Amazon River

Guilherme Eler

A new study estimates that the area of mangroves surrounding the mouth of the Amazon River, on the border between the states of Pará and Amapá, is at least 180 square kilometers (km²) larger than is known. According to an article published in August in the scientific journal *Current Biology*, the total extent of this type of transitional vegetation between land and marine environments reaches 1,713 km² at the vast mouth of the river, equivalent to approximately 15% of Brazilian mangroves. The plants present in the region are unique; they are a mixture of species adapted to freshwater environments, such as floodplains, with those of typical mangroves, where salinity is high.

On the muddy soil of the Amazon delta, which is a type of river mouth formed by several channels and small islands, forests were found with herbaceous species such as aninga (*Montrichardia linifera*). These were accompanied by trees typical of floodplains that appear outside their normal habitat, such as corticeira trees (*Erythrina crista-galli*) and some types of palm trees, including açaí (*Euterpe oleracea*) and buriti (*Mauritia flexuosa*). Mangrove environments are normally dominated by trees adapted to salt water and brackish environments. "However, the Amazon delivers so much fresh water into the Atlantic that the salinity is almost zero in its delta and for dozens of kilometers in a northerly direction along the coast," says the oceanographer Angelo Bernardino, from the Federal University of Espírito Santo (Ufes), lead author of the article written alongside Brazilian, US, Australian, and Scottish colleagues.

By definition, mangroves are a type of coastal ecosystem found in tropical and subtropical areas. They are characterized by plant species that have adapted to tolerate the presence of sea water. Their trees resist high salt concentrations and can surpass 35 meters (m) in height. The size is a response to the strength of the tides and to the renewal of nutrients by the local dynamics; since the water flowing from the ocean can reach depths of up to 10 m, the plants need to be large and have equally robust roots that emerge from the soil to help secure the plant. Due to the presence of salt water, trees with low salinity tolerance do not resist, and, over time, the environment is overtaken by mangrove species .

However, this is not what happens in some areas that neighbor the marine outlet of certain rivers. The existence of mangroves with freshwater plants is due to the pattern of rainfall and the influence of the mouth of a large river on parts of a coastal area. "In the dry season, with reduced river flow rates, the salt water penetrates the mangroves more," explains oceanographer Mário Soares, coordinator of the Mangrove Study Center at Rio de Janeiro State University (Nema-Uerj). "In the rainy season, there is a greater presence of fresh water. This prevents the environment being dominated by saltwater plant species." According to Soares, who did not participate in the study about the Amazon delta but has done research in the region for years, the mangroves located on the border between the state of Pará and Amapá are different than what is seen in the majority of Brazil.

The objective of an expedition headed by Bernardino in April of 2022 was to monitor the influence of the sediment transported by the Amazon, what is known as a river plume, at different points along its mouth. The trip is part of the of the National Geographic Society's Perpetual Planet Amazon Expedition, which promotes scientific excursions to the Amazon basin from the Andes to the Atlantic. The team, coordinated by the researcher from Ufes, explored 11 mangrove forests along the Amazon delta and collected data on the water, soil, salin-

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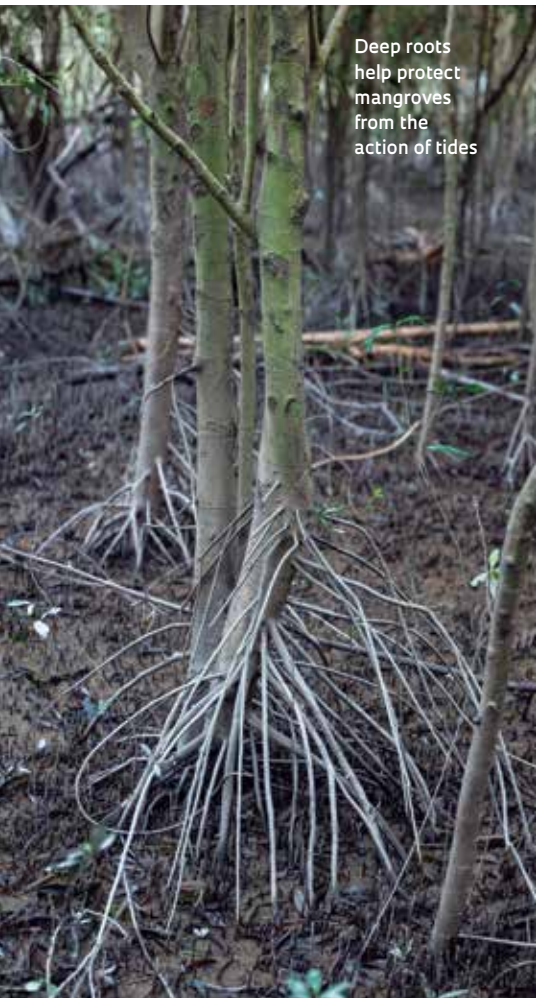
ity, plant composition of the forests, and carbon stocks of the ecosystems.

In addition to noting the presence of freshwater species that theoretically should not be in the mangroves, the expedition discovered something interesting. On the first stop, near the community on the Bailique archipelago, which is a five-hour boat trip from Macapá, the state capital of Amapá, the soil had an extremely low salinity that was close to zero parts per thousand (‰). "The Amazon is the largest river in the world in terms of water volume. There is no other place with so much sediment arriving at the mangroves on the coast," says Bernardino. It is estimated that close to the island of Marajó, on the coast of Pará, 3 million liters of water from the Amazon reach the ocean every second. This total represents almost 20% of the water that drains into the sea from all the rivers on Earth. The mass of sediment accumulated over a one-month period, which originates in the Andes, is equivalent to the weight of Sugarloaf Mountain in Rio de Janeiro.

Although less dominant, the influence of the Amazon plume was still present approximately 100 km to the north of the Bailique archipelago in the area surrounding Sucuriju, which lies on the coast of the state of Amapá. Due to the greater influence of waters from the Atlantic, the salinity in this location was between 5‰ and 11‰, which is seven to three times lower than the average rate for a typical area of ocean. As a result of the low salinity, and unlike what is usually found in the rest of Brazil, the soils in these mangroves in the Amazon delta were very acidic.



Deep roots help protect mangroves from the action of tides

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Geologist Valdenira Santos, of the Aquatic Research Center of the Institute for Scientific and Technological Research of the State of Amapá (Iepa), says that mangroves areas that were mapped were composed only of trees of the species popularly known as siriúba (*Avicennia germinans*), which is also present at the mouth of the Amazon, more than 230 kilometers further inland from the mouth of the river. Siriúba is a typical tree species traditionally found in mangrove environments, where salinity is high. In principle, it should not occur in regions far from the saltwater of the Atlantic. It is a situation unlike the one described in the article by Bernardino but it illustrates the spread of this type of ecosystem into unexpected locations. "We don't yet know the mechanisms that make these mangrove populations establish themselves in zones with a complete lack of seawater influence," comments Santos.

In addition to hosting plant species and being home to many animal species, such as birds, crabs, and fish, mangroves also have an important role in the sequestration of carbon dioxide (CO_2), the main atmospheric greenhouse gas. Because they are poor in oxygen, the muddy soils of the mangroves do not encourage the decomposition of the organic material that they contain. Parts of plants and trees that would normally rot in other environments and release CO_2 back into the atmosphere remain preserved at the bottom of these coastal ecosystems. In practice, mangroves act as carbon sinks.

This process is probably even more intense in the northern part of the Brazilian coast under the influence of the Amazon plume. The river sediment transported to the sea carries a large amount of organic matter. Therefore, analysis of the evolution of the quantity of carbon stored in the mangrove soil in the Amazon delta may serve as a metric of human activities in the river basin. A portion of the organic waste produced by deforestation and by the farming activities ends up in the region's mangrove swamps, where it remains preserved. Measuring the levels of carbon accumulated in the trees and soil of mangroves, says Bernardino, could be an indicator of the increase in activities, such as deforestation, in recent decades.

According to the report on the global mangrove situation, which was released in September of 2022 and was compiled by a group of environmental nongovernmental agencies that take part in the Global Mangrove Alliance, the area of the planet covered by this ecosystem has decreased by 5,245 km² (3.4% of the total) since 1996. However, that work suggests that the areas of mangroves with the greatest growth over the recent years are located within river mouths, such as in the Indragiri in Sumatra, the Amacura in Venezuela, and especially the Amazon. This good news could hide a worrying figure: the area occupied by mangroves may have increased in these coastal regions due to intensified deforestation. According to the report, this would mean that rivers were carrying more sediment to their mouth, thus increasing the stretch of coastline able to be occupied by these ecosystems. Another possible explanation is that the increased size of the mangroves could be due to the improvement in the techniques used for mapping these formations.

This situation, coupled with a rise in global sea level due to climate change, could also cause mangroves to move inland. An article written by researchers from Europe and Brazil published in May 2022 in the journal *Science of the Total Environment* analyzed satellite imagery and identified an increase of 157 km² in the area occupied by mangroves over the past 38 years along the coast of Amapá alone. According to that work, the growth is probably due to the increased sea level, which would have pushed this type of coastal ecosystem inland. ■

The scientific papers consulted for this article are listed in the online version.