Microorganisms are the main emitters of carbon in Amazonian waters

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A new study has found that the microbial food web accounts for most of the carbon circulating in Amazonia's lakes, floodplains and wetlands.

"We concluded from our research that the amount of carbon circulating in the microbial food web in floodplain lakes in the Amazon is up to ten times the amount circulating in the classical phytoplankton-zooplankton-fish food chain," said Hugo Miguel Preto de Morais Sarmento, a professor in the Hydrobiology Department of the Federal University of São Carlos (UFSCar) in São Paulo State, Brazil.

The study had support from the São Paulo Research Foundation—FAPESP and was published in the journal *Hydrobiologia*.

To understand the scale and consequences of global warming, it is necessary to understand the carbon cycle. Due to its huge size, the Amazon region plays a key role in the planet's carbon cycle. Hence, it is important to quantify the stocks and flows of biomass in Amazonia's terrestrial and aquatic food chains.

Most studies that set out to quantify the carbon cycle in the Amazon analyze terrestrial biomass (plants and animals) or the biomass in the waters of major rivers, such as the teeming Solimões.

To date, few scientific studies have investigated the role played in the carbon cycle by the aquatic biomass present in the floodplains and related areas (shallow lakes, secondary channels and wetlands) that comprise no less than 20% of the entire Amazon biome. Such rare studies have focused on the carbon cycle in the classical food chain, which runs from phytoplankton (primary producers) to zooplankton, fish and invertebrates (primary and secondary consumers, decomposers and detritivores).

The new study investigated the microbial food web, a term that refers to the combined trophic interactions among all microorganisms in aquatic environments, including viruses, bacteria, microscopic algae (phytoplankton), unicellular predators, such as ciliates (protozoans) and flagellates, and invertebrates.

"We set out to verify and quantify microbial food web interactions in two distinct periods—the rainy season, when water levels are high and the food web is simpler, with fewer interactions, and the dry season, when water levels are lower and the food web becomes more complex, with more interactions," Sarmento said.

The researchers chose to collect material for the study from the Puruzinho, a floodplain system in Amazonas State, Brazil, consisting of a narrow lake and an 8 km-long channel connecting it with the Madeira River, a tributary of the Amazon River.

Thirty water samples were collected approximately half a meter below the surface at the end of May 2014, during the latter part of the Amazon rainy season when water levels are highest in the Puruzinho system, and at the end of October 2014, during the dry season when water levels are lowest.

"It's a shallow lake, with a maximum depth of 11 meters. The water column is homogeneous, so there is no material difference in the microbial composition of the water collected at depths of half a meter, two meters or five meters. It would be different if the lake were deeper, in which case it would have two or more layers with different temperatures and levels of dissolved oxygen," Sarmento said.

The numbers of bacteria, phytoplankton, ciliates, flagellates and zooplankton in the samples were counted in the laboratory.

According to Sarmento, approximately 1 million bacteria should typically be found in 1 milliliter of water from the lake (equivalent to three drops). The quantity of viruses, which are even tinier, should be approximately 10 million, but the researchers did not count viruses in this study. The phytoplankton abundance is approximately 10,000 per ml. In the case of zooplankton, which are much larger organisms, some even visible to the naked eye, approximately 10 should be found in 1 liter of water from the lake.

"Phytoplankton and zooplankton are counted and measured one by one using an inverted optical microscope. For bacteria, we used a flow cytometer, the device used by clinical analytical laboratories to count platelets and cells in blood samples," Sarmento said.

The ultimate purpose of the study was to estimate the total carbon in the samples as accurately as possible. The researchers needed to identify the groups of bacteria in the samples and count their numbers to infer how much carbon each group contributed to the total. Another important part of the study, thus, consisted of genomic screening to identify the different groups of bacteria in a sample.

The next step was to estimate the average microbial carbon biomass in water from the Puruzinho collected at high or low water. The results showed that the amount of carbon in the Puruzinho microbial food web averaged 245.5 micrograms per liter, an order of magnitude more than the average for the classical food chain (phytoplankton-zooplankton-fish), which was 24.4 micrograms per liter.

In other words, 90% of all the carbon in the Puruzinho circulates in the microbial food web. If this same proportion serves as a parameter to estimate the total amount of carbon circulating in the microbial food web of all floodplains and wetlands in the Amazon, the amount of carbon in the region is clearly underestimated.

Another interesting finding was that the vast majority of microorganisms in the Puruzinho microbial food web (in terms of both diversity and total carbon) are heterotrophic, i.e., primary and secondary consumers and detritivores. The proportion of autotrophic microorganisms—unicellular algae that perform photosynthesis and are present in the phytoplankton—is insufficient to sustain the Puruzinho food web.

According to the study, primary producers are not sufficiently abundant to metabolize the carbon needed to sustain the system's food web. The question is where most of the carbon used by primary and secondary consumers comes from.

"Our hypothesis is that most of the carbon in the Puruzinho system's waters comes from leaves, decomposing matter, and organic particles in humus and litter from the surrounding forest," Sarmento said.

"In the absence of a microbial food web, all this carbon would accumulate at the bottom of the lake, where it would be sequestered in the silt and sediment. In actuality, however, much of the carbon that runs off from the banks is recycled in the microbial food web, returning to the atmosphere in the form of carbon gas and methane, both of which are greenhouse gases. Each element in this trophic web participates in the atmospheric carbon cycle."

Now that the researchers understand the composition of the microbial food web in the Puruzinho system, their next step will be to determine what the bacteria are doing.

"We want to understand the relationship between terrestrial organic matter and aquatic systems and specifically to find out where all the organic matter consumed in the lake comes from. We also want to know exactly what's produced in the lake and what comes from the forest in order to understand carbon flows in the Amazon more completely," Sarmento said.

More information: I. B. Feitosa et al, Plankton community

interactions in an Amazonian floodplain lake, from bacteria to zooplankton, *Hydrobiologia* (2019). DOI: 10.1007/s10750-018-3855-x

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