



WHAT CAN TAPIR POOP TEACH US ABOUT HEALTHY FORESTS?

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The Baird's tapir is the largest land mammal living in the Mexican Selva Maya, which is the largest tropical forest in America after the Amazon. Tapirs are herbivores that play a key role in maintaining the health of tropical forests by dispersing seeds in their feces (poop). Tapirs are mysterious, silent, and nocturnal characteristics that make them difficult to study. In our research, we analyzed the microbes in tapirs' feces to understand the health of tapir populations in the Mexican Selva Maya. We found that a large amount of variety in tapirs' fecal microbes is associated with a healthy tropical forest ecosystem. Maybe the analysis of the fecal microbes of wildlife can be used as a gentle technique to help us understand the health status of animals and the environments in which they live.

FECES

Material that is evacuated during defecation. Stool is made up of undigested food, bacteria, mucus, and cells from the intestines.

Figure 1

(A) We performed our study in the forest around Calakmul, in the Selva Maya in Mexico. Sampling sites are shown by colored dots on the map: dry season (red circles) and rainy season (blue squares). (B) A tapir in the dry season. (C) A tapir during the rainy season (Photographs: Jonathan Pérez-Flores).

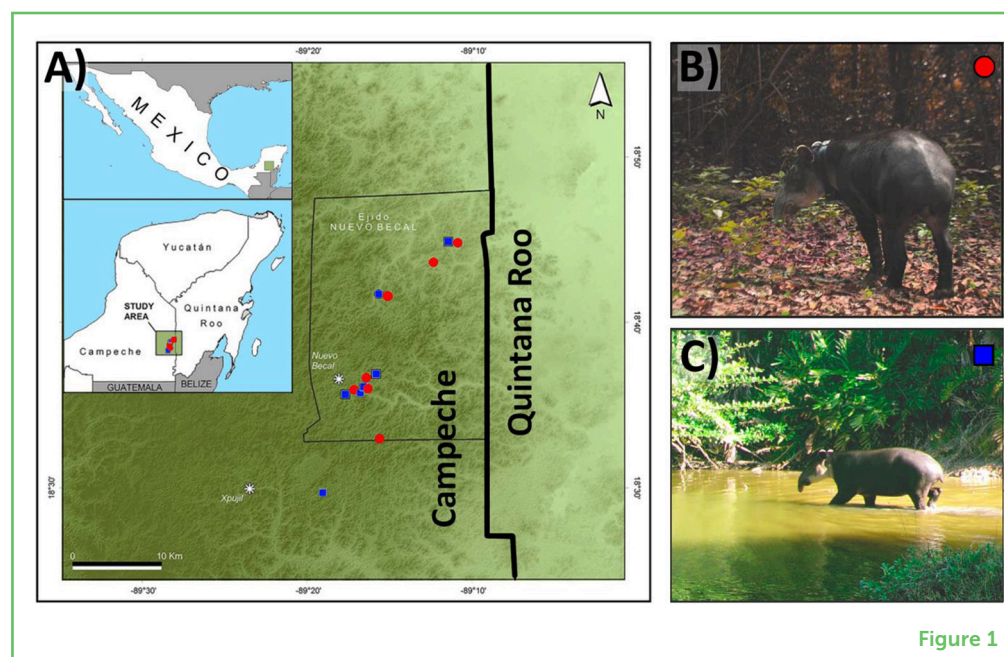


Figure 1

The tapir species that lives around Calakmul called the Baird's tapir. It is the biggest mammal in the Selva Maya, which is the largest tropical forest in America after the Amazon. Sadly, tapir populations have declined due to illegal hunting, fires, droughts, and habitat destruction. Baird's tapir is considered an endangered species by the International Union for Conservation of Nature [2].

Tapirs are shy, nocturnal animals that prefer to live in well-preserved forests, far away from noise and people. Tapirs travel several kilometers each night, visiting the same sites looking for food and water. Their travels create trails through the forest, which other animals can use.

Tapirs are herbivores—their diets mainly consist of fruits, leaves, stems, roots, bark, and flowers, from up to 70 plant species. They are not picky eaters and will eat the seeds and the skins of fruits. When they relieve themselves, the seeds return to the ground, along with the best fertilizer in the forest—their feces (Figure 2A). In just 1 year, an adult tapir will disperse over 9,000 seeds in one hectare of tropical forest. This is why they are called the silent gardeners of the tropical forests [3]. Tapir calves have stripes and spots on their bodies that help them hide from predators, such as jaguars. The calves find their own food and water.

Figure 2

(A) Tapirs are herbivores. Their feces contain seeds from the fruits they eat and provides good fertilizers for the seeds to grow in. Since tapirs walk throughout the tropical forest in search of food, they disperse seeds as they go. (B) We collected samples of tapir fresh feces in both the dry and rainy seasons. In the lab, we analyzed samples to determine the tapirs' diets and to study the diversity of their fecal microbiomes.

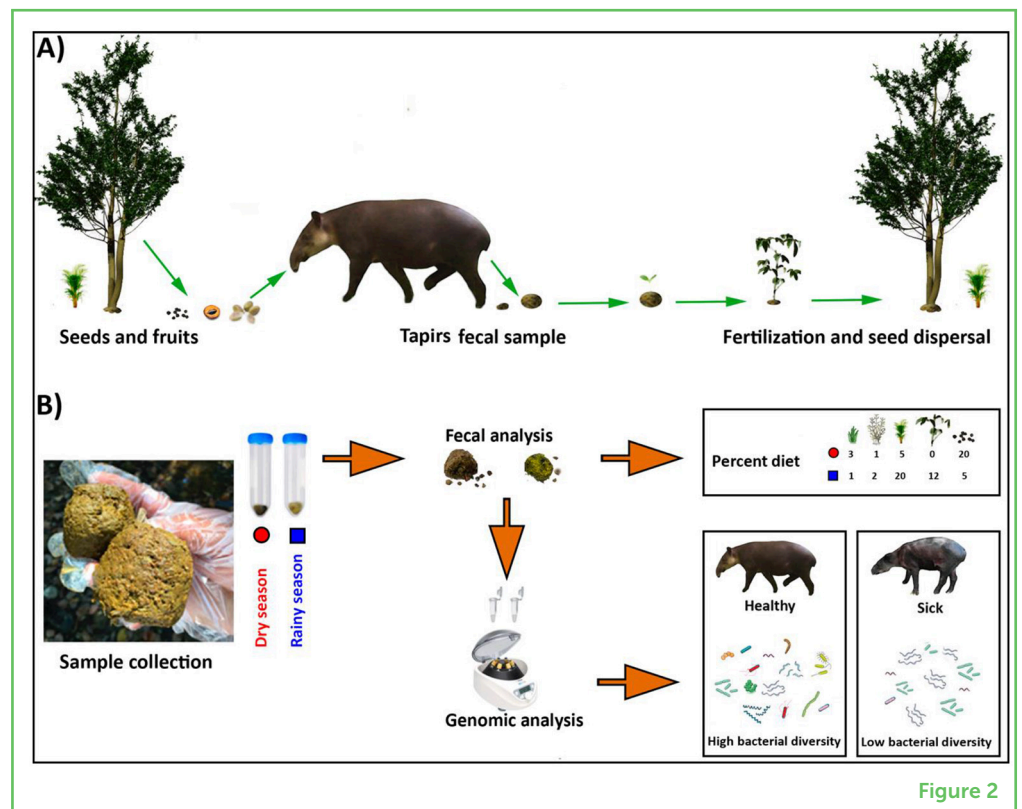


Figure 2

BACTERIA

Groups of tiny organisms, they are most diverse organisms on the planet.

MICROBES

Tiny organisms, most commonly bacteria or fungi, that can only be seen with a microscope.

HOST

An organism on or in which another organism (like a bacterium) lives.

TAPIR FECES: A STINKY INVESTIGATION?

When we hear the words “**bacteria**” or “**microbes**,” we generally think of something dirty or associated with a disease. However, the vast majority of microbes are harmless. In fact, microbes live in and on every single organism, and thousands of microbial communities actually help the animals they live in or on, which are called the **hosts**. Many recent studies have revealed the strong connection that exists between animals and their microbes. The types of microbes that live on and inside animals vary according to factors such as lifestyle, diet, age, gender, and host health. This tells us that a healthy community of microbes very likely means a healthy animal—which in turn tells us that the ecosystem the animal lives in is probably healthy, too [4].

FECAL MICROBIOME

All the various microorganisms that are part of an animal's feces.

DIVERSITY

Variety and number of species in a community.

GENOMIC ANALYSIS

Study (identification, measurement, or comparison) of all the genes of an organism (plants, animals, fungi, or microbes). Almost every cell in an organism's body has a complete copy of the genome.

DYSBIOSIS

Loss of microbial diversity that can affect the health of the animal.

In the wild, trained teams of scientists and veterinarians can trap animals briefly and release them after they have taken measurements and samples, which can tell them about the animals' health status. Working with tapirs presents a big problem because they are difficult animals to capture. Further, wild animals get really stressed when people trap them, and the shy tapir is no exception. Recently, a new approach has been developed that allows scientists to study animal health by analyzing the collection of microbes in their feces, called the **fecal microbiome**. We decided to study the **diversity** of the fecal microbiomes of Baird's tapirs from the Selva Maya, to learn about their health status during both the rainy and dry seasons.

THE SEARCH FOR BAIRD'S TAPIR FECES

Our team took long walks in the interior of the Selva Maya, in search of tapir latrines, as tapir toilets are commonly known. When we found a fresh fecal sample, we carefully stored it and brought it back to the laboratory. First, we used the fecal samples to study the diets of the tapirs, by analyzing the percentages of fruits, leaves, and stems present. Then, a part of the sample was used for **genomic analysis**, which tells us the numbers and types of microbes present in the tapir feces. During our year of sampling work, it was even possible to include samples from a sick tapir, which provided us with valuable information about the differences between fecal microbiomes from healthy and sick animals.

FECAL MICROBES: A CLUE TO TAPIRS' HEALTH

Our study used feces samples from tapirs as a safe and animal-friendly technique to study their health. We analyzed 47 samples, and the diversity of microbes found in these samples confirmed that tapirs have good health during both dry and rainy seasons, but the sick tapir had fewer bacteria in its feces (**Figure 2B**). Tapirs (and other animals) that are in poor health often have decreased microbial diversity in their fecal microbiomes; this is known as **dysbiosis**.

The names of bacteria are often a bit complicated to pronounce, even for scientists, but it is important to know their names and their roles within the host. The most abundant microbes living in tapir feces were Firmicutes, Bacteroidetes, Proteobacteria, and Kiritimatiellaeota, among others. Knowing which microbes are present helps us to understand what they do. Leaves, twigs, and fruits are not easy to digest, but with the help of microbes, they can be broken down into substances animals need to stay healthy, including proteins, vitamins, lipids, and sugars. When an animal feeds on the same food for a long time, such as when it lives in captivity and has a diet with no variety, the diversity in the fecal microbiome is lost, and that animal becomes more susceptible to certain diseases. We were happily surprised by

our results! Despite the major weather differences between the rainy and dry seasons in the Selva Maya, tapirs' fecal microbiomes did not change significantly (Figure 3). For this stability to occur, the environment must also be healthy, because our results showed that tapirs consumed similar amounts and types of food during both the dry season and the rainy season.

Figure 3

We learned that the tapirs of the Selva Maya around Calakmul are in good health because their microbiomes remained diverse through both the rainy and dry seasons. This tells us that the tropical forest is also healthy because it contains a great diversity of plants for tapirs to feed on throughout the year.

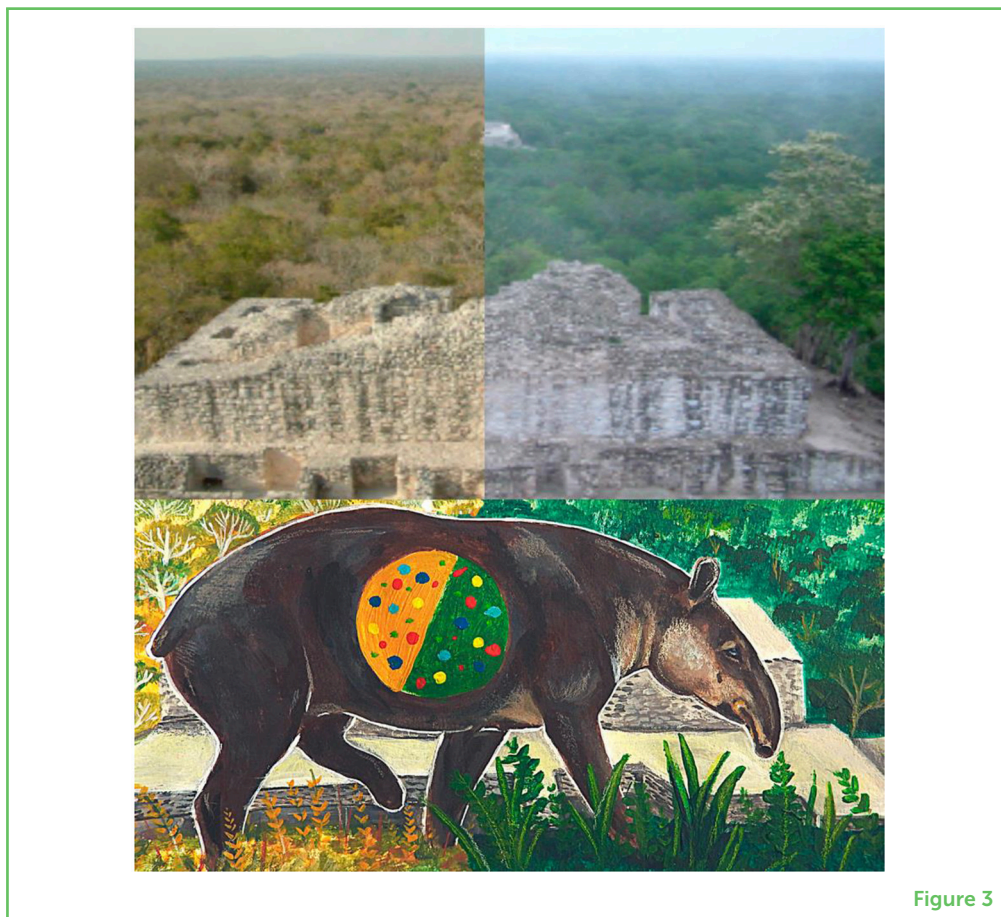


Figure 3

Our results suggest that the Selva Maya is a preserved tropical forest, with lots of water available and a great diversity of plants. The diversity of tapirs' fecal microbiomes helps maintain a healthy tropical forest because a healthy microbiome helps a tapir to digest many kinds of food and to then disperse a variety of seeds through its feces. In the future, we could study fecal samples to assess the health of other animals, too. Imagine what we could discover about other animals in the forests around Calakmul.

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REFERENCES

1. Pérez-Flores, J., Mardero, S., López-Cen, A., and Contreras-Moreno, F. M. 2021. Human-wildlife conflicts and drought in the greater Calakmul Region, Mexico: implications for tapir conservation. *Neotrop. Biol. Conserv.* 16:539. doi: 10.3897/neotropical.16.e71032
2. Naranjo, E. J., Amador-Alcalá, S. A., Falconi-Briones, F. A., and Reyna-Hurtado, R. A. 2015. Distribución, abundancia y amenazas a las poblaciones de tapir centroamericano (*Tapirus bairdii*) y pecarí de labios blancos (*Tayassu pecari*) en México. *Therya* 6:227–49. doi: 10.12933/therya-15-246
3. Paolucci, L. N., Pereira, R. L., Rattis, L., Silverio, D. V., Marques, N. C., Macedo, M. N., et al. 2019. Lowland tapirs facilitate seed dispersal in degraded Amazonian forests. *Biotropica* 51:245–52. doi: 10.1111/btp.12627
4. Zolti, A., Green, S. J., Sela, N., Hadar, Y., and Minz, D. 2020. The microbiome as a biosensor: functional profiles elucidate hidden stress in hosts. *Microbiome* 8:1–18. doi: 10.1186/s40168-020-00850-9

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YOUNG REVIEWERS



SHRESTHA, AGE: 11

I am very much interested in Science and Mathematics. I love to observe the natural world. I also love dancing and traveling. Painting is one of my favorite hobbies.



SMRUTIRANJAN, AGE: 14

I have a keen interest in reading science magazines and the biographies of scientists. Apart from my studies I love to play football.



Y7 LAURUS INTERNATIONAL SCHOOL OF SCIENCE, AGES: 10–11

We are the Laurus Year 7 class in Tokyo! We are interested in anything Science! Also we like to play Fortnite and chess.

AUTHORS



ALFREDO YANEZ-MONTALVO

I am currently a post-doctoral researcher at Tecnológico Nacional de México campus Instituto Tecnológico de la Zona Maya in Mexico. I am a microbial ecologist, passionate about understanding microbial communities and the changes in their diversity due to natural and human disturbances. I love poetry, sports, and sunsets. I believe that conserving nature, animals, and microbes is an important way of taking care of ourselves and our future. *yanez.af@gmail.com



OSIRIS GAONA

Osiris Gaona, Ph.D., is a biologist from the Faculty of Sciences at the National Autonomous University of Mexico. She has worked for over 23 years at the Ecology Institute in the Wildlife Conservation and Management Lab and in the Bacterial Ecology Lab, where she is currently working to understand the relationships between bacteria and their animal hosts. During her doctoral studies, she researched the role of bacteria in bats, through their various life stages. Osiris is also the founder and director of Soluciones Ambientales Itzeni AC, a non-governmental organization in Mexico focused on conservation and environmental education. She has been review editor for Microbial Symbioses for Frontiers in Microbiology since 2019. She also writes short fiction.



ARIT DE LEÓN-LORENZANA

Arit is an environmental engineer, microbial ecologist, enthusiast bioinformatician, and amateur ballroom dancer. Arit has worked with microbes from extreme environments and is passionate about mangrove conservation. She is also interested in identifying and assessing the impacts of climate change on mangroves and their microbes. Arit is currently working on the mangroves of the Yucatán Peninsula, Mexico and she is eager to keep learning and being mesmerized by microbes and all they do.

**BERNARDO ÁGUILA**

I am Ph.D. student and I am in love with science, including biology, ecology, and environmental sciences. I am very interested in studying bacteria, which have important roles in animals and ecosystems. I also like to culture and isolate bacteria to discover what are they doing in their natural environments, to unravel their intriguing secrets.

**LUISA I. FALCÓN**

I am a microbial ecologist at Universidad Nacional Autónoma de Mexico, fascinated by the diversity of bacteria and archaea in the environment. I love how microbes interact with each other to complement their metabolic capabilities, allowing for communities and ecosystems to exist.

**CARLA XIMENA NERI-BARRIOS**

Ximena Neri is an environmental scientist who has worked in the conservation of endangered species such as the Mexican wolf and bats. She is an emerging wildlife artist and has worked for Itzeni AC in the illustration of several wildlife guidebooks for children and non-academics. She never stops exploring how to protect nature and ensure a livable planet for future generations, and you can consistently find her championing social-led initiatives and making environmental science more accessible to everyone.

**JONATHAN PÉREZ-FLORES**

I am a post-doctoral fellow at El Colegio de la Frontera Sur in Mexico. I am a wildlife veterinarian and have been working on tapir conservation in Mexico for 15 years. My main interest is to understand the environmental and human-caused factors that affect tapirs' health. I love sports and working with communities to conserve our natural and cultural wealth. I hope that future generations will be able to appreciate and care for tapirs.