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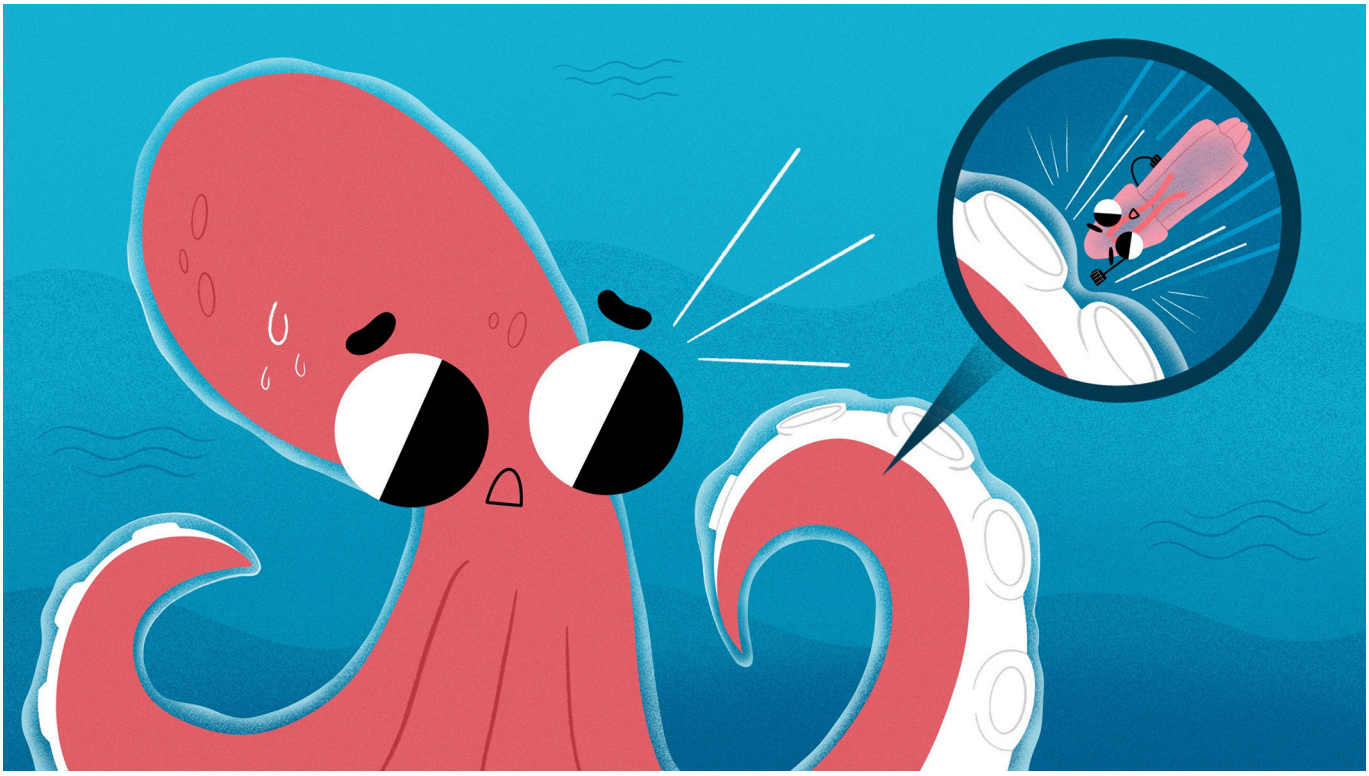
Published: 05 February 2025
doi: 10.3389/frym.2025.1426702



PARASITES: THE HIDDEN HITCHHIKERS OF CEPHALOPODS

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ANVITHA
AGE: 10

LORENZO
AGE: 13

RICCARDO
AGE: 12

Cephalopods (cuttlefish, squid, octopus, and nautilus) are remarkable marine creatures with extraordinary features like high intelligence, impressive camouflage abilities, blue blood, and three hearts. Yet, beneath the waves, they face a hidden threat from microscopic parasites. Parasites can wreak havoc on cephalopods, causing wounds that lead to infections, stomach aches that affect their appetite, and changes in their behavior. Luckily, cephalopods have a defense squad in their blood that battles these invaders. It is not all doom and gloom—parasites can help scientists uncover areas of the ocean where cephalopods travel and whether these areas are facing threats such as pollution and climate change. Scientists can examine

the relationship between cephalopods and their parasites, helping cephalopods all over the world stay as healthy as possible. Dive into this thrilling underwater world, as we embark on an adventure to solve the mysteries of cephalopods and their secret hitchhikers.

KNOWING CEPHALOPODS

Currently, there are about 1,000 known species of cephalopods found in oceans all over the world, from the steamy tropics to the freezing waters of the Arctic and the Antarctic to the deep abyss. Cephalopods that exist today include nautiluses, octopuses, cuttlefishes, and squids. In this article, we will focus on coleoid cephalopods, popularly known as octopuses, squids, and cuttlefishes (Figure 1). Cephalopods are not ordinary sea creatures; they are rockstars among all other mollusks, like mussels, clams, and snails! Cephalopods have their head connected to their muscular "foot" (a characteristic of the Mollusca group) that has evolved into appendages known as arms and tentacles. Cephalopods (octopuses, squids, and cuttlefishes) have eight arms lined with suckers to sense their environment. Their arms are involved in many different behaviors. Squids and cuttlefishes have a pair of feeding tentacles that only have suckers at the very end of the appendage. Cephalopods also have "smart" skin that changes color and texture in <1 s. Similar to clams and snails, coleoid cephalopods have copper-based blood, called hemolymph, with a blue color, but their blood circulates in a closed circulatory system oxygenated by two gill hearts and delivered throughout the body by a third main heart!

Even more astonishing, cephalopod intelligence rivals that of vertebrates. They have highly complex nervous systems that process huge amounts of information from their environments, allowing for quick decision making, communication, and problem solving. This is important for a squishy, shell-less animal that is on the menu for many marine predators. They have also been known to recognize individuals. In short, cephalopods' incredible features have fascinated scientists for centuries, inspiring us to learn more about their lifestyles.

CEPHALOPODS AND OCEAN HEALTH

In ocean ecosystems, cephalopods help to maintain nature's balance because they function as both predators and prey. They have a diverse diet including worms, clams, snails, crabs, and fishes [1]. They are also a favorite snack for predators such as sharks, seals, whales, dolphins, seabirds, and eels. Furthermore, cephalopods alert scientists about the ocean's health because they are some of the first species to notice when the oceans are in trouble, such as rising seawater

Figure 1

Examples of the diversity of coleoid cephalopods: **(A)** day octopus, **(B)** blanket octopus, **(C)** southern blue-ringed octopus, **(D)** flamboyant cuttlefish, **(E)** giant Australian cuttlefish, **(F)** common cuttlefish, **(G)** bigfin reef squid, **(H)** bobtail squid, **(I)** stubby squid.

Figure 1

temperatures or increased pollution. As ocean guardians, cephalopods signal potential problems in the underwater world.

Like us, cephalopods can get sick, and **parasites** are a major health threat. Cephalopod parasites can cause skin sores, loss of appetite, and even changes in their behavior [2]. Parasites can disrupt entire populations of cephalopods, which can affect the entire ecosystem. It is critical to keep cephalopods healthy because of their important roles in marine food webs, source of food for humans, relevance for scientific studies and education (in zoos and aquariums), as well as our economy. They are one of the top animals SCUBA divers and ocean goers want to see. Cephalopods even serve as the inspiration for soft robots!

PARASITES

An organism that attaches to a host for transport, food or shelter, often harming the host.

HOW DO PARASITES AFFECT CEPHALOPODS?

Parasites are tiny, sneaky creatures that love to live on or inside another animal, which is called the **host**. The host acts as a house and a source of food. This is a bit like having a houseguest who never leaves! Parasites can cause cephalopods a lot of trouble—they can make them feel tired, swim strangely, lose their appetite, or change their behavior. They might even get hurt, bleed, or have wounds on their skin that can become infected. If the water cephalopods live in is polluted or if the water temperature drastically changes (as can happen

HOST

Organism that provides food, shelter, or a place to live for other organism, sometimes while being harmed in the process.

with climate change), the situation can be even worse. Under these changed conditions, parasites have the upper hand in this underwater battle, making it harder for cephalopods to stay healthy.

WHO ARE CEPHALOPODS' PARASITE HITCHHIKERS?

Not all cephalopod parasites cause severe diseases—some can live in a cephalopod's body without apparent harm. By 2018, scientists had identified about 230 parasites affecting cephalopods. These parasites, which we will call "cephalopod hitchhikers", can be classified into three main groups: **helminths**, **copepods**, and **protozoans**.

Helminths are worms with peculiar names, such as digeneans, cestodes, and nematodes. They are generally found in the digestive tracts of cephalopods (Figures 2A–F). Helminth infections are usually rare, but some can damage cephalopods' tissues. In a rare case, parasites can live in an octopus's mouth area (Figure 3) [3]. Nematodes, also called roundworms, infect cephalopods' digestive systems and muscles, causing sores and other negative effects. Alarmingly, some nematodes can be transmitted to humans if they eat raw or undercooked cephalopods, leading to painful gastrointestinal issues. It is vital to cook octopus and other seafood properly to prevent potential nematode infections.

Next up are copepods, often called ocean lice. While many copepods play crucial roles in the ocean ecosystem, some species are parasitic and can damage host organisms (Figure 2G) [4]. Parasitic copepods can be found in the gills and mantle damaging gill tissues and causing irritation in the skin, and small scratches that can hurt or get infected by viruses or bacteria. Also, these parasites can cause breathing problems and make it harder for octopuses to breathe properly.

The third group of cephalopod parasites includes protozoans. Protozoans, tiny single-celled organisms, are the most frequent hitchhikers, particularly a type called marosporidians (Figure 2H). Imagine invaders in your kitchen, breaking things, making a mess, and changing the environment so nothing functions properly. That is what marosporidians do in the stomachs of octopuses. They cause stomach issues, block nutrient absorption, and weaken the animal's overall health, affecting its growth and ability to defend against other diseases (Figure 3). Although these protozoans do not kill cephalopods directly, they open the door to more problems, leaving cephalopods vulnerable to bacterial and viral infections [4].

HOW DO CEPHALOPODS DEFEND THEMSELVES AGAINST PARASITES?

An animal's **immune system** is key for protection against infections and diseases. Cephalopods do not have the type of immune system that

HELMINTHS

Parasitic worms, including flat, ribbon-like cestodes (tapeworms) and shorter, broader trematodes (flukes). These worms infect various organs in animal hosts.

COPEPODS

Tiny crustaceans that live in the ocean, which can be either parasitic or free living.

PROTOZOANS

Microscopic organisms of single cell that can live in water, soil, or inside other organisms.

IMMUNE SYSTEM

A complex network of organs, cells, and proteins that work together to protect the body from infections and diseases.

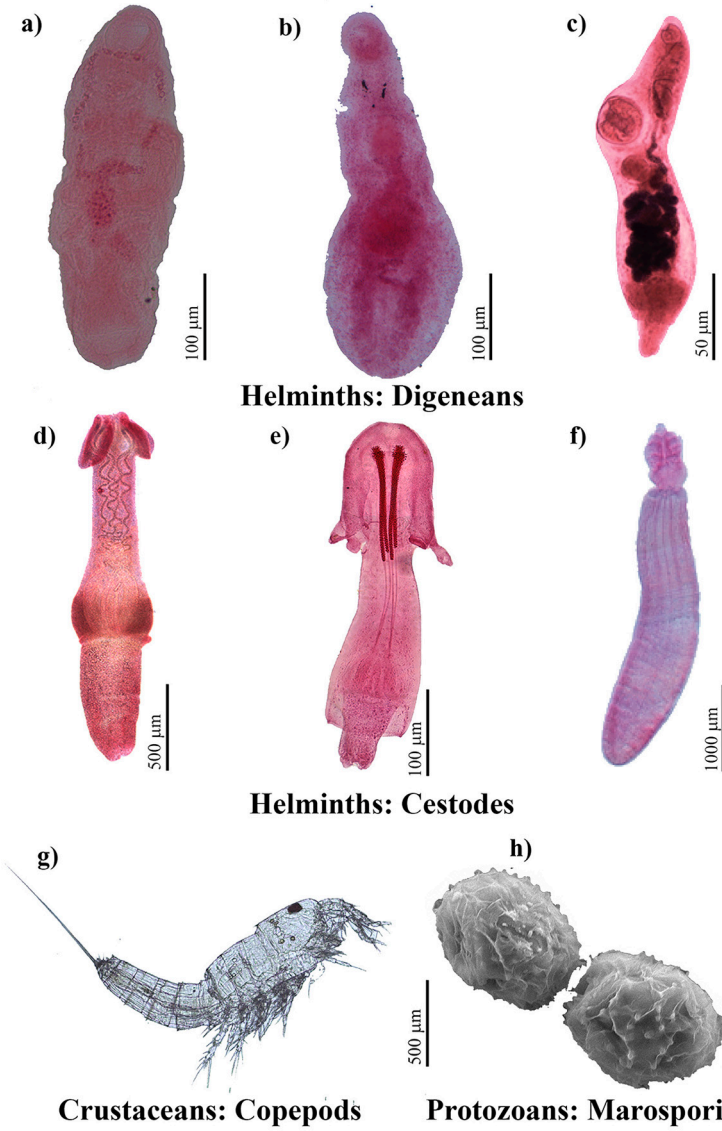


Figure 2

Parasites found in octopuses can make it difficult for the animals to absorb nutrients properly, but these parasites do not harm humans. **(A–F)** Six types of helminths classified into digeneans and cestodes based on their physical appearance. **(G)** Copepods, which are a type of crustacean, also known as ocean lice. **(H)** Marosporidians, which are a type of protozoans. **(A-C, G)** Part of the Collection of Aquatic Parasitology Laboratory at Cinvestav Mérida.

remembers germs, like humans do, which means they can get sick from the same disease repeatedly. This also means vaccines would not work on them. However, the immune system of cephalopods has effective external barriers and an internal army. External barriers, such as mucus and skin, help prevent parasites from entering the body [5]. If external barriers are breached, cephalopods have special cells and proteins that join forces to destroy the invader. In terms of protective cells, cephalopod blood contains proteins (like hemocyanin-the respiratory pigment that makes the blood blue!), and cells called **hemocytes**, which are important for wound repair and immune responses. Wounds cause an increase in circulating hemocytes, which are like the soldiers in cellular defense—they charge the "battlefield" and surround the invader. If the invader escapes the hemocytes, other tissues come to the rescue and destroy the invader.

HEMOCYTES

Cells found in the blood of invertebrates that help fight off pathogens, combat infections, and keep the organisms healthy.

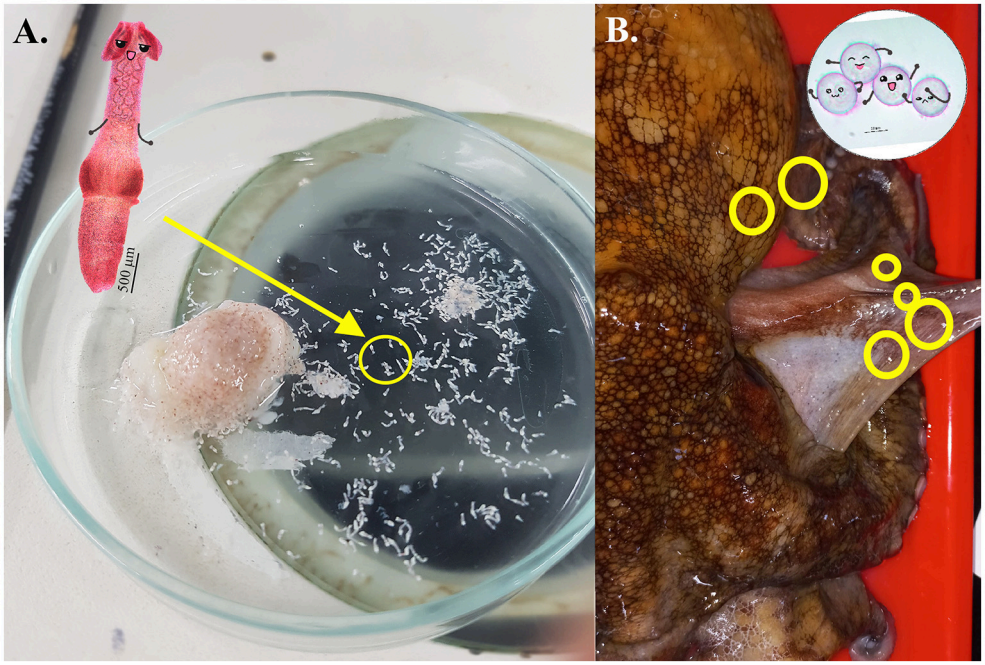


Figure 3

Figure 3

(A) A helminth parasite called *Prochristianella* is a worm that lives in the mouths of certain octopuses. The mouth tissue can have hundreds or even thousands of these parasites, but they do not harm humans that eat octopus. Yellow arrow indicates individual tapeworms and a single tapeworm to the left. **(B)** A helminth called *Aggregata polibraxiona* (small white spheres top left) usually lives in the digestive tract of most octopuses. When there is a heavy infection, it can show up as spots on the octopus's skin (yellow circles).

AGGLUTININS

Proteins found in the blood that help cells or particles stick together as part of the immune response.

Cephalopods also have substances in the fluid hemolymph called **agglutinins**, which are always ready to tackle parasites [5].

PARASITES: HITCHHIKERS OR MARINE DETECTIVES?

Now you know that cephalopods, like many other animals, can be negatively affected by parasites, and this can cause problems for ocean ecosystems. But surprisingly, these parasites can also play an essential role, acting as "detectives" in the sea.

Parasites act like secret tags that help scientists track the movements of cephalopods in the ocean. Imagine each of these parasites as a sticker that cephalopods collect when they explore different places in the sea. These stickers only stick when cephalopods visit areas where these parasites reside. So, if scientists find a squid or octopus with these stickers outside of those areas, they can infer that the cephalopods have previously visited those locations. These parasite stickers also provide scientists with clues about the timing of these visits and the environmental conditions of the habitats where they flourish. Thus, the more types of parasite stickers scientists find, the more details they can learn about the cephalopods' journey and movements.

Finally, even though parasites might seem unpleasant at first glance, they can also play a crucial role helping scientists understand the threats ocean animals face, like climate change and pollution, and how we can help protect the oceans from these threats. Because

parasites depend on the food web to complete their life cycles, studying which parasites are present in ocean animals can help reveal information about the animals' diets, movements, and even changes in the environment, like pollution or climate shifts.

In summary, parasites of cephalopods are mysterious underwater creatures that can harm their cephalopod hosts while helping scientists unravel the hidden secrets of the oceans. Scientists are continuing to learn about cephalopods and their tiny tag-along parasites to protect octopuses, squids, and cuttlefishes and keep marine environments healthy.

ACKNOWLEDGMENTS

This work was supported by the National Council of Humanities, Science and Technology [755501, 2019] and the Research Fund of the Cinvestav, Merida Unit, as well as autogenerated external services resources by MLA-M, Cinvestav-Merida. The authors thank the underwater photographers that contributed photos to this manuscript: Lawrence Scheele (giant Australian cuttlefish), Yury Ivanov (bigfin reef squid and bobtail squid), Sam Glenn (blue-ringed octopus), Damsea (common cuttlefish), Oksana Golubeva (flamboyant cuttlefish), Magnus Lundgren (blanket octopus), Brandon Hannan (day octopus), EV Nautilus (stubby squid).

REFERENCES

1. Hanlon, R., Vecchione, M., and Allcock, L. 2018. *Octopus, Squid, and Cuttlefish: A Visual, Scientific Guide to the Oceans' Most Advanced Invertebrates*. Chicago, IL: University of Chicago Press. doi: 10.7208/chicago/9780226459738.001.0001
2. Fiorito, G., Affuso, A., Basil, J., Cole, A., de Girolamo, P., D'Angelo, L., et al. 2015. Guidelines for the care and welfare of cephalopods in research–a consensus based on an initiative by CephRes, FELASA and the Boyd Group. *Lab. Anim.* 49(2 Suppl):1–90. doi: 10.1177/0023677215580006
3. Marmolejo-Guzmán, L. Y. G., Hernández-Mena, D. I. G., Castellanos-Martínez, S., and Aguirre-Macedo, M. L. 2022. Linking phenotypic to genotypic metacestodes from *Octopus maya* of the Yucatan Peninsula. *Int. J. Parasitol. Parasites Wildl.* 19:44–55. doi: 10.1016/j.ijppaw.2022.08.001
4. Hochberg, F. G. 1990. "Diseases of mollusca: cephalopoda. Diseases caused by protistans and metazoans", in *Handbook of Pathogens and Diseases in Cephalopods*, ed. O. Kinne (Helgoland: Biologische Anstalt Helgoland), 47–227.
5. Castellanos-Martínez, S., and Gestal, C. 2013. Pathogens and immune response of cephalopods. *J. Exp. Mar. Biol. Ecol*. 447:14–22. doi: 10.1016/j.jembe.2013.02.007

SUBMITTED: 02 May 2024; **ACCEPTED:** 15 January 2025;
PUBLISHED ONLINE: 05 February 2025.

EDITOR: Laura Lorenzoni, National Aeronautics and Space Administration (NASA), United States

SCIENCE MENTORS: Amaresh K. Ranjan and Martina Gaglioti

CITATION: Marmolejo-Guzmán LYG, Castellanos-Martínez S, Bennice CO, Carlyle WK IV and Aguirre-Macedo ML (2025) Parasites: The Hidden Hitchhikers of Cephalopods. Front. Young Minds 13:1426702. doi: 10.3389/frym.2025.1426702

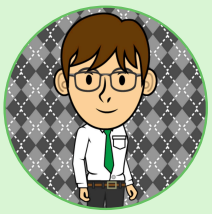
CONFLICT OF INTEREST: WKC was employed by OctoNation® 501(c)(3) Education Nonprofit Organization.

The remaining 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.

YOUNG REVIEWERS

ANVITHA, AGE: 10

My name is Anvitha Ranjan and I am a 10-year-old 5th grader. I love reading. I can sit with a book for long hours. I love to make my own story presentations in powerpoint too. The other best thing I love to do is ART!! I love painting and drawing, chess and am part of the school music band team. Overall, I am an amiable and kind kid—that is my teachers and my parents say 😊.



LORENZO, AGE: 13

Hey there! I am a curious Italian boy interested in science and politics. I love learning and staying in nature, and I hope to be a good Young Reviewer 😊!

RICCARDO, AGE: 12

Hi! My name is Riccardo and I love art, nature and animals. I am a very cheerful person, who loves playing outdoor with friends. I play volleyball, I go canoeing; and I like playing football with my friends.

AUTHORS

LINDA YACSIRI GUADALUPE MARMOLEJO-GUZMÁN

I am a biotechnologist by profession, but my fascination with water bodies has been with me since childhood. This passion led me to pursue a Ph.D. in marine sciences, with a focus on marine invertebrate diseases, particularly those affecting cephalopods like octopuses. I have dedicated my research to understanding the intricate world of marine life and the diseases that impact it. As a scientist, I find the complexity of cephalopods intriguing, and my work aims to uncover the mysteries of their biology and health.

SHEILA CASTELLANOS-MARTÍNEZ

I am a marine biologist from the Autonomous University of Baja California Sur (UABCS). My academic journey continued with a master's degree in marine resource management at CICIMAR-IPN. I pursued doctoral studies at the University of Vigo, Spain, followed by a postdoctoral fellowship at Cinvestav, Merida. My research has focused on octopus reproduction, tissue study, immune response and parasite classification. Now I am a researcher at IIO-UABC, investigating octopus parasites and bivalve immune response and the damage in their tissues.

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Dr. Chelsea Bennice is a marine biologist located in south Florida. She enjoys fieldwork and spending time underwater SCUBA diving and observing octopus behavior. Chelsea is currently a research fellow at Florida Atlantic University Marine Science Lab, where she studies multiple octo-topics including behavior, microbiology, and genetics. She is passionate about communicating her science to audiences of all ages and leads a science education and outreach program, Glenn W. and Cornelia T. Bailey Marine SEA Scholars. The community knows Chelsea as Octo-Girl.

WARREN K. CARLYLE IV

Warren K. Carlyle IV is an author of National Geographic's "Secrets of the Octopus" and the founder of OctoNation, a nonprofit organization that is home to more than a million members working to inspire wonder of the ocean by educating about octopuses. Warren describes himself as the octopus's PR agent—working with journalists, underwater photographers, and researchers to get the word out about these incredible underwater creatures.

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I am a senior professor at Cinvestav Merida, Mexico. My research centers on the study of the ecosystem of aquatic and marine parasites and the impact in their hosts. I also study bacteria that live in the ocean and how they affect the environment. My work dives into factors influencing parasite transmission and the long-term dynamics of the parasite population. *leopoldina.aguirre@cinvestav.mx