Marine Animal Bioluminescence

A host of simple and complex marine animals light up their world and ours with bioluminescence.

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Have you ever observed mysterious flashes of light in your reef tank late at night? Have you ever gone for a romantic night sail and watched the small twinkles of light as the bow of the sailboat cuts through the water? Or gone diving at night and turned off your dive light? If you have, you have observed bioluminescence. If you haven't, you should look for nature's fireworks show.

At one time, bioluminescence was explained by wild stories of sea monsters and other mysteries of the deep. But scientists now know that bioluminescence is the result of the oxidation of the substrate luciferin catalyzed by the enzyme luciferase. Light is generated as a product of this reaction. This light is termed bioluminescence when this reaction occurs within a living organism.

Bioluminescence is referred to as "cold light" because nearly 98 percent of the energy from the reaction is efficiently used to produce visible light, which leaves very little energy released as heat.

Two Ways to Glow
Bioluminescence can be divided into two kinds: intrinsic and bacterial luminescence.

Intrinsic luminescence occurs when the organism itself produces its own luciferin and luciferase. This type of bioluminescence can be distributed widely over an organism's body.

Bacterial luminescence is when an organism that can't produce light itself has a mutualistic relationship with bacteria that can. These organisms host the bacteria in a specific location, such as their gut. The bioluminescent bacteria are always producing light. Unlike intrinsic luminescence, in order for an organism to have bacterial luminescence it must first acquire the bacteria through inoculation and culture a population of it. The small squid in the genus Euprymna develop a specific organ to attract an "infection" of the right kind of bacteria.

Why Glow?
Bioluminescence is very common in marine life and occurs in at least 14 different phyla. Organisms use bioluminescence to accomplish various tasks. It can be used for attracting mates, counter-shading, to startle predators, communication and prey detection/attraction. Many organisms that are bioluminescent use this ability for more than just one thing.

The first recognized functions of bioluminescence were found in fireflies. They use the extra-cellular bioluminescence in their abdomen to attract mates and lure prey. Scientists have found that the rhythm and frequency of fireflies' bioluminescent flashes are the secret behind mate attraction. It has also been found that some female fireflies will use their bioluminescence to attract male fireflies of other species and eat them — talk about false advertising!

Bermuda Glow Worms
The Bermuda glow worm (Odontosyllis enopla) also uses bioluminescence to attract mates. Female glow worms release a bioluminescent slime that attracts males. When the males arrive the females release their eggs, and the males release sperm to fertilize the eggs. Male glow worms flash bioluminescence sporadically to signal their approach to the females.

Other Bioluminaries
Krill and some squid use bioluminescence to counter-shade their bodies when in the water column. Most animals are counter-shaded, darker on top and lighter underneath. Animals that live in three-dimensional spaces, such as water or air, must have even more pressure on them to hide from predators below, beside and above them. But even the lightest white underside of an animal still blocks out light and causes a silhouette when viewed from below.

The deep sea squid (Histoteuthis heteropsis) is covered with bioluminescent photophores. These create counter-shading that masks the silhouette of the squid by replacing the light that the body of the squid blocks out. The photophores on the ventral side (underside) luminesce to make the squid's skin appear the same brightness as the surrounding water. This

allows the squid to be virtually invisible when viewed from below. Counter-shading can also be used when hunting. Using bioluminescence to mask a silhouette allows squid to remain virtually undetected while stalking prey.

Shallow-water nocturnal “squid” in the genus Euprymna also use bioluminescence for counter-shading. These small cephalopods are difficult to obtain but can be kept in a 10-gallon or larger aquarium. They prefer live food like shrimps and small crabs.

Organisms such as the deep sea jellyfish and Bermuda glow worms use bioluminescence to startle predators. When glow worms are agitated they bioluminesce to catch there predator off guard and frighten them away with there blue-green light display.

When agitated the deep sea coronate jellyfish (Atolla vanhoeffeni) produce a bioluminescent display to either blind or startle their predators long enough to escape.

Zooplankton have been found to bioluminesce after being eaten. This illuminates their predator from within, which in turn makes it vulnerable to predation.

Black dragonfish (Aristostomias) use bioluminescence in the form of a “secret” channel to communicate. Most bioluminescence is a characteristic blue-green color, which is the wavelength of visible light that travels the farthest in seawater. Red light is one of the first wavelengths attenuated by seawater; most deep-sea fish are not sensitive to red light. However, the dragonfish is one marine organism that produces red light. They absorb short wavelengths of blue-green light and use filters and florescence to re-emit a longer wavelength of red light. Thus, dragonfish are able to communicate using the red bioluminescence because they are able to see the red light, whereas other organisms living at the same depth are not.

The deep sea anglerfish is a classic example of bioluminescence being used for prey attraction. The bioluminescence is localized at the end of the lure that hangs over the mouth of the fish. As the prey draws nearer to the light it is lured into the danger zone, and the anglerfish eats it with its large mouth.

There are many species of lanternfish and flashlight fish and some of them occur in shallow water. One example is Photoblepharon palpebratus, which lives at depths of 161/2 to 165 feet in the warm waters of the Pacific Ocean, Indian Ocean and Red Sea. These bioluminescent fish are often on display at leading public aquariums, such as the Shedd Aquarium in Chicago. They require special conditions in captivity, such as dim lighting conditions, caves or overhangs and a large enough aquarium to comfortably house a school of them.

Small Dynamos
The most commonly observed bioluminescence, both on the reef and in a reef tank, is not produced by the larger, more familiar animals mentioned above, but by very small organisms. The luminescent trail behind boats from large aircraft carriers to small kayaks is most probably caused by billions of plankton, such as copepods, radiolarians and especially dinoflagellates.

Seeing is Believing
There are a few ways in which one can observe the fireworks in the night created by bioluminescence. The first of which is to take up a nocturnal water activity, whether it is diving, snorkeling, swimming or boating. An easy way to observe bioluminescence is to splash seawater at night. The zooplankton will bioluminesce from the agitation of the surface water. In some places bioluminescence is so thick that boats leave a light trail behind them (see sidebar).

Bioluminescence can also be observed by watching specific animals that have bioluminescent behavior, such as Bermuda glow worms spawning. From two to three days after the full moon at 56 minutes after sunset the worms swim to the surface and begin their mating ritual.

Bioluminescence can also be observed in your aquarium in the comfort of your home. Reef tanks with new live rock are especially likely to have bioluminescent organisms on them. Many of these organisms will be very small just like the plankton that boats and divers churn up.

If you wait with a flashlight to try and identify the organisms that produce the light, you will most likely not be able to find them due to their small size, if they are very small. The best method to observe bioluminescence in your home reef tank is to wait at least an hour past sunset, turn off all the lights in the house, get your eyes adapted to the dark and peer into your tank; you may discover that you have your own personal light show every night!

Vacations to Glow Over

Bermuda's Bioluminescence
The island of Bermuda is known for its crystal-clear waters and pink sandy beaches. One of the undeveloped biological jewels of Bermuda is the stunning bioluminescent display that appears in the water of select bays the second and third day after a full moon. In the summer and early fall, scientists, locals and visitors alike gather on Ferry Reach Bridge in Whalebone Bay Park to witness the bioluminescent spawning of the Bermuda glow worms that begins precisely 56 minutes after sunset. You can also enjoy this underwater light show through guided boat tours by the Bermuda Underwater Exploration Institute.

Airlines such as USA 3000, Continental and Jet Blue offer competitive fares. Keep in mind when planning a trip to Bermuda that everything on the island is imported and prices tend to be two or three times those in the United States. However, the American dollar is accepted on par with Bermudian currency throughout the island, so there is no need to exchange your money before or during a trip.

Puerto Rico's Bioluminescence
Vieques, Puerto Rico, is home to Bioluminescent Bay. Bioluminescent Bay is the brightest bioluminescing bay in the world. This can be attributed to the 720,000 dinoflagellates that are found in every gallon of the bay's water. Ecotours and kayaking trips are offered through BioBay and other outfitters for a modest fee. While swimming or kayaking on this marvelous bay, be sure to take the time to look behind you and observe the bioluminescent trail that marks where you've just been. A trip to Vieques needs to be timed to lunar cycles, as the best days for observing bioluminescence are following the full moon when the sky is especially dark. There is not as much of a time-of-the-night constraint as there is with the worm spawning.

Reasonable fares to Vieques are offered through Cape Air and US Airways. If you are looking for a place to stay in Puerto Rico and not break the bank, we recommend camping. Camping is allowed in areas such as Sun Bay with a free permit. When traveling to Puerto Rico, don't worry about converting your money as the official currency is the U.S. dollar.

Watching the bioluminescence in Bermuda you can expect to see numerous inch-long distinct bluish-green swirls that appear on the surface of the water, followed by short pulses of the same color moving quickly toward these illuminated circles. This is because the female worms are using a bioluminescent slime to attract males to mate. In Vieques, after the sun goes down and your eyes adjust to the dark, you will realize that the water that you're kayaking on or swimming in is glowing with this vibrant bluish-green color. This is because many really small organisms contribute to the bioluminescent effect when disturbed. No matter which of these locations you choose to visit you're sure to experience a natural wonder unlike any other.

Don't feel disappointed if you are not able to reach one of these two destinations. There are still ways for you to observe bioluminescence and not have to travel far from your home. If you are in saltwater at night and you turn off your dive light, wave your hands around in the water and look for the bioluminescence produced by the plankton.

Author Bios
James Wood, Ph.D., is a marine biologist and faculty member at the Bermuda Institute of Ocean Sciences (BIOS). He teaches marine invertebrate zoology and other courses and conducts research on marine life, especially cephalopods. He has kept aquaria all his life and published his first FAMA article in 1991.

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