Desires of microscopic shrimp illuminate evolutionary theory

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A nighttime light display on a coral reef in the Florida Keys sparked a study that provides novel insight into the factors that drive the evolution of new species.

University of California, Santa Barbara, PhD student Emily Ellis and her colleagues in the laboratory of Dr. Todd Oakley are interested in the evolution of complex traits, particularly those related to vision and visual signaling. One such trait brought them on a sampling trip to the Keys: bioluminescence. In particular, the bioluminescence produced by a little-studied microscopic crustacean, the ostracod.

"We were on this new hunt to find this bioluminescence that we had heard so much about from collaborators, but never seen with our own eyes," Ellis remembers, "and all of a sudden the whole reef just lit up, there was just light everywhere. It was just like a concert."

She knew at that moment that she had stumbled upon the subject of her PhD research. "I've always been interested in speciation and how species form, but this is a whole different mechanism, that light can influence speciation," Ellis says. "I thought it was just fabulous."

An underlying question for evolutionary biologists is, why are there so many species? And particularly, why do some lineages have greater species diversity than others? Ellis points out a clear example: the incredible number of species of insects, versus the relatively small number of species of mammals. One popular theory to explain this difference is that lineages that have been around longer have more time to diverge. And yet, there are many cases where two groups have been around for equal lengths of time, but one group has more overall species.

"So we want to know is, what is it about one group that gives them a unique advantage to invade new niches?" asks Ellis.

Hence the idea to study specific traits, and how they arise and are selected. Evolutionary theory holds that traits that play a role in mating and reproductive success, undergoing sexual selection, drive species diversification—a concept often likened to an "arms race." In other words, if something happens to males that creates diversification, the females have to follow.

"Otherwise they wouldn't be able to recognize each other," Ellis explains.

But this idea remains a hypothesis that scientists are still testing, and a source of active debate within the field of evolutionary biology. And that's where bioluminescent ostracods come in.

These millimeter-sized, shrimp-like animals can be found all across the globe, in both marine and freshwater environments. They've even been found living in leaf litter in tropical rainforests. There are an estimated 20,000 species of ostracods, but only about 200 that produce bioluminescence.

There are two separate instances of bioluminescence in ostracods. One type is used as a defense mechanism, in which threatened ostracods emit a cloud of bioluminescence to distract predators. Interestingly, these animals don't have eyes, so it is unlikely that they use their bioluminescence to communicate among themselves.

The second instance is what Ellis and her colleagues traveled to the Keys to see: bioluminescence used as a mating display. There are around 60 species of ostracods with this type of bioluminescence, but they are only found in the Caribbean.

By comparing the numbers of species of ostracods that have evolved bioluminescence for either mating displays or defensive purposes to related species without bioluminescence, Ellis realized she could gain very useful evidence to support or refute the theory of sexual selection as a driver of species diversification. With this technique, known as sister-clade comparision, evolutionary scientists look at groups of species that have common ancestry and age, known as sister clades, comparing the number of species with a particular behavior to the number without.

"What's really great about our study is it's actually simple," Ellis says. "We're attempting to answer a really complex problem with simple methods."

As it turns out, there is only one evolutionary origin for mating-display bioluminescence in ostracods, which means there is not enough statistical strength to investigate the sexual selection question with just ostracods. So Ellis decided to broaden her study to include all bioluminescent marine animals that have related species that use the trait for both defensive purposes and mating displays. She limited her investigation to animals whose phylogenies (or historical lineages) have already been published. She found 8 useful phylogenies for bioluminescent mating displays and 12 for defensive bioluminescence, across a broad group of marine animals including octopuses, crustaceans (including the ostracods), fish, and a worm.

The results provide clear support for the sexual selection theory. "We definitely documented a strong pattern of increased diversification with the origin of bioluminescent courtship displays, and there was absolutely no correlation with bioluminescence used for defense," Ellis says.

She is quick to point out that for now her research is just documenting a pattern that provides better insight into the process of species diversification, not implying actual causation.

However, this is just the tip of the iceberg of what it might be possible to learn about evolution from the ostracod. Studies have shown that each species that uses bioluminescence for mating displays has a unique signaling pattern. Ellis looks forward to shedding more light on these fascinating creatures with her ongoing research.

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