Echolocation with Light: A New Form of Active Sensing in Fish?

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Questions & Answers from the Presentation

What about chemiluminescent fish? Could they be doing something similar in the dark?

Yes, most certainly, particularly in those species where a specialized light organ is situated immediately adjacent to the pupil. In fact, the idea was first suggested for flashlight fish by Howland, H. C., et al. (1992). "Detection of eyeshine by flashlight fishes of the family anomalopidae." Vision Research 32(4): 765-769. Because of this, we talk about "**daytime**" active photolocation. Chemiluminescence seems to be far too weak to be of use during the day in the photic zone.

Do ocular sparks work during overcast sky?

They could. Some fish species seem to be focusing all of Snell's window, the circular window through which light from the above-water hemisphere is refracted and sent down into the water column. This cone with an angle of ca. 96° from the perspective of an observer looking upward. Because Snell's window is not a single point source such as the sun, it results in a broad light patch rather than a small, "sparkling" focal point.

Do these light effects play a role in intraspecific communication?

They might – but we have not yet investigated this, because we assume other forms of communication are more important. Intra-specific interactions in our triplefin species take place in shaded parts of the substrate and are mostly characterized by fin and tail movements (Wirtz, P. (1978). "The Behaviour of the Mediterranean *Tripterygion* Species" (Pisces, Blennioidei). Zeitschrift für Tierpsychologie 48(2): 142-174. Ocular sparks are often seen in single individuals while moving around on the substrate.

Is active photolocation specific for fish?

Active photolocation is relatively weak and therefore will only function well over very short distances (centimeters rather than meters). Due to the fact that in aquatic environments interaction distances between organisms are short, aquatic organisms such as fish may be most likely to use active photolocation. We have not looked in the possibility that active photolocation exists in terrestrial systems, but there have been suggestions that it may work in short-distance prey-searching in e.g. some passerine birds with white cheeks.

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Doesn't it work in the opposite way? The predator might detect its prey by seeing the ocular reflection.

Sure, but this could help a small prey fish rather than representing an elevated risk. Given that benthic predators are typically highly cryptic sit-and-wait species, attracting its attention implies it turns its gaze to the source. Since retroreflective eyeshine is much stronger when looking and focusing the light source, this may improve the ability of small fish that use active photolocation to detect a previously overlooked.

The reflected spark should consist of polarized light – is there a selectively higher sensitivity of the triplefin prey fish?

Although this is an exciting possibility, but a (quick) look at ocular sparks in the lab using polarization filters suggested that they do not reflect polarized light. Moreover, even if it would, this mechanism would require (1) that the polarization is maintained through the whole pathway from triplefin to the scorpionfish and back, (2) still be strong enough to be visible as a component of the mixed signal coming from a scorpionfish's eyeshine and (3) triplefins to be able perceive polarized light. This is still insufficient to reject the idea altogether, but we currently set other priorities.

Why do scorpionfish have bright pupils?

See Santon, M., et al. (2018). "Daytime eyeshine contributes to pupil camouflage in a cryptobenthic marine fish." Scientific Reports 8(1): 7368.

How close can triplefins get to a real scorpionfish before they are eaten?

Own observations indicate that triplefins can get as close as 7 cm and still have a good chance to escape an attack because of their ability to "explosively" shoot away.

How is it possible that researchers have overlooked the possibility of active sensing using light?

Humans are spoiled by artificial light and therefore have become blind to the subtle effects generated by reflection (of sunlight). That these make a significant difference over short distances is simply overlooked.

Is it possible that fish that have the ocular spark also use it for predation?

Sure. Visual modelling suggests that this is possible for at least one type of prey. See Bitton, P.-P., et al. (2019). "Visual modelling supports the potential for prey detection by means of diurnal active photolocation in a small cryptobenthic fish." Scientific Reports 9(1): 8089. What is still missing, however, is a specific behavioral experimental test of the kind done with hatted triplefins and scorpionfish (Santon et al 2020).

I have 4 fishes in my well but cannot see them. Can they see us from top or sense us? How can we see them?

I have not thought about this situation very much at all, but here are some spontaneous thoughts. From the perspective of the fish, they see you as a dark shade against a bright sky (assuming the well is in the open). Fish will definitely respond to that by fleeing, presumably because it resembles an approaching predator. You do not see the fish, because the top-view of fish is often darker and matches the background of deeper or murky water well. They obviously have no interest in signaling their presence to organisms above the surface. Very many fish display bright structures sideways (often on fins that can be folded), not upwards. If the bottom of the well would be illuminated, it would be easy for you to see them.

I have also watched my fishes in my well standing up in the sunlight. Does that mean that they use sunlight?

That is a very interesting observation for which I have no good explanation without more information. If this species is not a typical surface-feeding fish, the mouth is positioned low in the face – as is true for most fish species. Hence, they would need to "stand up" if they intend to pick small food items (e.g. insects) from the surface or to gulp air when the water is poor in oxygen. Specialized surface-feeders such as mullets or archerfish have their mouth far up their face, in line with their (usually flat) back.

If the three types of fish are placed together, is there a group behavioral effect that would negate the presence of a shade?

I am not sure whether I understand the question correctly. I interpret it as follows: "If the three hat treatments (none, clear, shaded) are placed together, is there a group effect that would affect the effect of the shading treatment?" If this is the question, then the answer is: (1) If anything, we would expect the shaded fish to follow the two other treatments. This would weaken the effect that we hypothesized and is therefore conservative with respect to our hypothesis (shaded fish move closer to scorpionfish). (2) The statistical analysis is corrected for "group of three" as a random factor. Hence, we specifically looked at the position of a fish relative to the group in which it was ("closer or further away from the scorpionfish relative to the other group members"). This compensates for the overall differences between triplets – with some being perhaps further away and others closer for group coherence reasons.