

Can chromatic aberration enable color vision in natural environments?

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Stubbs and Stubbs present a novel visual mechanism based on chromatic aberration that might allow animals with only one spectral photoreceptor-type to perceive color (1) (see ref. 1 for details about their mechanism). The authors chose cephalopods to showcase their hypothesis and claim that discrepancies between earlier (2, 3) and recent (4, 5) negative behavioral color vision tests in cephalopods can be explained by their (1) mechanism. Although the Stubbs and Stubbs mechanism works in theory, we identified several factors that would decrease the utility of the suggested signal, given the visual ecology of cephalopods.

The strength of the signal depends on how saturated the color of the object is. For the eye to quickly find the focal length that results in the best focus, the viewed object should come to focus at a narrow range of focal lengths while remaining defocused at all other focal lengths. The focus of an object with a broadband reflectance will change significantly less than the focus of an object reflecting a narrow range of wavelengths because the “whiter” object’s focus will be equally distributed at all focal lengths. Although most of the colored surfaces to which cephalopods camouflage are broadband, Stubbs and Stubbs (1) used only saturated colors to test the mechanism’s performance (Fig. 1).

Importantly, viewing distance reduces the strength of any signal. Because of the wavelength-dependent attenuation and turbidity of the water (7), the object’s color-contrast rapidly diminishes with increasing distance. The water’s turbidity further blurs the object’s edges, minimizing the remaining signal even more (Fig. 2). Additionally, the spectrum of the down-welling

light becomes narrower at greater depths, leaving little information at shorter and longer wavelengths. Stubbs and Stubbs’ (1) calculations were at a shallow depth of 3 m, using ultraclear pelagic waters (chlorophyll value 0.043 mg m^{-3}), and at a sighting distance of zero. We argue that using deeper, benthic-coastal waters and a range of relevant viewing distances would result in a substantially weaker signal.

Finally, Stubbs and Stubbs (1) explain that at short ranges the object focus is affected by the viewing distance, as well as the object’s spectrum. Thus, without an additional cue for the object’s distance (e.g., via stereopsis), the animal will fail to sense the color of nearby objects. Because benthic octopuses are mostly monocular (8) and inspect detailed conspecific signals at less than a body-length’s distance (9), and most frequently respond to camouflage cues that are closest to them (10), such a limitation undermines the mechanism’s usefulness when color vision is presumably most important: at short ranges.

We conclude that the Stubbs and Stubbs (1) mechanism could work for a narrow range of visual tasks. The viewed object would need to be both not too close so as to confuse the spectral discrimination mechanism, nor too far for the water’s attenuation and turbidity to completely destroy the signal, in very shallow and clear waters, and have saturated colors. Although cephalopods may have evolved adaptations that deal with all these limitations or even use this mechanism to detect aposomatic signals, for example, we wait to see how an animal that indeed exhibits the Stubbs and Stubbs mechanism tackles these limitations.

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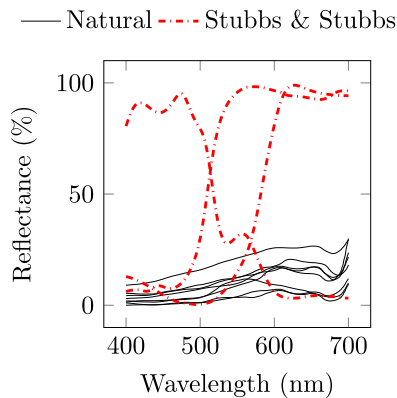


Fig. 1. Reflectance spectra (solid black lines) from underwater substrate (including live coral, dead coral, sand, green algae, brown algae, and red algae) (data from ref. 6) are a lot duller than the saturated spectra used in Stubbs and Stubbs (data from ref. 1) study (dash-dotted red lines).

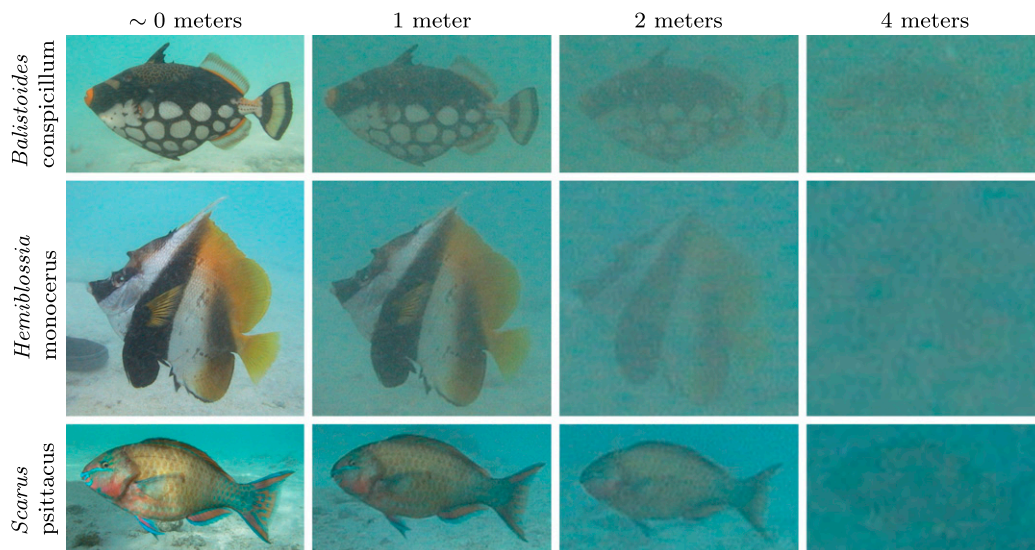


Fig. 2. The color and edge information of fish deteriorates with increasing viewing distances (taken at a depth of 0.5 m in reef water outside of Heron Island, Australia) (images courtesy of N.J.M.).

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