Visual communication based on color signals in aquatic environments

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Application Note

The rich variety of animal coloration patterns includes visual signals being subject to sexual selection, such as the colorful peacock's tail which is attractive to members of the opposite sex, or natural selection, such as cryptic coloration in order to avoid being detected by potential predators. Visual signaling depends on the reflectance properties of the signal itself, the perceptual capabilities of a potential receiver, the ambient lighting conditions under which signaling takes place, the visual background against which signals are perceived, and how the signal is transmitted through the environment. Understanding the evolution of animal coloration requires studying and interpreting visual signals by using measurement methods such as reflectance spectrophotometry in combination with data on visual processing of a likely receiver at the receptoral and postreceptoral level.

In fishes (and other taxa), the objective measurement of natural coloration patterns is difficult to apply since many fish species have the ability to change color within minutes or even seconds based on the fact that skin cells contain various pigments or reflective crystalline structures which can be neurally or hormonally triggered. Especially, under stressful condition many fishes loose their color quickly. It is therefore necessary to collect spectral information from unrestrained animals in order to avoid potentially misleading changes in color expression. A technique incorporating the Andor iDus CCD detector DV420A-OE attached to a Shamrock SR-163 spectrograph allows for collecting reflectance data from free-swimming fish (Fig. 1A & B) under laboratory conditions. To that aim, light coming from selected skin areas illuminated with a daylight-mimicking light source is collected via a fused silica lens connected to a telescopic extension that is mounted on a camera body. A SMA fiber optic is fitted to the camera body in order to feed the collected light into the spectrograph. This set-up can be used to measure the reflectance of visual signals in a species-specific wavelength range. For instance, in addition to a spectral sensitivity in the human-visible range (VIS: 400 - 700 nm) many fish species are capable of vision in the ultraviolet wavelength range (UV-A: 320 - 400 nm) and use these wavelengths for visual interactions. The depicted approach is also especially suited for studying the important but still largely unknown role of dynamic changes in color expression depending on different social and behavioral contexts such as competition or mate choice as well as antipredator response.

In addition, as mentioned before, the conspicuousness of visual signals is largely influenced by the environmental lighting conditions and the color as well as brightness contrast that is generated against the visual background. Radiance and reflectance measurements using the iDus CCD detector in combination with the Shamrock spectrograph provide the valuable opportunity to study the role of animal visual communication under semi-natural or specific artificial conditions thereby better referring to the abovementioned requirements for visual signaling. Accordingly, the application of perceptual models to quantify visual signals from a receiver's perspective, which is absolutely necessary in the study of visual communication, leads to more reliable results when being based on spectral measurements using the presented approach.

Figure 1: The two model species used for studying the ecology and evolution of visual signals. (A) Color photograph showing the characteristic traits of a male threespine stickleback (*Gasterosteus aculeatus*) in terms of the orange-red breeding coloration and the blue eyes according to human perception (400 - 700 nm). Some body regions of stickleback males also reflect at UV wavelengths (300 - 400 nm) and females use both, the UV as well as human-visible coloration of males for mate choice decisions [1]. The threespine stickleback is distributed over the whole northern hemisphere and has been extensively studied with regard to visual communication, especially in an evolutionary and ecological context [2]. (B) Color photograph showing the conspicuous color patterns in male (right) and female (left) *Pelvicachromis taeniatus*. This strikingly colored African river cichlid species is a novel model organism to study the evolution of complex visual signals. For example, the blue-purple color pattern on the female belly was shown to act as breeding coloration and its color intensity is an indicator of individual female quality [3].

References

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[2] Milinski, M. & Bakker, T. C. M. (1990). Female sticklebacks use male coloration in mate choice and hence avoid parasitized males. Nature 344: 330-333.

[3] Baldauf, S. A., Kullmann, H., Bakker, T. C. M. & Thünken, T. (2011). Female nuptial coloration and its adaptive significance in a mutual mate choice system. Behav. Ecol. 22:478-485.

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For more information on current applications of the iDus CCD detector and the Shamrock spectrograph in our lab, please, contact us. You can also view current research on this topic at our website.

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