REFLECTANCE SPECTRA FROM FREE-SWIMMING STICKLEBACKS (GASTEROSTEUS): SOCIAL CONTEXT AND EYE-JAW CONTRAST

by

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Summary

The color patterns of many organisms change rapidly with social context but such dynamic signals have been little studied with current methods. In this study we applied objective spectrophotometry techniques to the color displays of unrestrained male threespine sticklebacks, to assess the influence of social context on coloration. Analyzing our data with a color space model based on stickleback visual physiology, we found that unrestrained males enhanced saturation of both their blue eye and red jaw color in response to the presence of a mature male or female conspecific. Divergence between the eye and the jaw lead to enhanced contrast, likely increasing conspicuousness. We found little relationship between measures of color saturation and condition, but the color of males in better condition varied more with social context. This study is the first to evaluate contrast between stickleback color pattern elements quantitatively and the first in which reflectance spectra were collected from free-swimming fish. The methods presented here could be used in future studies of sticklebacks and could potentially be adapted to other animals.

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Introduction

In fishes and other taxa, social stimuli may act through neural and hormonal mechanisms to trigger changes to pigment-bearing cells, and thus color patterns, within minutes or even seconds (Fuji & Novales, 1969; Bagnara & Hadley, 1973). Color patterns are clearly important in behavioral interactions and to fitness (Andersson, 1994), yet socially mediated color change has been surprisingly under-emphasized in recent behavioral studies. This is in part because it is difficult to analyze color patterns during social interactions with the techniques now recommended for visual signals (Endler, 1990; Bennett et al., 1994). In the work that has been done, most ethologists have either assessed the color of unrestrained animals subjectively or immobilized experimental subjects with restraints or anaesthetics. The limitations of the former method are well documented (Endler, 1990; see below also) but the immobilization necessary for collecting recommended spectral data may also be problematic, since it can cause potentially misleading changes to pigmentation patterns (McLennan & McPhail, 1989a). In this study, we used a novel technique to collect spectral data from unrestrained, social sticklebacks. This made it possible for us to conduct analyses incorporating models based on stickleback visual physiology. This is the first evaluation of social influences on color expression, in a species with dynamic coloration, that uses current spectrophotometry methods and physiologically-based visual analyses.

The red-dominated nuptial coloration of the male threespine stickleback is both an example of a socially influenced display trait and one of the best known and best studied color signals in nature (reviewed by Rowland, 1994). Studies of stickleback coloration have built on classic ethological investigations (Tinbergen, 1951) to yield many important results in sexual selection (e.g. Milinski & Bakker, 1990; Candolin, 1999a) and speciation (e.g. McPhail, 1969; Boughman, 2001). Most such studies have treated social context only incidentally, but work by McLennan & McPhail (1989a, b, 1990) and Candolin (1999a, 2000) has shown that both red jaw intensity and blue eye coloration are adjusted in response to conspecifics, and that such adjustments may be adaptive. These important findings are limited, however, by either their reliance on human-based assessment of male coloration (directly with human eyes or using photographic systems that mimic human vision) or restraint of the subject males, or both.

It is important to analyze stickleback coloration in terms of the stickleback visual system because color vision in this species differs from that of