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Using red light for in situ observations of deep-sea fishes

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Abstract

Observations of animals in the deep ocean typically require the use of bright lights that can damage eyes and disrupt normal behaviors. Although the use of infrared light is an effective means of unobtrusive observation on land, it is far less effective in the ocean where long wavelength light is rapidly attenuated by seawater. Here we describe in situ observations of the behavior of the sablefish, *Anoplopoma fimbria*, around a baited site under different lighting conditions. Fish were observed with low-light-level imaging that had adequate sensitivity to compensate for the attenuation losses associated with the use of long wavelength light in water. ROV-based experiments compared the number of sablefish seen around bait, illuminated alternately with red vs. white light. Significantly more fish were seen under red light than white light with the average number of sablefish observed per 10 min viewing interval under red light being 38.9 ($\pm$18.5 SD) compared to 7.5 ($\pm$7.1 SD) under white light. Under both red and white light sablefish spent only brief periods in the illumination field (10.5 s [$\pm$8.7 SD] under red light and 6.6 s [$\pm$8.7 SD] under white light). It appeared that sablefish were responding to competing drives of attraction to the bait and avoidance of the lights and that the avoidance was greater for white light than for red light. Observations were also made with the newly developed deep-sea observatory, Eye-in-the-Sea, using long wavelength LED illumination. The onset of LED illumination did not generally produce a startle response from fish around the bait, and in some cases invoked no response at all. However, in the majority of cases the fish moved out of the circle of red-light illumination during the 7.5 s recording period, indicating that the light was detectable and aversive to these fish. This was true with both 660 and 680 nm LED illuminators. We conclude that while a sharper short-wavelength cutoff of the illumination source is required to achieve truly unobtrusive observation, red light is nonetheless significantly less disruptive than white light for observing deep-sea fish behavior, and can provide adequate illumination when used in combination with image-intensified cameras.

Keywords: *Anoplopoma fimbria*; Behavior; Red light; Sablefish; Vision; USA; California; Monterey Bay

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1. Introduction

In spite of recent developments in ocean exploration and monitoring, unobtrusive observation of biological activity remains a scientific frontier. Our primary means of viewing animals in the deep ocean or in surface waters at night requires the use of bright incandescent lamps that are disruptive to the life processes of the animals that live there. Animals capable of swimming often flee from the lamps or swarm around them (Verheijen, 1958; Forward, 1988). Sedentary animals often shrink back, temporarily ceasing their normal activities and animals with sensitive eyes may be permanently blinded (Herring et al., 1999). To really understand life in the oceans we must find ways to study oceanic communities and populations without modifying the habitat and frightening the inhabitants with intrusive, artificial lights. On land, this is accomplished using infrared illumination, which is invisible to the animals being observed but visible to infrared cameras that record their behavior. This methodology is generally impractical for in situ observations of marine animals, because infrared light is attenuated so rapidly in seawater that observations are restricted to distances of less than one attenuation length (1.5 m for 700 nm light) (e.g. Matsuoka et al., 1997). Therefore, most behavioral observations of marine organisms using far-red or infrared illumination have been conducted in a laboratory setting where the animals are confined to a very small viewing volume (e.g. Strickler, 1977; Batty, 1983; Widder, 1992; Fisher and Bellwood, 2003). In order to observe large animals in their natural state, a much larger viewing volume is needed. Here we describe in situ observations of fish behavior viewed with far-red illumination in combination with low-light-level (LLL) cameras that have adequate sensitivity to compensate for the long-wavelength attenuation losses.

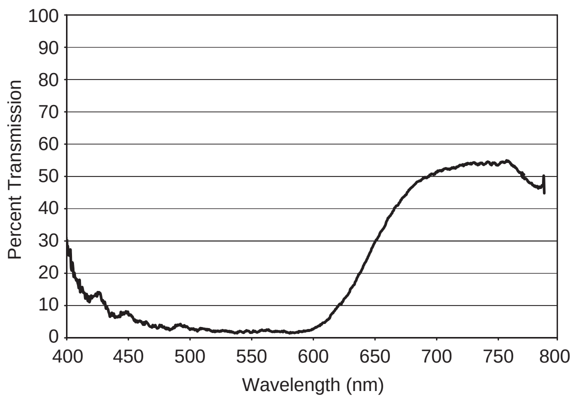

Fig. 1. Transmission through red plastic filters used on ROV *Ventana*'s camera lights for these experiments.

2. Materials and methods

2.1. ROV-based experiments

Experiments were conducted in October 2000 using the ROV *Ventana* fitted with an intensified video camera (Kongsberg Simrad ISIT) that has a photometric sensitivity of 5×10^{-6} LUX and a radiometric sensitivity of 25 mA/W at 700 nm. Illumination was provided by the ROV's four camera lights (DSPL HID 400 W daylight) of which two were fitted with red plastic filters with 10% transmission at 620 nm and 50% transmission at 680 nm (Fig. 1). Either the two red filtered lights or the two white unfiltered lights were illuminated for each period of observation. A bait cage, used to prevent scavengers from moving the bait outside the field of view of the camera, was placed approximately 2 m in front of the ROV at a depth of 520 m in Monterey Canyon (36°46.9′ N 121°55.0′ W). Recordings began at 20:00 and ended before 05:00 the following morning.

The ROV *Ventana* is trimmed to be positively buoyant in order to ensure recovery in the event of a power loss. This necessitates continuous use of down-thrust for the ROV to sit on the bottom. In order to achieve a truly unobtrusive observation capability, it is necessary to eliminate the acoustic, electrical, and mechanical disturbances associated with the ROV. This was a primary motivation for the development of the Eye-in-the-Sea (EITS) deep-sea observatory (Widder, et al. in prep).

2.2. Eye-in-the-sea experiments

The EITS is being developed as an unobtrusive sub-sea observatory (Fig. 2). Briefly, it consists of