Behavioral responses of two deep-sea fish species to red, far-red, and white light

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ABSTRACT: The relatively unobtrusive deep-sea camera system Eye-in-the-Sea (EITS) was deployed in Monterey Bay Canyon, California, USA, to assess the relative photosensitivity of 2 deep-sea fishes, *Coryphaenoides acrolepis* and *Anoplopoma fimbria*. Previous studies addressing the *in situ* response of deep-sea fishes to red and white light were done in the presence of ROV-induced stimuli. Here, we report on the behavioral response of *C. acrolepis* and *A. fimbria* in a vehicle-free environment when subjected to white (full visible spectrum), red (685 nm), and far-red (695 nm) illumination *in situ*. Under far-red light conditions, *A. fimbria* spent significantly more time in the field-of-view and demonstrated an increase in entrances/exits when compared to the situation under red-light and white-light conditions. No significant difference in the average time *C. acrolepis* spent in the field-of-view was found between any of the test wavelengths; however, the entrances-to-exits ratio for *C. acrolepis* decreased during white-light conditions. While *A. fimbria* often displayed a flight response at the onset of white and sometimes red (685 nm) illumination, *C. acrolepis* did not demonstrate a similar behavioral response when exposed to light within its range of visual sensitivity. *A. fimbria* undergo a dramatic ontogenic shift in depth, inhabiting well-lit, near-shore waters as juveniles and moving into deeper waters as adults. It is thought that *C. acrolepis* spend part of their early life history in the light-limited mesopelagic, below the permanent thermocline, and move into deeper waters as they mature. Based on the results of the present study, we hypothesize that systematic differences in the phototactic responses of deep-sea fishes are a function of life history as well as spectral sensitivity.

KEY WORDS: Deep sea · Red light · Fish behavior

INTRODUCTION

High pressure, lack of light, and limited access to deep collection sites all present serious challenges to the sampling and/or observation of deep-sea fishes (Smith & Baldwin 1997). Difficulty in net-sampling deep-sea fishes without significant modification or damage to their physiology has generally precluded laboratory-based behavioral studies. *In situ* collection methods (e.g. submersibles, remotely operated vehicles [ROVs]), on the other hand, rely on bright white (full visible spectrum) lights, which may cause irreversible retinal damage to the animal of interest (Douglas et al. 1995, Herring et al. 1999). Sampling devices

such as traps, which block out light while maintaining constant pressure and temperature, have proven valuable (Childress et al. 1978, Phleger et al. 1979, Wilson & Smith 1985), but typically involve small sample sizes and small specimens/species. As a result, arguments have been made for the value of *in situ* video and still imagery capture via vehicle-free or 'lander' systems (Phleger & Soutar 1971, Priede & Merrett 1996, Priede et al. 1998). Baited cameras are highly effective at attracting scavengers and subsequent predators, which may be drawn in by the resulting chemosensory and perhaps mechanosensory stimuli (Wilson & Smith 1984, Smith 1985, Priede & Smith 1986, Henriques et al. 2002). Many of the vehicle-free camera systems

used to obtain images of the deep are also equipped with bright white illuminators; however, these illuminators are typically used as intermittent strobes and likely result in only a periodic effect (Wilson & Smith 1984, Priede et al. 1998). Red light as a form of unobtrusive illumination has been employed in multiple shallow-water studies (Jury et al. 2002, Mills et al. 2005) and a few deep-sea studies (e.g. Widder et al. 2005).

In the present study a relatively unobtrusive video observation system, the Eye-in-the-Sea (EITS) (Widder et al. 2005) was used to record the response of deep-sea animals to different wavelengths of light *in situ*. The vast majority of deep-sea fishes possess a single visual pigment, with maximal sensitivity in the blue-green region of the visible spectrum (Douglas et al. 1995), which coincides with the available wavelengths of light from attenuated surface radiance and bioluminescence (Denton 1990). Electrophysiological, morphological, and some behavioral studies have indicated that most deep-sea fishes have limited sensitivity to longer wavelengths (Partridge et al. 1988, Douglas & Partridge 1997, Widder et al. 2005). However, a few genera (*Pachystomias*, *Aristostomias*, and *Malacosteus*) in 1 family of meso-/bathypelagic fishes, are known to produce far-red bioluminescence and to have long-wave visual sensitivity (O'Day & Fernandez 1974, Widder et al. 1984, Bowmaker et al. 1988, Partridge et al. 1989, Partridge & Douglas 1995), and the possibility cannot be discounted for some others (Douglas et al. 2002).

Widder et al. (2005) demonstrated that the deep-sea fish *Anoplopoma fimbria* (sablefish, Anoplopomatidae) responded to red light *in situ* even though this species has a maximum visual sensitivity at 491 nm (Ali & Wagner 1975). From these results it appeared that sablefish were able to detect long-wave (680 nm) light; although, how far into the far-red spectrum that sensitivity extended was not clear. Widder et al. (2005) carried out observations with a single illuminator, making it impossible to test the response of deep-sea fishes to >1 wavelength of illumination during a given deployment. In order to overcome this limitation, we added an additional illuminator to the EITS system for the purposes of comparing effects of different wavelengths of illumination.

Here, we describe the behavioral response of 2 deep-water species, the Pacific grenadier *Coryphaenoides acrolepis* (Macrouridae) and the previously mentioned sablefish *Anoplopoma fimbria* to white, red, and far-red illumination. Both species were frequently recorded at our study sites in Monterey Bay, California, USA. *C. acrolepis* is a common benthopelagic, mid-slope species (Cohen et al. 1990) thought to spawn at depth (Phleger 1971, Stein & Pearcy 1982). Buoyant eggs float up to depths below 200 m and develop in the midwater until settling in the benthopelagic as juveniles. Studies suggest that, compared to the well-developed olfactory system, vision may play a minor role in the feeding strategies of certain adult macrourid species, such as *C. armatus* (Wagner 2002, 2003). One proposed explanation for the large eyes of adult macrourids is to locate the peri-anal light organ of potential mates (Okamura 1970). *A. fimbria*, also benthopelagic, is found in surface and near-shore waters during early life-history stages and migrates to deeper waters as adults (Armstrong 1996). In order to assess the relative photosensitivity of these species, we recorded their behavior when subjected to white, red (λmax = 685 nm), and far-red (λmax = 695 nm) illumination *in situ*.

MATERIALS AND METHODS

Equipment. EITS, Ver. 2.0, was used to record deep-sea video during this study. EITS is an autonomous deep-sea viewing platform designed for deployment down to 1000 m from a ROV or submersible (Fig. 1). The basic EITS system consisted of red-light illumination in conjunction with an intensified camera, photomultiplier tube (PMT) trigger, an onboard computer, data storage, and custom-programmable software. In order to compensate for the low-light conditions due
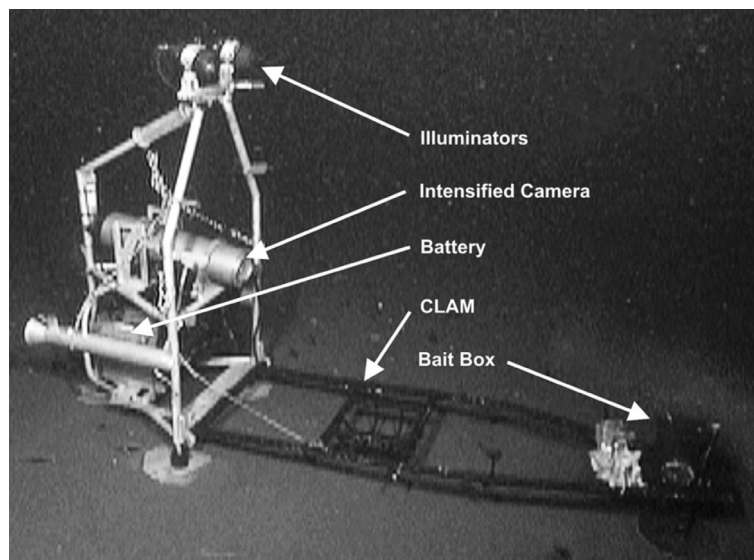

Fig. 1. *In situ* image of Eye-in-the-Sea (EITS) deployed in Monterey Bay, California. Bait was attached to the framework of the cannibalized ladder alignment mechanism (CLAM) and inserted into the bait box. Image provided by MBARI/ROV 'Ventana'. Viewing platform length: 2.5 m; height: 2.2 m

to red-light attenuation, an intensified CCD camera (ITT 880, ITT Industries Corporation) with extended sensitivity in the blue range was used. The camera was fitted with a 2.54 cm f/0.95 lens, with a fixed focal length of 25 mm.

Ancillary devices on the EITS included an electronic jellyfish (E-jelly) capable of imitating 5 different luminescent displays, and a hydrophone. While on deck, the EITS's data storage and software program were accessible through an Ethernet communication port. All parameters (illuminators, E-jelly, recording period and frequency, time and trigger mode) were fully programmable by the user. Video from the CCD camera was streamed to an onboard PC-104 capture card and stored directly on an 80 GB hard drive using a MPEG 4 compression format. The system was mounted on an aluminum tripod frame and powered by a 24 V rechargeable, lead acid Seabattery (DeepSea Power & Light) (Fig. 1). A bait box was fastened to a foldable bait alignment frame, the cannibalized ladder alignment mechanism (CLAM), 2 m away from the camera (Fig. 1). During the present study, 2 independently operated LED illuminators were used. Illuminators were fitted with red LEDs (685 nm), red LEDs with a high-pass filter (695 nm), or white LEDs.

Spectral measurements. The spectral irradiances of the EITS's red illuminators were measured in air with a spectroradiometer (OL 754 UV-Vis, Optronic Laboratories). Each red illuminator package comprised of 40 red (685 nm) LEDs and an optional filter slot. A long wave pass filter glass substitute (Corion), with a peak transmission at 711 nm, was used to reduce short-wavelength emissions. White illuminators consisted of 35 white LEDs. Illuminators were aligned on an optics bench 2 m away from the spectroradiometer and powered by a 12 V DC/1 amp bench-top power supply. Spectral irradiance of the white, red, and far-red illuminators were recorded (400 to 750 nm) at 5 nm intervals.

Using Smith & Baker's (1981) diffuse attenuation coefficients, K, for irradiance in the clearest ocean waters, irradiance at 2 m from the illuminators in water, $E(\lambda)_w$, was calculated as:

$$E(\lambda)_w = E(\lambda)_a e^{-Kz} \qquad (1)$$

where z is the distance from the illuminator and $E(\lambda)_a$ is the in-air irradiance, from 400 to 750 nm at a distance of 2 m.

In water the red illuminator had a peak irradiance of 2.47×10^{-7} W cm^{-2} nm^{-1} at 685 nm, and the far-red illuminator had a peak irradiance of 1.64×10^{-8} W cm^{-2} nm^{-1} at 695 nm, whereas the white illuminator had a broad spectral distribution with a peak irradiance of 9.03×10^{-9} W cm^{-2} in the blue region (465 nm) (Fig. 2). Total irradiance values for white, red, and far-red illuminators were 1.4×10^{-7}, 1.35×10^{-6}, and 7.51×10^{-8} W cm^{-2}, respectively.

Study sites and experimental conditions. During fall 2005, spring 2006, and fall 2006, the EITS was deployed at 3 sites in Monterey Bay for a total of 6 dives (Table 1). All deployments were done with Monterey Bay Aquarium Research Institute's (MBARI) hydraulically powered ROV 'Ventana', deployable to depths of 2300 m. The ROV's swing arm stabs (suspension arms) held the camera in position during the deployment and recovery dives. Deployments were made using baited traps and the E-jelly optical lure. Carcasses from local fish species
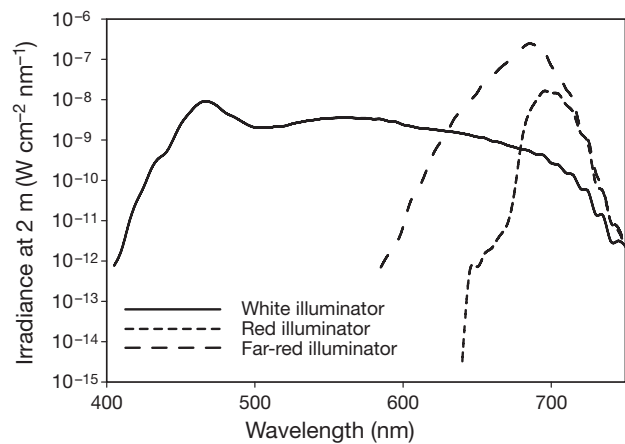

Fig. 2. Radiometric recordings for illuminators. Measured peak intensity wavelengths in water at 2 m from EITS illuminators occurred at: white (465 nm), red (685 nm), and far red (695 nm)

Table 1. EITS deployment specifications. Note: Total recording time only includes timed events when a single illuminator was on, with the exception of 9 September 2005, during periods of no electronic jellyfish activity

Dive No.	Date	Dive site coordinates		Depth (m)	Deployment period (h)	Total recording time (min)	Illuminators (λ)
		Latitude	Longitude				
1	19 Sep 2005	36° 44.15′ N	122° 02.813′ W	636	24	468	695 nm
2	20 Sep 2005	36° 44.111′ N	122° 02.758′ W	641	48	120	680 nm, 695 nm
3	22 Sep 2005	36° 45.606′ N	121° 59.608′ W	626	24	264	680 nm, 695 nm
4	18 May 2006	36° 42.708′ N	122° 11.239′ W	882	48	110	680 nm, 695 nm
5	22 May 2006	36° 42.685′ N	122° 11.319′ W	888	48	123	680 nm, 695 nm
6	28 Sep 2006	36° 42.360′ N	122° 09.95′ W	888	48	383	White, 695 nm

were used as bait. Fish heads and backbones were strapped to the CLAM's black aluminum frame. Larger chunks of fish flesh were placed in a flow-through black plastic bait box, which had 6.0 mm wide slits along the sides and top. When possible, the system was aligned so that direction of Camera view was across-current at the time of deployment. The system was programmed to run in both timed and timed/triggered mode. Upon recovery, all video clips were downloaded from the EITS to a topside laptop computer and stored for later analyses. The EITS was programmed to record for 1 min at 5 min intervals, starting during the ROV deployment period. The program ran until the EITS was recovered or the system's battery life was exceeded, typically 30 to 36 h after deployment on the seabed. Illuminators were programmed to turn on at the start of the 1 min recording period and turn off at the end of the 1 min recording period. Red-light experiments consisted of 1 min of red illumination every 5 min over a 30 min interval, followed by 1 min of far-red illumination for the same recording interval. This program (red, dark, red, dark followed by far-red, dark, far-red, dark) was repeated multiple times throughout each mission. A white- versus red-light experiment was conducted in the same manner, but using far-red and white illumination. Although the E-jelly ran during portions of Dives 4 and 5, it was programmed to remain off during the red-light experimental period.

Video analysis. Only video clips from the timed mode and in the absence of the ROV were used in these analyses. A total of 1150 MPEG 4 video clips of 1 min each were analyzed. Type and number of deep-sea species were recorded. When *Coryphaenoides acrolepis* or *Anoplopoma fimbria* were present (Fig. 3), 3 activities were noted in each 1 min block for both species: (1) time spent in the field-of-view, (2 the number individuals entering the field-of-view, and (3) and the number of individuals exiting the field-of-view. Due to differences in depth-of-field between the white, red, and far-red illuminators, only fish swimming between the camera and the bait container at the end of the CLAM were used in the final analyses, in order to standardize the volume viewed between the 2 different viewing regimes. The field-of-view in this study was defined as 2 m deep by 0.84 m wide. Data from closely spaced deployments in time at the same study site were pooled for analysis. Statistical analysis was performed applying Winstat® statistical software for Excel. The Kruskal-Wallis test was used to test for a normal distribution. Data were not normally distributed, and differences in time spent in the field-of-view during periods of unfiltered (685 nm) and filtered (695 nm) illumination were analyzed for significance using the Mann-Whitney *U*-test. Values were considered significant at p < 0.05.
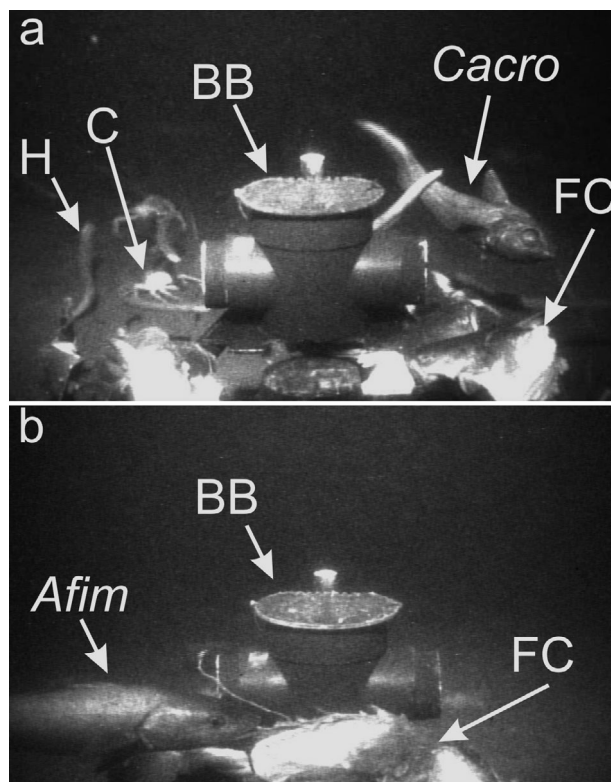

Fig. 3. Frame grabs from EITS video with red illumination. (a) *Coryphaenoides acrolepis* (*Cacro*) 18 May 2006; (b) *Anoplopoma fimbria* (*Afim*), 22 September 2005. BB: bait box; FC: fish carcass; H: hagfish; C: tanner crab

RESULTS

Species present at study sites. With the exception of *Eptatretus deani* (black hagfish), *Anoplopoma fimbria* was the most common fish species present on Dives 1, 2, 3, and 5, whereas the most abundant megafauna during Dives 4 and 6 was *Coryphaenoides acrolepis*. During each study period, the number of individuals for all species present fluctuated over time. *A. fimbria* were frequently present early in the deployment period, but tended to drop off in numbers over time. Often they would reappear in pulses later in the deployment period. A similar pattern was detected in *C. acrolepis*. In addition to *C. acrolepis*, *A. fimbria*, and *E. deani*, other fish species seen around the study site included *Somniosus pacificus* (Pacific sleeper shark), *Antimora microlepis* (finescale mora), and *Apristurus* sp. (cat shark). Since these species were observed infrequently, they were not included in the quantitative behavioral analysis.

***Coryphaenoides acrolepis* activity in red light.** A Mann-Whitney *U*-test on the average amount of time *C. acrolepis* spent on camera in the presence of red versus far-red illumination indicated there was no sig-

nificant difference (Fig. 4a). Moreover, there was no prominent difference in the ratio of *C. acrolepis* entrances to exits between illumination conditions (Fig. 4b). Under both illumination conditions, *C. acrolepis* appeared undisturbed and, unless bumped by another individual, rarely displayed startled behavior.

Since a current meter was unavailable during this study, drift direction of marine snow and loose pieces of bait were used as an indicator of current direction. It was observed that most of the macrourids aligned themselves with the current and approached the bait from the down-current direction. Once *Coryphaenoides acrolepis* approached the CLAM, they would frequently maintain a position downstream of the bait container, with their heads pointing upstream.

***Anoplopoma fimbria* activity in red light.** Data from Dives 2 and 3 revealed a significant difference in the average time *A. fimbria* spent in the field-of-view under the 2 illumination conditions (Fig. 4c). Although there was no statistical difference (p = 0.28) in average time on camera during Dives 4 and 5, there was a considerable difference in entrances to exits, indicating a tendency for *A. fimbria* to avoid the study site under red illumination. Throughout Dive 4, *A. fimbria* were not present in the field-of-view during periods of red illumination. *A. fimbria* data had a consistent pattern of smaller ratios of entrances to exits during periods of red illumination (Fig. 4d). To test the effect of changes in illumination intensity at the same wavelength on fish behavior, we fitted both illuminators with the 711 nm filter and used them simultaneously during the 1 min recording periods on Dive 1. During this experiment, the average amount of time individual *A. fimbria* were detected in the field-of-view, 16.7 s, was comparable to the single illuminator at 695 nm average,

Fig. 5. *Coryphaenoides acrolepis* and *Anoplopoma fimbria*. (a) Average time spent in the field-of-view and (b) the ratio of entrances to exits during periods of far-red illumination (black) and white illumination (white), 28 September 2006. No. of ind. viewed under each condition displayed at end of bars. **✱** Significantly different pair (Mann-Whitney *U*-test: p < 0.05)

17.4 s, on Dive 2, but lower than the average of Dive 3, 23.7 s.

Four primary behavioral patterns were observed for *Anoplopoma fimbria*: (1) rapidly swimming through the field-of-view, which was commonly seen during the initial deployment period; (2) active and aggressive feeding on the bait; (3) a rapid turn in swimming direction or abrupt cessation of feeding within the first 1 or 2 s of red illumination; and (4) a slow meandering around the periphery of the circle of illumination when the red illuminator was on. Aggressive feeding behavior was most prevalent during, but not limited to, periods of far-red illumination.

White- versus red-light experiments. Both *Coryphaenoides acrolepis* and *Anoplopoma fimbria* were observed at the study site during Dive 6. The swimming pattern of *A. fimbria* was noticeably different during periods of white illumination. *A. fimbria* were frequently observed darting outside the field-of-view at the onset of the white illumination period. For *A. fimbria* there was a significant decrease in average time spent on camera during white-light exposure; however, in the *C. acrolepis* assemblage there was no significant difference in the average time spent in the field-of-view between light treatments (Fig. 5a). A decrease in the entrances-to-exits ratio during periods of white light was observed in both species (Fig. 5b), indicating an avoidance of the study site under white-light illumination.

DISCUSSION

Analysis of *Anoplopoma fimbria* and *Coryphaenoides acrolepis* swimming behavior during periods of white, red (685 nm), and far-red (695 nm) illumination indicated that both species respond minimally to longer wavelengths of red light; however, responses to these wavelengths of light were species specific.
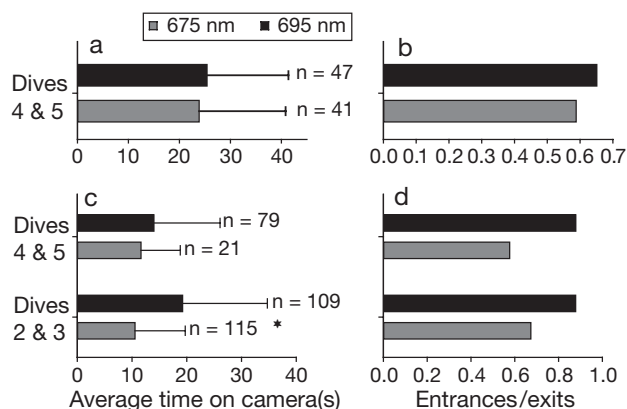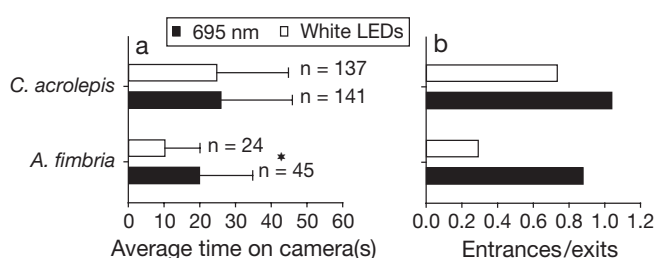

Fig. 4. (a,b) *Coryphaenoides acrolepis* and (c,d) *Anoplopoma fimbria*. (a,c) Average time spent in the field-of-view and (b,d) the ratio of entrances to exits during periods of red illumination (gray) and far-red illumination (black). No. of ind. viewed under each condition displayed at end of bars. **✱** Significantly different pair (Mann-Whitney *U*-test: p < 0.05)

A. fimbria often spent significantly more time in the field-of-view during periods of far-red illumination, whereas *C. acrolepis* behavior was not statistically different when exposed to shorter and longer wavelengths of red light. The decrease in *A. fimbria* time on camera during red- and white-light conditions is consistent with their known range of visual sensitivity *in situ* (Widder et al. 2005).

Results from the present study show that deep-sea fishes tend to avoid regions of illumination within their range of detection. The entrances-to-exits ratio was used as a species-specific proxy for the degree of response to illumination wavelength. A ratio well below 1 indicated aversion to each wavelength, whereas a high ratio (>1) indicated attraction to specific wavelengths. *Anoplopoma fimbria* assemblages consistently had lower entrances-to-exits ratios during periods of red- or white-light illumination, while ratio values close to 1 during exposure to far-red light indicate minimal disturbance or detection at that wavelength of illumination. *A. fimbria* were frequently observed skirting the field-of-illumination's periphery under white and red conditions, but we did not note the same type of avoidance behavior from individual *Coryphaenoides acrolepis* during any illumination condition. Although entrances-to-exits ratios for *C. acrolepis* did not indicate a strong behavioral response to the red wavelengths used in this study, there was a slight decrease in the ratio values when white light was present.

The visual systems of *Anoplopoma fimbria* and *Coryphaenoides acrolepis* have adapted to the spectral quality of the depths they inhabit. The intensity and spectral quality of light changes with depth, and, in optically clear waters, blue light travels the furthest (Jerlov 1976). Since deeper waters are devoid of red light, with the exception of biologically produced red light, which is made available by a very limited number of fish species (Widder et al. 1984), visual pigments of deep-sea fishes have a wide absorption spectrum and, as a result, capture light from a broad emission range (Bowmaker et al. 1994). Below depths where sunlight can penetrate, bioluminescence is the only source of illumination. Montgomery & Pankhurst (1997) make the argument that the type of visual sensitivity required for surface light detection in the mesopelagic zone is also well adapted for detection of bioluminescence in the aphotic zone. *A. fimbria* undergo a dramatic ontogenic shift in depth. As juveniles, *A. fimbria* live in well-lit, near-shore surface waters and move off shore and into the light-limited environment of the deep sea as adults (Armstrong 1996). Life in such a dynamic depth range and light regime (Armstrong 1996) requires a broad sensitivity spectrum. Conversely, *C. acrolepis* primarily inhabit depths devoid or nearly devoid of sunlight. The flight

reaction we observed in *A. fimbria* during periods with shorter wavelengths of light could potentially be a hardwired response as a method of predator avoidance in the well-lit surface waters during early development. This could also explain why we do not seem to see the same type of response from a deep-dwelling species like *C. acrolepis*.

Anoplopoma fimbria actively avoid white illumination compared to red illumination. This study confirms findings by Widder et al. (2005) that *A. fimbria* respond adversely to periods of white illumination as indicated by a decrease in the average time on camera and a lower ratio of entrances to exits. In a study by Wilson & Smith (1984), *Coryphaenoides* spp. behavior appeared unaltered by the presence of white illumination, as it was shown not to act as an attractant in the absence of bait nor did it deter fish from the viewing area during baited studies. The *C. acrolepis* present in this study were not attracted to the field-of-view during white-light conditions, and the decreased ratio in entrances to exits demonstrated avoidance during this time. Presented with white illumination clearly within their range of detection, *C. acrolepis* do not appear to respond to the same degree as *A. fimbria*. In the adult stages of life, certain macrourid species likely rely on olfaction and mechanoreception to find food sources and possibly use vision to find mates or, to a lesser extent, food (Wagner 2002, 2003). Bailey et al. (2007) suggested that grenadiers use olfaction to locate food sources from a distance, but rely on gustation and mechanoreception at close ranges to the source. It is possible that vision plays a minor role in the feeding ecology of adult *C. acrolepis*.

Coryphaenoides acrolepis and *Anoplopoma fimbria* are frequently observed around artificial food falls (Isaacs & Schwartzlose 1975, Smith 1985). Drazen et al. (2001) suggested that scavenged material may be an important component in the diet of adult *C. acrolepis* and could account for up to 20% of their total food consumption. Laboratory experiments conducted by Smith (1978) using hyperbaric chambers have revealed low metabolic rates in macrourids. Limited food availability in deep-sea benthic zones and predator avoidance are competing factors in metabolic requirements. *A. fimbria* are capable of sustaining long periods of food depravation (Sullivan & Smith 1982), likely an adaptation to the periodic nature of food availability in the deep sea. Lokkeborg et al. (1995) demonstrated that response to a low-concentration odor plume was higher in food-deprived *A. fimbria*, whereas satiated individuals spent the majority of their time resting on the bottom, away from the light during periods of exposure to odor plumes. We propose that the observed *A. fimbria* behavior around our baited camera was the result of competing sensory inputs. During

periods of white and red illumination, vision out-weighed olfactory cues; however, at wavelengths near the upper limit of their sensitivity range, *A. fimbria* were influenced primarily by olfaction and their level of starvation.

One of the limitations of red-light illumination in the ocean is the decreased range compared to white-light systems. We worked around this shortcoming by using an intensified camera. This solution had the added benefit of enabling us to record *in situ* naturally biolu-minescent events. Bioluminescent events were rarely detected during timed recording periods and were normally the result of mechanical disturbances during feeding events. Sea whips *Halipteris californica* and sea pens *Umbellula* sp. were likely the main sources of observed bioluminescence.

Intensity of the red-illumination source dropped by more than an order of magnitude with the addition of the 711 nm high-pass filter. Although we limited ana-lyzed observations to a distance of 2 m from the cam-era, fauna were often detected at greater distances from the system. In previous deployments, in which both illuminators were fitted with high-pass filters and operated in unison, a greater field-of-view of up to 4 m from the camera was possible, and there was no dis-cernable difference between the average amount of time *Anoplopoma fimbria* spent in the field of view under different levels of intensity at the same wave-length (695 nm). Future deployments will involve the use of both illuminators fitted with high-pass filters given that 2 far-red illuminators provide sufficient lighting and species observed to date appear mini-mally affected by this illumination.

Based on the results of the present study, the benefits of the EITS 2.0 system for deep-ocean behavioral experiments are: (1) it is a relatively unobtrusive view-ing platform, free from ship noise and white light; (2) it can be positioned to view specific areas of interest, including fragile habitats such as thickets of deep coral; (3) it can be equipped with up to 3 light sources of different wavelengths and programmed to come on in different combinations; and (4) it can be deployed for multiple days at a time. There are tradeoffs be-tween attenuation of light in water, camera sensitivity, and animal sensitivity when conducting unobtrusive observations in the deep sea. Data presented here and in Widder et al. (2005) suggest that, although lower wavelengths of red light are detectable by some deep-sea species, far-red light (695 nm) is sufficiently un-obtrusive for most deep-sea applications.

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