



## Studying the swift, smart, and shy: Unobtrusive camera-platforms for observing large deep-sea squid

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### ABSTRACT

The legend of the “kraken” has captivated humans for millennia, yet our knowledge of the large deep-sea cephalopods that inspired this myth remains limited. Conventional methods for exploring the deep sea, including the use of nets, manned submersibles, and remotely operated vehicles (ROVs), are primarily suited for studying slow-moving or sessile organisms, and baited camera-traps tend to attract scavengers rather than predators. To address these issues, unobtrusive deep-sea camera platforms were developed that used low-light cameras, red illuminators, and bioluminescence-mimicking lures. Here, we report on several opportunistic deployments of these devices in the Wider Caribbean Region where we recorded several encounters with large deep-sea squids, including the giant squid *Architeuthis dux* Steenstrup 1857, *Pholidoteuthis adami* Voss 1956, and two large squid that may be *Promachoteuthis* sp. (possibly *P. sloani* Young et al. 2006). These species were recorded between depths of 557 and 950 m. We estimate the Mantle Lengths (ML) of *Promachoteuthis* were ~1.0 m, the ML of the *Pholidoteuthis* was ~0.5 m, and the ML of the *Architeuthis* was ~1.7 m. These encounters suggest that unobtrusive camera platforms with luminescent lures are effective tools for attracting and studying large deep-sea squids.

### 1. Introduction

Large cephalopods are arguably the most iconic marine invertebrates worldwide (Guerra et al., 2011). Appearing in numerous works of fiction, ranging from Greek mythology to modern-day movie blockbusters, these species have captured people’s imaginations for millennia (Guerra and González 2009). Yet filming large deep-sea cephalopods in the wild has proven challenging (Ellis 1998) and they are mainly encountered as dead or dying individuals after stranding in shallow waters (Kubodera et al., 2018; Guerra et al., 2018; Remeslo et al., 2019) or as incidental bycatch in deep-sea trawls (Bolstad and O’Shea 2004; Guerra et al., 2004; Judkins et al., 2016). Thus, there is a need to develop reliable methods for recording these elusive species in their natural habitats (Roper and Shea 2013; Guerra et al., 2018). Moreover, many large

deep-sea cephalopods, such as the giant squid *Architeuthis dux* and the colossal squid *Mesonychoteuthis hamiltoni*, are ecologically important deep-sea predators (Cherel et al., 2009), serve as prey for deep-diving cetaceans (Judkins et al., 2015), and have extensive geographic ranges (Coro et al., 2015; Remeslo et al., 2019). Knowledge of the behaviour, distribution, and abundance of these species is therefore a key component to understanding deep-sea ecosystems (Hoving et al., 2014).

Deep pelagic ecosystems are the least studied biomes on this planet (Webb et al., 2010). The most common method for sampling species in these habitats is with nets; however, these tools are biased toward capturing “only the slow, the stupid, the greedy and the indestructible” (Herring 2002). Indeed, many quick moving and alert species can actively avoid trawl nets (Kaartvedt et al., 2012) and this could explain the low representation of certain taxa, including large-bodied squids, in

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many trawl studies (e.g., Judkins et al., 2016). Sightings of large squid are also notably rare from other methods for studying deep-sea species including submersibles and remotely operated vehicles (ROVs). This may be attributable to deep-sea vehicles generally including some form of propulsion that creates a mix of sound and vibrations. They also tend to use bright illumination, enough to allow for a pilot to navigate and interact with the environment even though many squids have sensitive eyesight (Hanlon et al., 2018) and can detect low frequency sounds (Mooney et al., 2010). These squid may therefore sense and then actively avoid the disturbances created by deep-sea vehicles before they themselves can be sighted by any onboard cameras.

An alternative method for recording deep-sea species that may be less obtrusive is to use stationary or passively-drifting camera platforms. Without the need for active propulsion, these devices do not require moving parts and can thus create minimal noise. Also lacking the need to navigate, these devices can use lighting at a lower intensity. To further reduce the impact of these lights, white lights can also be switched for red lights. Many deep-sea species, including squid, have monochromatic visual systems that are adapted to blue downwelling light and blue bioluminescence rather than long wavelength red-light (Frank and Case 1988; Seidou et al., 1990). Using red light may thus be a less obtrusive method for illuminating deep-sea species for videography. Indeed, some deep-sea fish species are seen more frequently and spend more time on camera under red than white light scenarios even at comparable light intensities (Widder et al., 2005; Raymond and Widder 2007).

The potential benefits of using unobtrusive camera-platforms for filming deep-sea squid are clear, yet it should still be noted that some form of bait will likely be required to effectively attract these species in the vast expanse of the deep pelagic realm. It is also important that this bait should be sufficiently enticing for the target species (Diete et al., 2016). For example, dead-animal bait (e.g., dead fish or shrimp) may attract scavengers, while live bait may attract more active predators. To attract an active predator, such as most large squid, would therefore require a lure that simulates a living animal. Thus, Widder (2013) developed an optical lure, called an E-Jelly, that imitated the pin-wheel bioluminescent “burglar alarm” of a deep-sea scyphozoan *Atolla wyvillei* (Widder 2007). While large squid do not appear to prey on jellyfish (e.g. Chereil et al., 2009, Bolstad and O’Shea, 2004), this display would still serve as a conspicuous signal for attracting visual predators such as squid because the “burglar alarm” is thought to be stimulated by another animal attacking the jellyfish.

Applying this knowledge regarding the potential sensitivity of deep-sea squids to both bright lights and loud noises as well as the efficacy of using a visual lure, Widder (2013) developed an unobtrusive deep-sea camera platform. This camera system, called the *Medusa*, used low-light cameras, red illuminators, and a bioluminescence-mimicking optical lure. As an example of the value of this technology for filming large deep-sea squid, on the first deployment of the *Medusa* with the E-Jelly attached in the deep waters off the coast of the Ogasawara Islands, Japan it recorded the first video of a live giant squid in its natural habitat (Widder 2013). During that expedition four additional sightings of giant squid were made from the *Medusa* plus one sighting from the Triton 3300/3 submersible, also outfitted with red light illuminators and a bioluminescence-mimicking lure. To further substantiate the efficacy of unobtrusive camera-platforms for filming large deep-sea squid, we report on several other encounters of large deep-sea squid that were filmed in the Wider Caribbean Region using both the *Medusa* and an earlier prototype of the *Medusa* called the *Eye-In-The-Sea* (EITS). Specifically, we describe two encounters with a squid that might be a very poorly known species, *Promachoteuthis sloani*; an encounter with *Pholidoteuthis adami*; and an encounter with an exceptionally large cephalopod, most likely a juvenile *Architeuthis dux*.

## 2. Methods

During both 2004 and 2005, the EITS was repeatedly deployed in the

northern and north-eastern Gulf of Mexico. A full description of the EITS platform can be found in Widder et al. (2005). During these deployments, the EITS was deployed on the seafloor in various habitats to characterize which species were attracted by the bait crate, containing diced bonito *Sarda* sp., and the E-Jelly (Supplementary Materials 1). The E-Jelly was programmed to turn on and off on a 1min duty-cycle during deployments. On two separate deployments at a deep-sea brine pool in August 2004 and next to a *Lophelia* sp. coral reef in August 2005 (sites A and B respectively in Fig. 1), a large squid was sighted that may have been *Promachoteuthis sloani* (Fig. 2).

In 2012, the EITS was rebuilt and upgraded as the *Medusa* (Supplementary Materials 2). The *Medusa* consisted of a black aluminium frame holding a low-light camera (Model #KPC-SLL650BHE, KT&C, Korea), two custom-built LED illuminators that emit red light around 680 nm, a conductivity temperature-depth recorder, a battery pack that would allow for > 48hr of continual recording at a resolution of 58DPI and 30 frames per second, and a 1.5 m bait arm to which either an E-Jelly and/or a bait crate could be attached. After being deployed in water and successfully filming a live giant squid (Widder 2013), the *Medusa* was used between 2012 and 2014 to characterize the benthic communities of the northeast Exuma Sound, The Bahamas (site C in Fig. 1). During these expeditions, the *Medusa* was used as a benthic lander and a bait cage filled with diced bonito *Sarda* sp. was used as an attractant. In October 2013, an unidentified squid that was possibly *Pholidoteuthis adami* (Fig. 3) was observed.

In June 2019, the *Medusa* was adapted for use as a mid-water drifter by tethering it to a surface buoy (Supplementary Materials 2). Specifically, the frame of the *Medusa* was tethered by up to 2,000 m of 12 mm polypropylene line to a surface buoy. During deployments, the *Medusa* would drift passively for 24–36 h before being recovered via an Iridium satellite beacon (iBCN, MetOcean) that was mounted to an aluminium frame around the surface buoy. The E-Jelly was used for every deployment and a mesh bag filled with roughly 250 g of fresh mahi mahi *Coryphaena hippurus* was also opportunistically attached to the bait arm. After several deployments at various depths (Table 1, sites D, E, and F in Fig. 1), a large *Architeuthis dux* was sighted (Fig. 4).

To estimate the size of the *Architeuthis dux*, it was possible to use the E-Jelly as a reference (Fig. 5). The E-Jelly provided a flat and square surface of known dimensions (0.21 m length x 0.13 m wide) that could be used to estimate the size of an object on the same horizontal plane of perspective (García-Salgado 2003). We chose to estimate the length of the single arm that was attached to the E-Jelly as there were several frames when this appendage was held relatively straight and close to being in line with the bait arm. By extending lines from the left and right sides of the E-Jelly until they converged, we identified the vanishing point. We then drew a third line between these two lines, termed the middle perspective line. By extending a diagonal line from one of the corners of the E-Jelly in the foreground through the intersection between the middle perspective line and the rear line of the E-Jelly and continuing this diagonal line until it reached the opposite perspective line, we could estimate distance relative to the length of the E-Jelly (0.21 m).

## 3. Results

### 3.1. Unidentified squid, possibly *Promachoteuthis sloani*

In August 2004, the EITS was deployed next to a brine pool at a depth of 647 m. After being deployed for 4hr, the E-Jelly was programmed to activate for the first time and within 86sec a squid was recorded rapidly approaching the E-Jelly (Fig. 2A and B: Supplementary Materials 3). A year later the EITS was deployed again, this time next to a *Lophelia* sp. coral reef at a depth of 557 m. Once again a squid approached and attacked the E-Jelly within <5 min of being turned on (Fig. 2C and D; Supplementary Materials 4). Both squid had notable features including a free dorsal mantle margin, small eyes, and thick stalked muscular

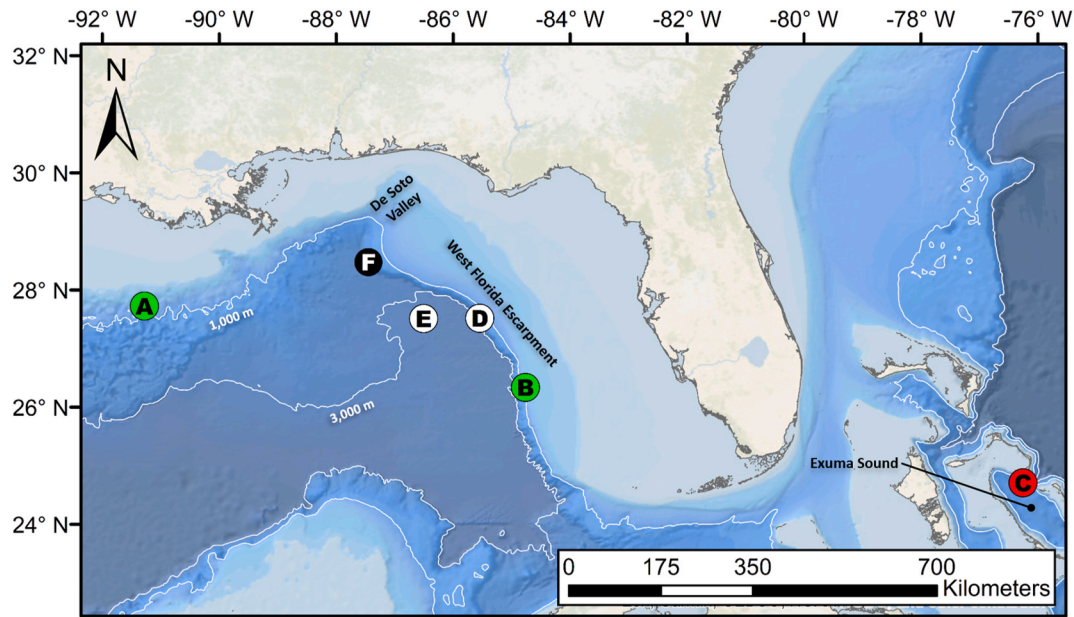


Fig. 1. Deployment locations for the Medusa and the Eye-In-The-Sea within the Wider Caribbean Region. Green circles A and B represent Eye-In-the-Sea deployments on which *Promachoteuthis sloani* was sighted in 2004 and 2005 respectively. The red circle C represents the deployment of the Medusa in the Exuma Sound on which a *Pholidoteuthis adami* was sighted. Map created in ArcGIS v.10.6 using the ETOPO1 Global Relief Model (Amante and Eakins 2009). White circles D and E represent Medusa deployments in 2019 that did not record large squid, while the black circle F represents the deployment on which a giant squid *Architeuthis dux* was filmed. Two deployments were conducted at the location of each black and white circle. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

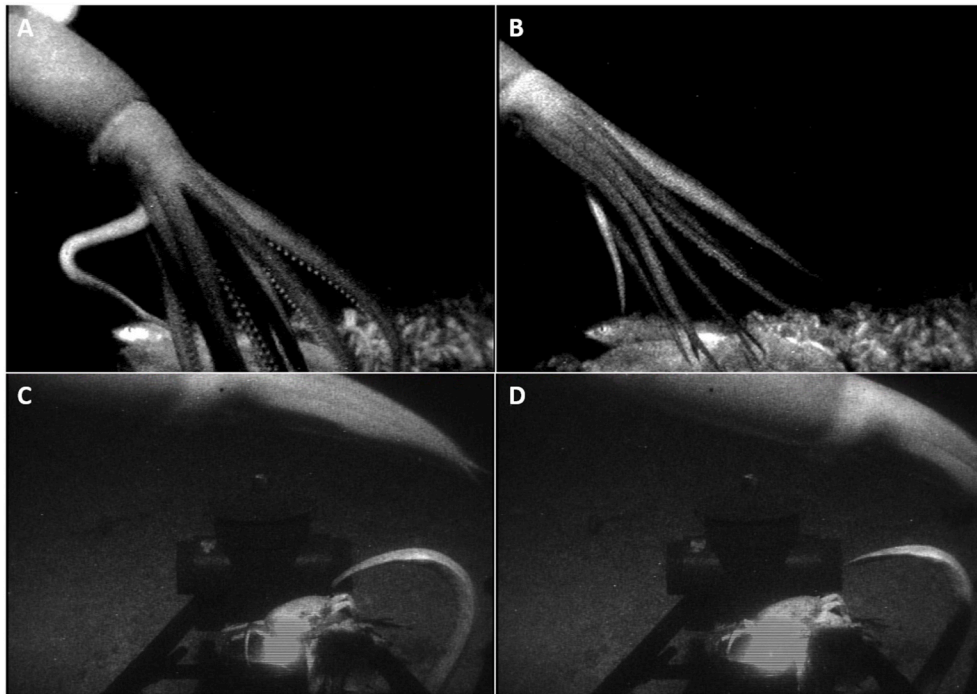


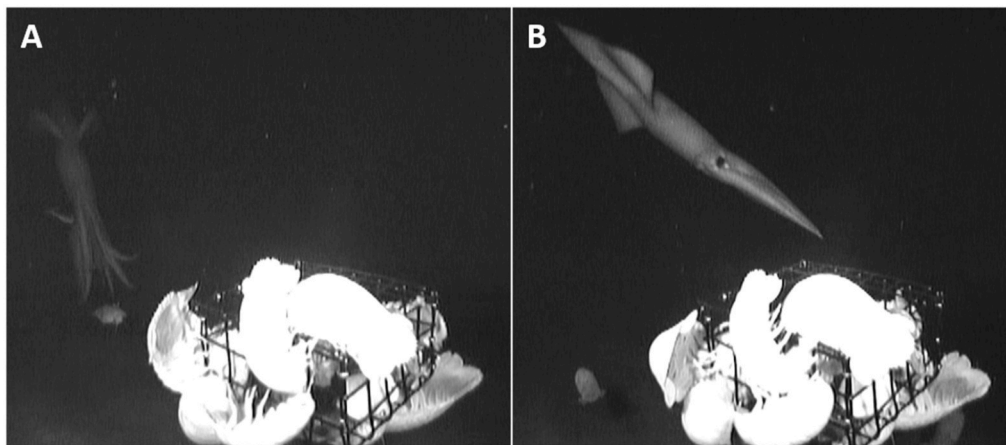
Fig. 2. Image of unidentified squid, possibly *Promachoteuthis sloani* recorded from one encounter. around brine pools (A,B) and a *Lophelia* sp. coral reef (C,D) in the northern Gulf of Mexico.

tentacles that were about 60% the length of the arms. The tentacle base width appeared equivalent to the arm base width and there were no suckers visible and no obvious club on the tentacle. Two series of suckers were visible on the arms. The posterior portion of the mantle was never visible and only the anterior-most regions of the large fins were seen flapping as the squid swam up and out of the frame. The fins were attached dorsally two body-widths back from the anterior mantle. In

neither instance was it possible to use the E-Jelly as an accurate reference of size but we estimated the mantle length (ML) to be around 1 m based on the field of view at the point of closest focus.

These squid could not be identified definitively to any known family. However, they are similar in general morphology to a recently described species, *Promachoteuthis sloani*. Similarities include (1) general shape and morphology, (2) relative fin size and insertion on mantle, (3) small





**Fig. 3.** Images of *Pholidoteuthis adami* recorded in the Exuma Sound in The Bahamas. In the bottom centre of both images a bait crate was being fed upon by several giant isopods *Bathynomus giganteus*. In image A, the squid was seen approaching a swimming *B. giganteus*, although the squid jetted away before it made contact. In Image B, the squid was approaching another swimming isopod.

**Table 1**

Summary information regarding the six Medusa deployments. \* Medusa depth is reported to the nearest 10 m as the exact depth changed over the deployment. \*\* Signifies when the giant squid was spotted. Two deployments were conducted at each site (i.e., A1 and A2) and the letter in each deployment number refers to the location on Fig. 1.

Deployment Number	Date Deployed	Initial Lat/Long	Medusa Depth* (m)	Seafloor Depth (m)	Bait
A1	9-Jun-2019	27.3991, -86.5042	1830	3060–3150	E-Jelly
A2	11-Jun-2019	27.5090, -86.5053	1830	3090–3150	E-Jelly/ mahi mahi
B1	13-Jun-2019	27.5120, -85.5592	1450	2650–3200	E-Jelly/ mahi mahi
B2	15-Jun-2019	27.3631, -85.5224	1100	3200–3260	E-Jelly/ mahi mahi
C1**	17-Jun-2019	28.4773, -87.4468	750	1800–2080	E-Jelly/ mahi mahi
C2	19-Jun-2019	28.3709, -87.4459	750	2600–2630	E-Jelly

eyes deeply embedded in head, (4) unusual tentacles. Although we were not entirely confident in this identification, the family Promachoteuthidae is known from only a few specimens and *P. sloani* was described by Young et al. (2006) from only two immature specimens (a third small specimen is now in the USNM collections), the largest of which was 102 mm ML. Thus, we suspect the squid we described may have been larger, possibly more mature *P. sloani*.

### 3.2. *Pholidoteuthis adami*

In October 2013, the Medusa was recording several giant isopods *Bathynomus giganteus* feeding on a bait crate at a depth of 950 m. A squid was seen approaching the bait crate, but it never opened its appendages to strike and instead inhaled and jetted away (Fig. 3A, Supplementary Materials 5). Within 10sec, the squid returned and briefly opened its appendages to strike one of the smaller *B. giganteus* that was swimming towards the bait crate. Once again, the squid did not make

contact and instead jetted away. Another 8sec later, the squid approached another swimming *B. giganteus* near to the bait crate. This time the squid struck the isopod but quickly retreated without any attempt to manipulate the potential prey (Fig. 3B, Supplementary Materials 5). This squid was essentially identical to other *Pholidoteuthis adami* that have been observed in the Gulf of Mexico and western North Atlantic (e.g. Vecchione 2001; Hoving and Vecchione 2012).

### 3.3. *Architeuthis dux*

In June 2019, the Medusa recorded a squid at a depth of 759 m with a bottom depth of about 1,800 m and water temperatures of 6.3 °C (Fig. 4, Supplementary Materials 6). Initially, the squid maintained its distance from the E-Jelly and bait but would undulate its arms and tentacles up or down tracking the oscillating movement of the Medusa (Fig. 4A). The squid remained visible for approximately 40 s before moving offscreen. Within 26sec, the squid reappeared again but continued to maintain its distance for another 24sec before once again moving off screen. The squid remained offscreen for just under 4min before reappearing directly in front of the camera. This time, the squid immediately approached Medusa before striking both the E-Jelly and bait arm (Fig. 4B).

The first appendage to make contact appears to be a tentacle (Fig. 4B), although subsequently only one of the arms appeared to make sufficient contact to attach onto the bait arm. Only attached by a single appendage, the squid swung two additional arms onto the E-Jelly (Fig. 4C and D). A few seconds later, the squid released its grip on the bait arm and jetted away (Fig. 4E and F). The entire encounter lasted 13sec. While the squid was holding onto the E-Jelly, its fins could be observed beating regularly, potentially for stabilization.

Using the E-Jelly as a reference, we estimated the length of this squid's arm to be at least 1.68 m (Fig. 5). In addition, this is likely an underestimation for two main reasons. Firstly, as previously noted, the angle of the arm was clearly less than 45° away from the horizontal planes of perspective of the E-Jelly and so our measurements would foreshorten the length of this appendage. Secondly, we did not measure the entire length of the arm as the distal end was curved back on itself and we were unable to estimate the size of this section of the arm. It should also be noted that as we only measured the length of the arm, the total length of this squid from the tentacle clubs to the tip of the mantle would be even larger.

Knowing the arm length of this individual to be approximately 1.7 m, we used this as a guide to narrow down potential candidate species. However, as arm length data are not as frequently reported as are measurements of ML, we selected a conservative 1 m ML threshold to

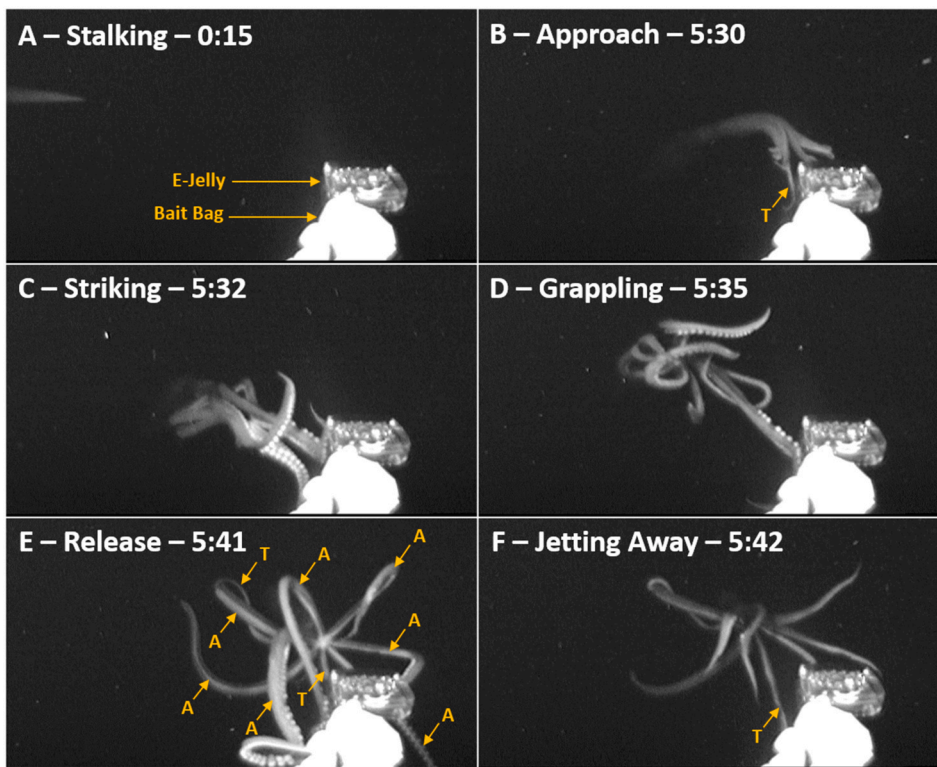


Fig. 4. Sequential video stills (A–F) of a giant squid approaching the E-Jelly. In image E, all eight arms and two tentacles are visible. A single tentacle is also clearly visible in image B and F. Time stamps refer to the full video in [Supplementary Materials 2](#).

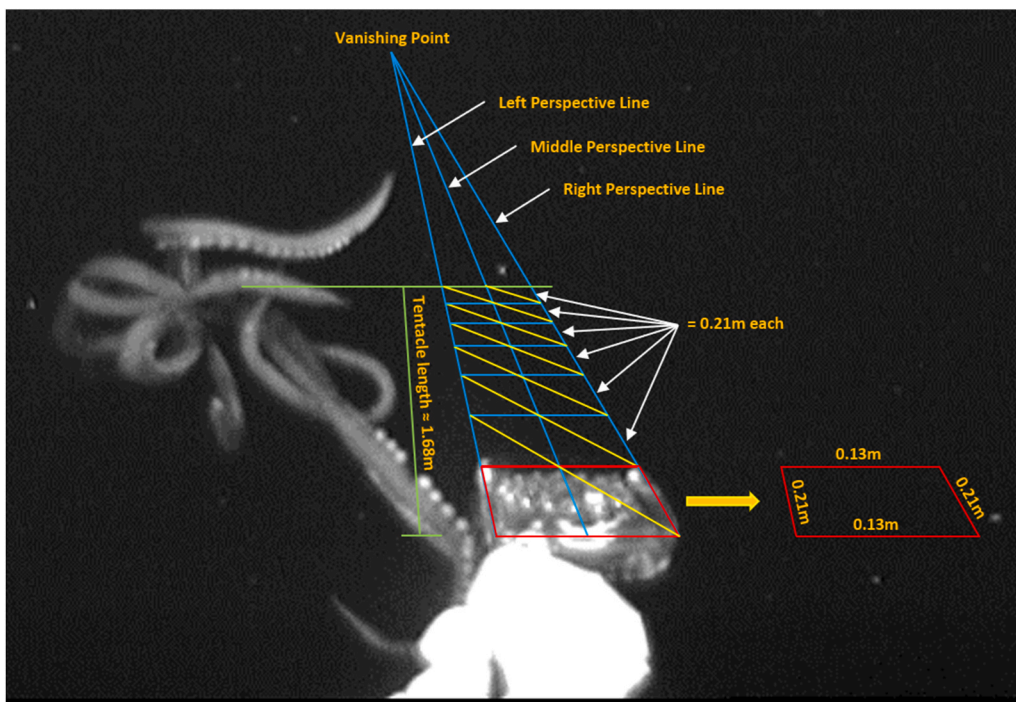


Fig. 5. Size estimate of the giant squid using the E-Jelly as a reference for perspective. The outline of the E-Jelly is marked in red. The blue lines are extensions of the E-Jelly's sides to find the vanishing point. The yellow diagonal lines were used to measure distance, in terms of the E-Jelly's length, along the perspective lines. The green lines mark the length of the giant squid arm that was estimated to be 1.68 m long. It should be noted that this measurement did not include the recurved distal section of this arm. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

begin our search. Extensive surveys have identified approximately 100 species of mid-water cephalopods in the northern Gulf of Mexico (Judkins et al. 2015, 2016) but only three species have been reported with ML exceeding 1 m. These are *Taningia danae*, *Asperoteuthis acanthoderma*, and the giant squid *Architeuthis dux*. *Taningia danae* is a large squid in the family Octopoteuthidae, which is characterized by having

tentacles that do not grow past the paralarval stage and thus the presence of visible tentacles in the video eliminated this species (Fig. 4B,E, F). The arms of *T. danae* are also relatively short and would have had visible photophores on the tips of arms II. Thus, the two remaining known candidates in the Gulf of Mexico that can exceed mantle lengths of 1.5 m were *A. acanthoderma* and *Architeuthis dux* (Judkins et al.,

2009; Roper et al., 2015). Both species have a relatively slender body-shape that would match up with the recorded individual; however, the tentacle morphology of these species is quite distinct. The tentacles of *A. acanthoderma* are extremely thin with small photophores running down their length to the tentacular club. The tentacular club is also expanded by its trabecular membranes and has numerous, small suckers on the distal portion, ending with a larger photophore at the tip of each club. The tentacles of the observed individual appear much thicker than those of *A. acanthoderma* and the clubs do not appear to have greatly expanded trabecular membranes. Thus, we propose that this individual was most likely an *A. dux* due to a combination of its size, shape, and tentacle structure. Moreover, if we assume that arm length is comparable to mantle length (i.e., ML ca. 1.7 m), as has been previously reported for giant squid (Guerra et al., 2004; Paxton 2016), then the length of this squid from the tip of the mantle to the tip of arm was likely over 3.4 m. This was comparable to the largest ML observed in male *A. dux*, which is around ~ 1 m ML (Guerra et al., 2004; Hoving et al., 2004), although fully grown females can reach MLs of almost 3 m (Paxton 2016). This individual was therefore likely a mature male or a juvenile female.

#### 4. Discussion

We report on the use of unobtrusive deep-sea cameras to record three poorly known deep-sea squids, including *Pholidoteuthis adami*, *Architeuthis dux*, and possibly *Promachoteuthis sloani*. As similar technology was also used to record the first videos of live giant squid in the waters of Japan (Widder 2013), we propose that the combination of low-light cameras, red illuminators, and bioluminescence-mimicking optical lures are effective tools for the study of large deep-sea cephalopods. The value of such technology is clear when considering that these species are only rarely encountered using more common sampling methods such as mid-water trawls (e.g. Judkins et al., 2016) and even short videos or photos can provide unique insights into their appearance (Hoving et al., 2013), behaviour (Hoving et al., 2012; Kubodera et al., 2007; Vecchione 2019), and distribution (Jamieson and Vecchione 2020). For example, the use of towed deep-sea cameras recently confirmed the presence and potential abundance of bigfin squid (*Magnapinna* sp.) in the waters of Australia (Osterhage et al., 2020) and ROV footage also revealed the novel vertical head-up orientation of the ram's horn squid (*Spirula spirula*) (Lindsay et al., 2020). Moreover, as these two examples were recorded using camera systems that are associated with relatively high levels of light and/or sound production, we expect that the unobtrusive camera systems used in this study may provide even greater insights into the undisturbed behaviours of large deep-sea cephalopods.

The footage presented in this study supports the idea that *P. sloani*, *P. adami*, and *A. dux* are primarily visual predators. For example, *P. adami* did not approach or interact with the *Sarda* sp. bait that presumably provided the largest olfactory signal but instead rapidly approached and briefly attacked the quick swimming *B. giganteus*. Both *P. sloani* and *A. dux* were also recorded attacking the E-Jelly while ignoring the bait nearby. Moreover, *A. dux* repeatedly tracked (i.e., the “attention” stage in a squid attack sequence) the “bobbing” movements of the Medusa and stalked the camera-platform for at least 6min before finally approaching for the attack. This behaviour clearly indicates that visual stimuli can elicit hunting behaviours in *A. dux*. It also provides further evidence as first indicated by Kubodera and Mori (2005) that *A. dux* are not sluggish sit-and-wait predators as previously suggested by Roper and Boss (1982), Norman (2000), and Nixon and Young (2003). Instead, they appear to stalk their prey actively before approaching for an attack.

Each of our squid encounters also provides new information regarding the range and distribution of these species. Only three individuals of *P. sloani* have ever been identified and each of these were found in the North Mid-Atlantic Ridge (Young et al., 2006; Vecchione et al., 2010). If the two individuals that we observed were indeed the same species, this extends the range of this *P. sloani* over 10° of latitude

south and west into the northern Gulf of Mexico. In contrast, there are several reports of *P. adami* from the Gulf of Mexico and throughout the western Atlantic (e.g. Roper and Jereb, 2010; Hoving and Vecchione 2012), yet this species had not previously been reported from the geographically isolated Exuma Sound. *Architeuthis dux* has also been reported previously in the Gulf of Mexico, and indeed all major water bodies except the Southern and Arctic Oceans (Coro et al., 2015). It is also interesting to note that we observed *A. dux* at a depth of 759 m, the three previous sightings of live giant squid in the deep waters off the coast of Japan were recorded between 630 and 900 m (Kubodera and Mori 2005; Widder 2013), and have been caught between depths of 400 and 600 m in fisheries around New Zealand (Bolstad and O'Shea 2004). This suggests that the vertical distribution of *A. dux* occupies most of the dysphotic zone.

While our data suggests that unobtrusive camera systems, such as the Medusa, are versatile tools for the study of deep-sea cephalopods, we recommend that future studies assess the value of using low-light systems or optical lures in a more scientifically-robust manner. For example, while the bioluminescence-mimicking E-Jelly appears to be an effective tool for attracting cephalopod species, future studies could assess whether lures of differing intensities, colours, or light patterns vary in their capacity to attract various taxa of deep-sea cephalopods. Other studies could also assess how the intensity or precise wavelength of the red illuminators affects which species will approach the camera.

As the methods for filming large deep-sea cephalopods are refined and this increases the efficiency at which new footage of these species can be recorded, this will eventually allow us to start answering new questions about these species. For example, if it becomes possible to collect reliable observations of large cephalopods from a single study area, it may be possible to begin assessing population trends for these species. Indeed, it is somewhat ironic that *A. dux* is arguably the most iconic deep-sea species (Guerra et al., 2011), yet almost nothing is currently known about its conservation status. One of the largest threats *A. dux*, and many other deep-sea cephalopods, may face is sound pollution. Loud low-frequency sounds, such as those emitted during seismic surveys, can cause significant trauma to cephalopods (André et al., 2011) and the growing global use of seismic surveys has been associated with several stranding of *A. dux* (Guerra et al., 2011; Leite et al., 2016). The threat posed by seismic surveys may also be compounded by other potential threats such as chemical pollution (Bustamante et al., 2008) or climate change (Levin and Le Bris 2015). Understanding the risk posed by these threats is key to assessing the long-term viability of many deep-sea cephalopods and without this information, the future of these enigmatic species will remain uncertain.

#### Author contributions

Nathan J. Robinson: Conceptualization, Investigation, Data Curation, Writing - Original Draft, Visualization. Sönke Johnsen: Conceptualization, Investigation, Resources, Writing - Review & Editing. Annabelle Brooks: Investigation, Writing - Review & Editing. Lee Frey: Methodology. Heather Judkins: Investigation, Writing - Review & Editing. Michael Vecchione: Conceptualization, Investigation, Writing - Review & Editing. Edith Widder: Conceptualization, Investigation, Data Curation, Methodology, Resources, Writing - Review & Editing, Supervision.

#### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.dsr.2021.103538>.

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