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First-ever observations of a live giant squid in the wild

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The giant squid, *Architeuthis*, is renowned as the largest invertebrate in the world and has featured as an ominous sea monster in novels and movies. Considerable efforts to view this elusive creature in its deep-sea habitat have been singularly unsuccessful. Our digital camera and depth recorder system recently photographed an *Architeuthis* attacking bait at 900 m off Ogasawara Islands in the North Pacific. Here, we show the first wild images of a giant squid in its natural environment. Recovery of a severed tentacle confirmed both identification and scale of the squid (greater than 8 m). *Architeuthis* appears to be a much more active predator than previously suspected, using its elongate feeding tentacles to strike and tangle prey.

Keywords: giant squid; *Architeuthis*; first observation in natural habitat; feeding behaviour

1. INTRODUCTION

Little is known of the behaviour of the deep-sea giant squid, *Architeuthis*. Available information is fragmentory, based on dead or dying animals that have been washed ashore or inadvertently captured in commercial trawl nets (Aldrich 1991; Roeleveld & Lipinski 1991; Okiyama 1993; Förch 1998). During 1996–1999, scientists from the US and New Zealand have invested considerable time and resources in trying to capture them and to visualize them from cameras on ROVs and free-diving sperm whales off New Zealand, but had no success (from Smithsonian Natural History Web site, http://www.mnh.si.edu/natural_partners/squid4/Default.html).

As for the New Zealand research, we also used sperm whales (*Physeter macrocephalus*), the most effective hunters of giant squid, as guides to target the specific locations and depths where large mesopelagic cephalopods (including *Architeuthis*) are most likely to occur in Japanese waters. Each year between September and December, sperm whales gather to feed in deep water off Ogasawara Islands (*ca* 26–27 N, 142 E) in the North Pacific Ocean. Reports in recent years have demonstrated that giant squids are present in the region and are one of the target prey species of the sperm whales (Mori 1997; Mori *et al.* 1999). *Architeuthis* remains have been found floating at the surface and have been recovered from commercial bill-fish vertical long-line fisheries, both as individual severed tentacles snared on baited lures and also as two entire specimens (Kubodera 2004).

Data collected since 1996 by the Ogasawara Whale Watching Association on sperm whale distributions show that these whales gather in a region adjacent to a steep and canyoned continental slope, approximately 10–15 km southeast of Chichijima Island (figure 1). Depth loggers attached to sperm whales in the region recorded repeated and consistent dives by these whales to depths of 800–1000 m during the day and 400–500 m at night (Aoki *et al.* 2004).

Over three seasons (2002–2004), we used these depth and location data to make 23 targeted deployments of self-contained camera/depth logger systems (Watanabe *et al.* 2003) on baited vertical long lines.

2. METHODS

(a) *Remote camera system*

A vertical long-line camera and depth logging system were deployed (figure 2*a*). A length of 400–1000 m of combination tetron/nylon mainline was suspended below three large floats. A National Institute of Polar Research (NIPR) camera/depth recorder housing (figure 2*b*) was attached to the end of this line. Below the camera, bait rigs were suspended from a 3 m nylon monofilament line, weighted down by a 23 cm lead squid jig with a triple hook crown. Two 0.5 m side branches were attached; the first bore a single large hook with a fresh Japanese Common Squid (*Todarodes pacificus*) of 22–25 cm mantle length (ML). The second branch bore a mesh bag filled with freshly mashed euphausid shrimps as an odour lure. A second bait squid was attached directly to the weighted squid jig. The NIPR system contained a digital camera, timer, strobe, depth sensor, data logger and depth-activated switch (Watanabe *et al.* 2003). The camera captured JPEG images of around 150 KB. The system was configured to commence operation below 200 m, taking images every 30 s for 4–5 h. The orientation of the camera was always vertical, facing downwards towards the baits.

(b) *Molecular sequence*

A 1276 bp sequence of mtDNA COI gene was extracted from a flesh tissue obtained from the severed tentacle that remained attached to the squid jig. Extraction, amplification, cloning and sequencing methods follow Carlini & Graves (1999) and Kano & Kase (2004).

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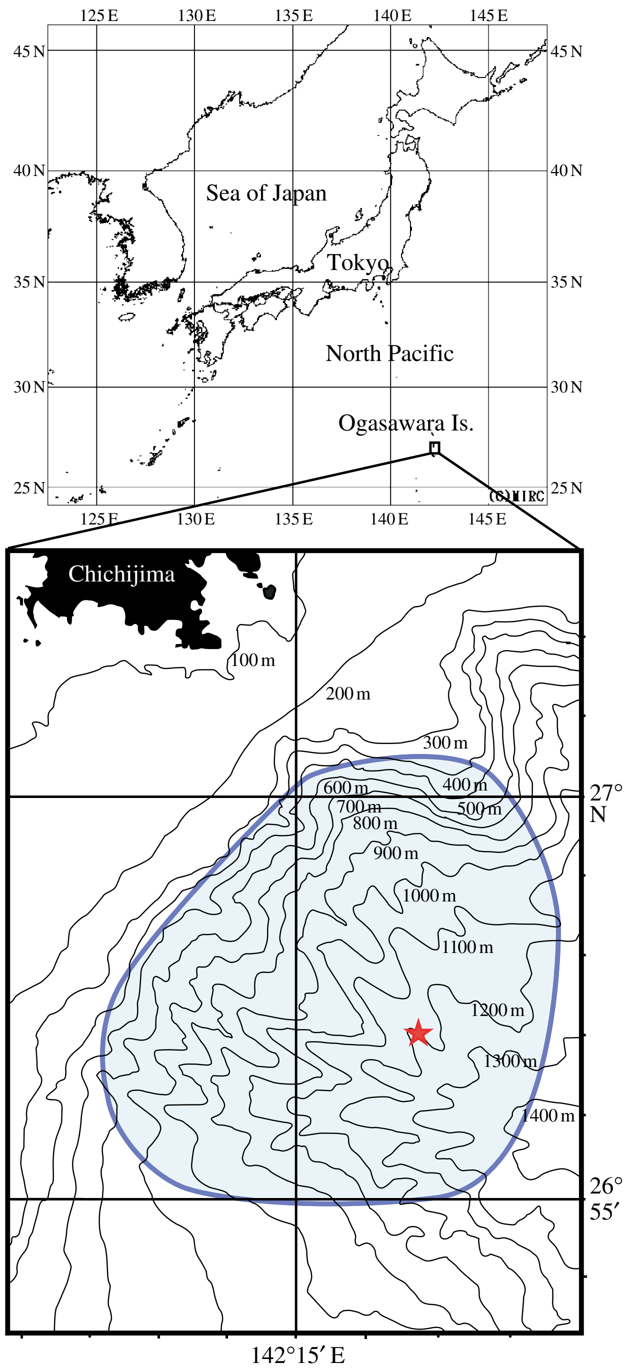

Figure 1. Research area and location of *Architeuthis* capture (star). Seafloor contours are in metres.

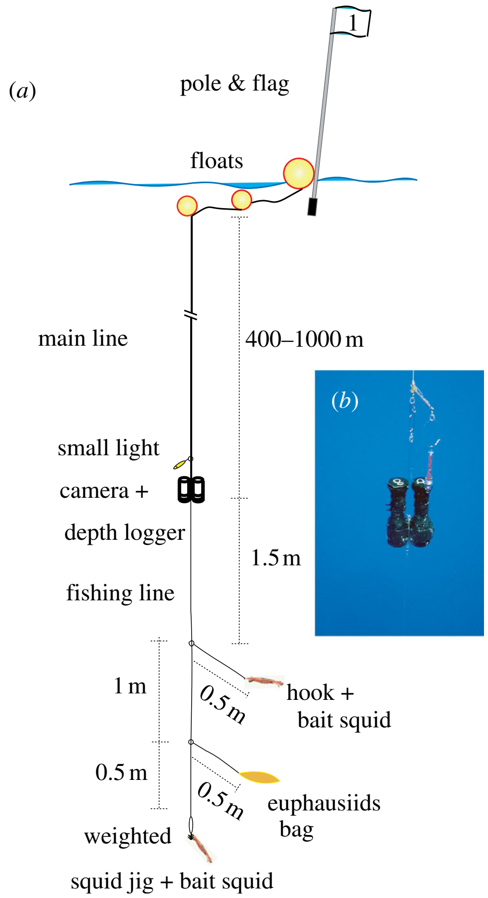

Figure 2. (*a*) Diagram of vertical long-line system used for survey. (*b*) Remote camera system.

(c) *Size estimation*

Based on available datasets for *Architeuthis* morphology (Roeleveld & Lipinski 1991; Förch 1998; Kubodera 2004), ML was estimated from tentacle club length (TCL) according to the equation $y=2.393x-107.956$ (y; ML in mm, x; TCL in mm, $n=7$, $r=0.941$, ML=1200–2020 mm). Diameter measurement of the largest sucker on the tentacle club (LSD) enabled ML estimation according to $y=61.69x-18.105$ (y; ML in mm, x; LSD in mm, $n=9$, $r=0.791$, ML=1040–2020).

3. RESULTS

At 09.15 h on 30 September 2004, an individual giant squid attacked the lower squid bait of one of our camera systems at 900 m over a seafloor depth of 1200 m at 26°57.3′ N, 142°16.8′ E (figure 1). The squid's initial attack was captured on camera (figure 3*a*) and shows the two long tentacles characteristic of giant squid wrapped in a ball around the bait. The giant squid became snagged on the squid jig by the club of one of these long tentacles. More than 550 digital images were taken over the subsequent 4 h which record the squid's repeated attempts to detach from the jig. For the first 20 min, the squid disappeared from view as it actively swam away from the camera system. For the next 80 min, the squid repeatedly approached the line, spreading its arms widely (e.g. figure 3*b*) or enveloping the line. During this period the entire camera system was drawn upwards by the squid from 900 m to a depth of 600 m (figure 3*g*). Over the subsequent 3 h, the squid and system slowly returned to the planned deployment depth of 1000 m. For the last hour, the line was out of the camera frame, suggesting that the squid was attempting to break free by swimming (finning and/or jetting) away from the system. Four hours and 13 min after becoming snagged, the attached tentacle broke, as seen by sudden slackness in the line (figure 3*c* versus *d*). The severed tentacle remained attached to the line and was retrieved with the camera system (figure 3*e*). The recovered section of tentacle was still functioning, with the large suckers of the tentacle club repeatedly gripping the boat deck and any offered fingers (figure 3*f*).

The tentacle portion was 5.5 m long and its identification was confirmed by both morphology (paired suckers and lugs along tentacle shaft, a character unique to giant squids) and by DNA sequence analysis. COI sequence

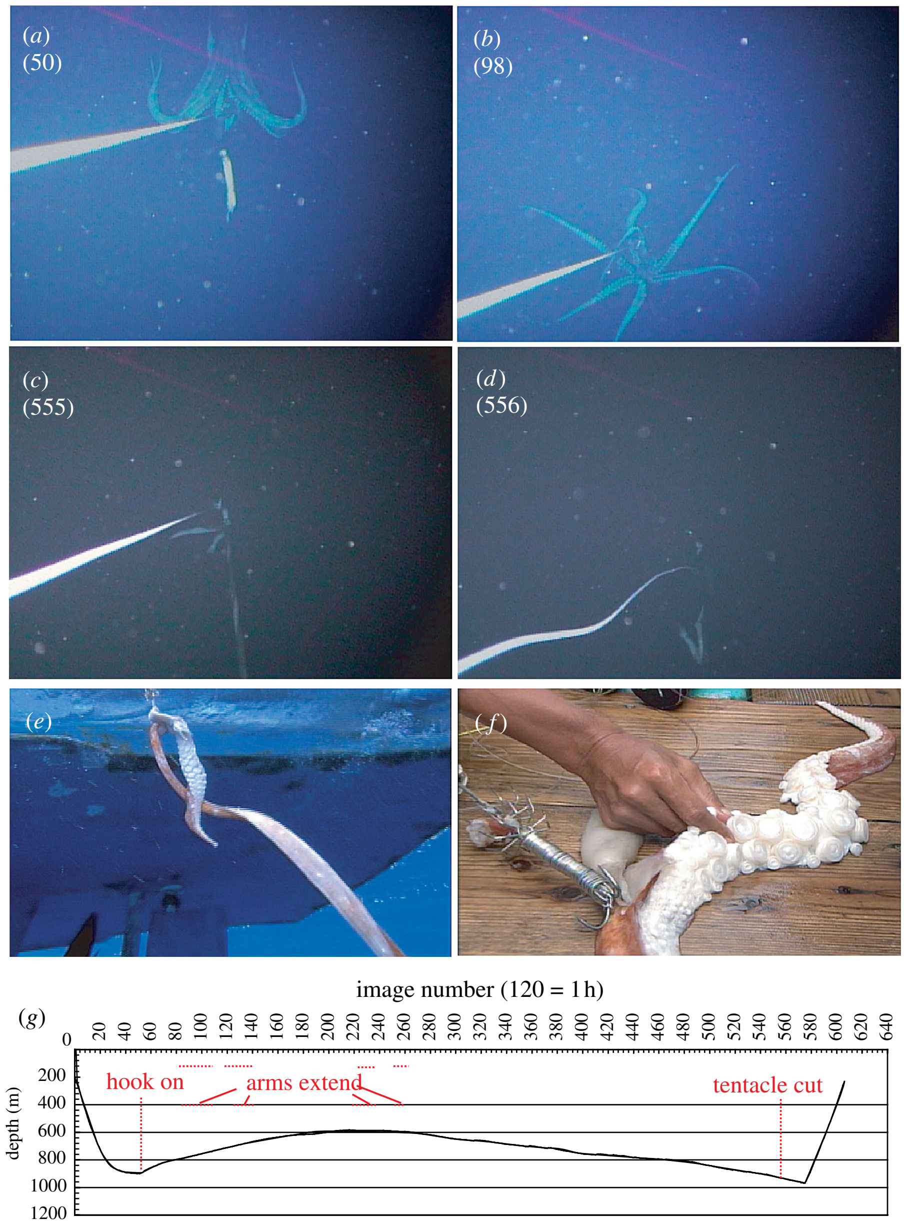

Figure 3. Digital images captured by remote camera system at 26°57.3′ N, 142°16.8′ E on 30 September 2004 (image numbers in parentheses in (*a*)–(*d*). (*a*) First image of *Architeuthis*; (*b*) spread arms; (*c*) tentacle attached to jig; (*d*) subsequent image (30 s later) at moment of tentacle break, as seen by sudden slackness in the line; (*e*) squid jig with tentacle attached; (*f*) tentacle club on deck; and (*g*) summary of depth, image number and *Architeuthis* behaviours recorded by the remote camera system.

extracted from our recovered tentacle was as given in the electronic supplementary material.

This sequence was 99.7–100% match with the sequence extracted from five intact *Architeuthis* specimens collected around Japanese waters (Kubodera 2004).

The recovered tentacle had a club length of 720 mm and a LSD of 28 mm. ML estimates are 1615 mm by TCL and 1709 mm by LSD. The head and arm portion of *Architeuthis* usually occupies 60–70% of the body length, so that this animal would have been approximately 4.7 m in length from tip of fin to tips of normal arms and over 8 m in total length including the long tentacles (assuming that the 5.5 m long recovered tentacle portion was severed at its base).

4. DISCUSSION

Images and depth data provide the first records of feeding behaviour for *Architeuthis*. The giant squid was hunting at 900 m during the day (09.15 h), a depth below the deepest penetration of light from the surface. Sperm whales feed at this depth during the day and at 400–500 m at night. It is probable that giant squid rise in the water column at night to feed in these shallower depths.

The most dramatic character of giant squids is the pair of extremely long tentacles, distinct from the eight shorter arms. The long tentacles make up to two-thirds of the length of the dead specimens collected to date. The longest giant squid on record was 18 m total length (Clarke 1969), of which more than 12 m was made up of this tentacle pair. As these feeding tentacles can stretch as they decay, upper size claims for giant squids may be overestimated. Giant squids are unique among cephalopods as they can hold the long tentacle shafts together with a series of small suckers and corresponding lugs along their length that enable the shafts to be ‘zipped’ together. This results in a single shaft bearing a pair of tentacle clubs in claw-like arrangement at the tip.

As with many meso- and bathypelagic squids, giant squid incorporate pockets of ammonia solution within their flesh to enable neutral buoyancy (Clarke *et al*. 1979). Live animal orientation and hunting techniques by giant squid have previously been unknown although many authors presumed *Architeuthis* to be a sluggish, neutrally buoyant squid. Our images suggest that giant squids are much more active predators than previously suggested (Roper & Booss 1982; Hanlon & Messenger 1996; Norman 2000; Nixon & Young 2003) and appear to attack their prey from a horizontal orientation (figure 3*a*). The long tentacles are clearly not weak fishing lines dangled below the body, as seen in figure 3*b,c*. Figure 3*a* also sheds light on the retraction of these tentacles once a prey has been captured. It appears that the tentacles coil into an irregular ball in much the same way that pythons rapidly envelop their prey within coils of their body immediately after striking.

There is still much to learn about these spectacular animals. This encounter was part of an ongoing and broader research program by the authors on the biomass and composition of large meso- and bathypelagic cephalopods of Japanese waters. Investigations of such deep-water cephalopods have been problematic in the past due to probable net avoidance, proximity to terrain too rough for trawling and the general difficulties of investigating deep-sea environments (high costs, need for large ships and specialist equipment). We have demonstrated the strong potential of this relatively simple technique and approach in investigating a group of animals for which little information is available. We look forward to further insights from such research.

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The supplementary Electronic Appendix is available at http://dx.doi.org/10.1098/rspb.2005.3102 or via http://www.journals.royalsoc.ac.uk.