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SHORT NOTES

Hadal cephalopods: first squid observation (Oegopsida, Magnapinnidae, *Magnapinna* sp.) and new records of finned octopods (Cirrata) at depths > 6000 m in the Philippine Trench

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Abstract
During a manned submersible dive in the Philippine Trench, a solitary oegopsid squid of the monogeneric family Magnapinnidae was observed swimming close to the seafloor at 6212 m. The estimated mantle length of the squid was ca. 10 cm. The long slender terminal arm and tentacle filaments characteristic of adult *Magnapinna* were not obvious in the video. The filaments may have been contracted or may not yet have developed. This observation is the first record of squid at hadal depths and extends the known bathymetric range for any squid by 1477 m; an increase of ca. 30%. We also observed four cirrate octopods between 6212 and 6224 m. Although the video quality was poor, these octopods did not appear to be the same species as those reported previously in the Java Trench. These observations extend the known hadal occurrence of cirrates, and cephalopods in general, from the Indian Ocean to the equatorial North Pacific Ocean, suggesting that their global presence in depths > 6000 m may be more extensive than previously recognized.

Keywords Bigfin squid · Dumbo · Cirrate · Octopoda · Hadal zone · Subduction trench · Pacific Ocean

Introduction

Historically, the Cephalopoda were not considered a characteristic Class at hadal depths (depths > 6000 m; Belyaev 1989), but recently, the demersal cirrate octopod *Grimpoteuthis* sp. was recorded in situ as deep as 6957 m in the Indian Ocean (Jamieson and Vecchione 2020). These observations extended the known maximum depth range for cephalopods by 1812 m confirming previous captures that implied octopods may inhabit areas as deep as 8000 m (Ushakov 1952; Birstein and Vinogradov 1955; Akimushkin 1963). The recent hadal octopod records were, however, comprised of just two individuals from one trench ecosystem in the Indian Ocean; therefore, the extent of geographic occurrence of octopods and other cephalopods, such as squids, at these depths remains unresolved due to so few sightings.

The Order Oegopsida includes the deepest known squids. Some are known to inhabit bathypelagic and abyssopelagic waters, often just above the bottom (e.g., Osterhage et al. 2020). The deepest unequivocal record of a squid to date is a 'bigfin squid' (Family Magnapinnidae, Vecchione and Young 1998) observed at 4735 m by manned submersible in the western Atlantic (Vecchione et al. 2001). However, other deep observations of squids have been made; including another magnapinnid photographed at 4708 m in the Kermadec Trench in the SW Pacific Ocean (previously unpublished observation). Although this record is close to the maximum depth record from western Atlantic, the location was in the South Pacific, consistent with a broad geographic distribution of these squids living at great depths.

Magnapinna Vecchione and Young 1998 is a remarkable squid genus, distinctive for their very large fins and extremely long vermiform arm and tentacle filaments (Vecchione et al. 2001). In situ imagery has shown *Magnapinna* to be a deep-sea genus with vertical distribution depths > 1000 m, and with a potentially cosmopolitan distribution, although the number of specimens and in situ

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observations remains extremely low (Vecchione et al. 2001, 2002; Guerra et al. 2002; Guerrero-Kommritz et al. 2018; Osterhage et al. 2020).

This study reports the first in situ observation of a squid at hadal depths (> 6000 m); a magnapinnid recorded on video by a manned submersible at 6212 m in the Philippine Trench in the western Pacific Ocean.

Materials and methods

Video recording was undertaken using the manned submersible DSV *Limiting Factor* (Triton 36k/2; Triton Submarines LLC, US; rated for full ocean depth; Jamieson et al. 2019), deployed from the DSSV *Pressure Drop* during the Philippine Trench leg of the Ring of Fire 2021 expedition.

The primary dive objective was to locate the wreck of the USS *Johnston*, DD-557, that sank in 1944 during combat off Samar, part of the Battle of Leyte Gulf (Willmott 2005). Due to the sensitive nature of this shipwreck being a war grave, the exact location is confidential. The approximate location was ~ 50 km east of the southern tip of Samar Island at the entrance to the Leyte Gulf on the overriding (western slope) side of the Philippine Trench between depths of 6172 and 6242 m (Fig. 1).

The submersible was deployed on 27 March 2021. Video data were acquired using two externally mounted High-Definition (HD) video cameras (IP Multi SeaCam 3105; Deep Sea Power and Light, San Diego, CA, USA), illuminated by 15,500 lm LED lights (LED-1153-A3-SUS; Teledyne Bowtech, Aberdeen, UK). One camera was positioned vertically, looking down at the seafloor at 90° from horizontal, while the other was positioned at 45° toward the seafloor in the direction of travel. Depth and temperature were recorded by twin Conductivity, Temperature and Depth (CTD) probes (SBE 49 FastCAT, SeaBird Electronics, Bellevue, WA, USA).

The submersible traversed the seafloor, maintaining an altitude above the bottom of between 2 and 3 m on a heading perpendicular to the trench axis. The submersible maintained that heading and altitude for 3 h 55 min, during which time the submersible had traveled ca. 2 km between 6172 and 6242 m. Video data were downloaded following the dive and viewed manually. The submersible does not record altitude data, nor did it have laser scales. Therefore, mantle lengths (ML) are estimates.

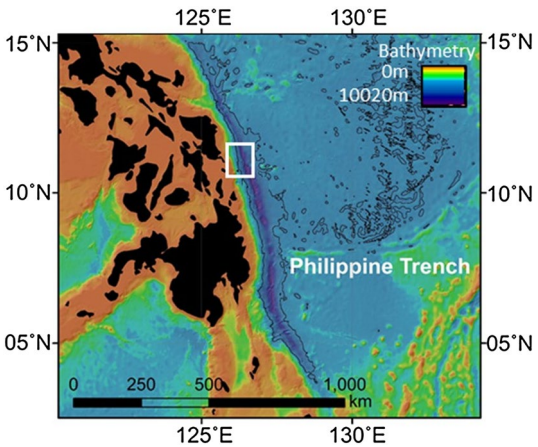

Fig. 1 Study area on the eastern slope of the Philippine Trench in the North Pacific Ocean. White box indicates approximate location

Results and discussion

At 103 min into the dive, a solitary oegopsid squid was observed swimming close to the seafloor at 6112 m with its body horizontal and arms widely spread. The altitude of the sub was unfortunately too high to image the squid in detail but there was sufficient resolution and shadow definition to identify it to the monogeneric family Magnapinnidae based on morphometrics (the extremely large terminal fins and the sizes of the proximal arm sections relative to the mantle; see the left shadow in Fig. 2C) as well as the spread-arm posture characteristic of the family (Vecchione and Young 2016; Fig. 2A–C). Although the submersible has no scale bars or laser scales for reference, the squid appeared to be small, approximately 10 cm ML and swimming ca. 20 cm above the seafloor, based on its size relative to the field of view at 2 m altitude. The fins could be seen moving in manner typical of a swimming magnapinnid, proving that it was alive and not moribund. The individual appeared to be a juvenile on the grounds of its small mantle length, and because there was no visible sign of the long filamentous distal arms and tentacles. Previously unpublished, higher resolution images of a *Magnapinna* sp. from 4708 m in the Kermadec Trench, shown in Fig. 2D for comparison, demonstrate very similar morphology, including lack of obvious filaments, angles of arms from the mantle axis, and size and position of fins relative to mantle length.

Also seen on the submersible transect were four cirrate octopods (Fig. 3). The resolution of the image at such a high altitude above bottom also meant that detailed morphological characters were not recorded. Two of the individuals (filmed at 6218 m) were positioned on the seafloor with their arms spread, stretching the webs into a complete circle. Their fins were moving but they remained stationary. The third, at 6212 m, was the same except the webs were less taut. The fourth individual, at 6224 m, was seen swimming close to the seafloor with its arms more visible as the webs were relaxed. Mantle length could not be estimated from above but the diameter of the arm crown with webs fully extended was estimated at ca. 30 cm for all four individuals.

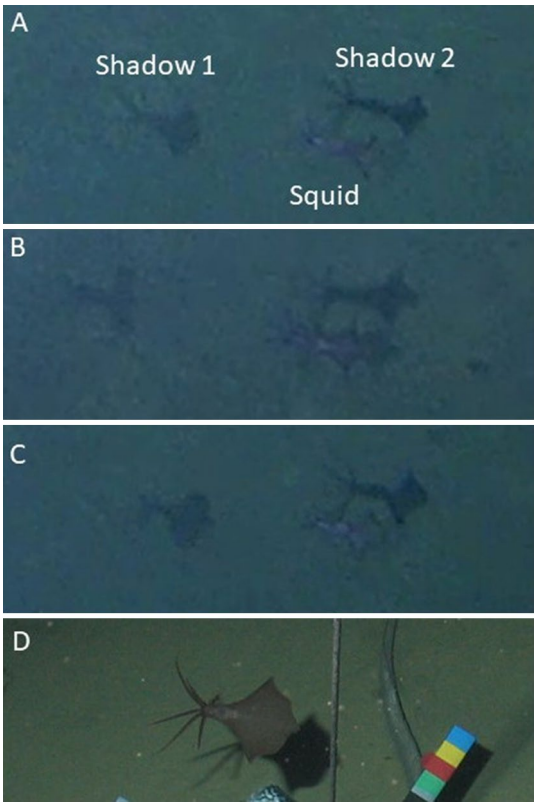

Fig. 2 **A**–**C** Frame grabs from the HD video showing the *Magnapinna* sp. swimming close to the seafloor. Shadows and squid indicated in **A**. **D** For comparison, a similar sized *Magnapinna* sp. photographed at 4708 m in the Kermadec Trench, SW Pacific Ocean, in 2014

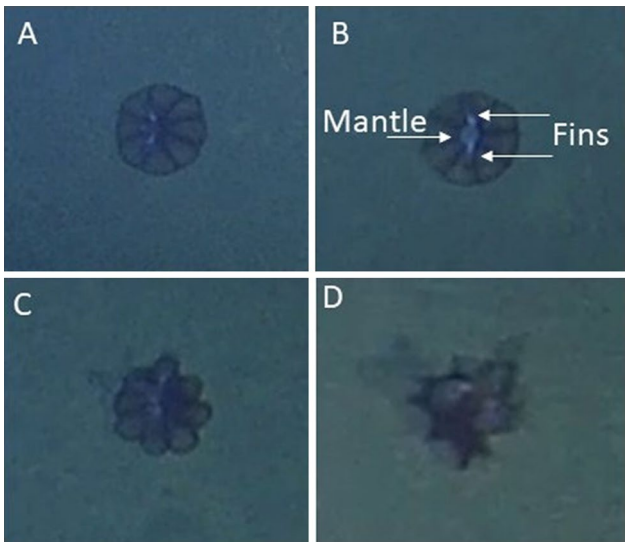

Fig. 3 Four individual cirrate octopods on the seafloor at 6227 m in the Philippine Trench. Mantle and fins indicated in **B**. The diameter of the arms fully extend in **A** is estimated to be ca. 30 cm. In **A**, **B** and **C,** they are sitting essentially motionless on the seafloor, whereas in **D** the individual is swimming close to the seafloor

The four individuals were recorded at 1 h 27 min, 1 h 28 min, 1 h 47 min and 2 h 42 m into the 3 h 55 min observation period; therefore, they were all relatively close to one another, having all been encountered within 85 min, and the first two were just one minute apart.

Two other submersible dives were undertaken around the wreck of the USS *Johnston* but no other cephalopods were observed. The only organisms observed on these dives were occasional penaeid shrimps (*Benthesicymus crenatus*) and an unidentified species of crinoid, both of which are known from these depths (Oji et al. 2009; Swan et al. 2021).

The significance of the observations in this study differs between the two taxa. First, the magnapinnid squid at 6212 m adds 1477 m to the maximum known depth of any squid, an increase of ~ 30% on their bathymetric range (Fig. 4). This is the first time that squid have ever been recorded at hadal depths. Second, the sighting of cirrate octopods extends their known hadal range from the only previously documented occurrence in the Java Trench, Indian Ocean, to the Philippine Trench in the equatorial western North Pacific Ocean. This suggests that cirrate habitation of depths greater than 6000 m may be more widespread than previously recognized and certainly not restricted to the Java Trench.

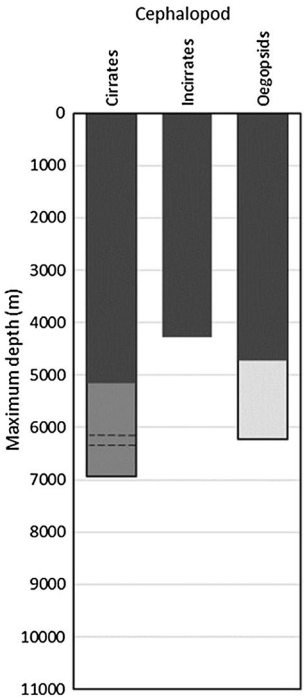

Fig. 4 Maximum known depth range for cirrates, incirrates and oegopsids (dark bars) with the recent cirrate depth range extension from Jamieson and Vecchione (2020) (dark gray bar), with the new cirrate octopod records from this study indicated by dashed lines. The light gray bar represents the depth extension for the oegopsids from this study

Magnapinna sp., are typically oriented vertically, hovering with the fins upward and the filamentous tips of the arms and tentacles dangling down from the widely spread brachial crown. The filaments, however, grow out during the juvenile stage of development (Vecchione and Young 2006) and are retractable (Guerra et al. 2002). Therefore, not seeing them may indicate either that the squid was a late juvenile or that its filaments were retracted. Although the vertical positioning is a characteristic posture, specimens of Magnapinna have been seen swimming horizontally near the bottom (e.g., Osterhage et al. 2020, Fig. 3).

Identification of the cirrate octopods is a problem. They do not appear to be *Grimpoteuthis*, as previously reported from the Java Trench (Jamieson and Vecchione 2020). The appearance and behavior of our observed cirrates is similar to those reported by Collins and Villanueva (2006), which were identified as members of the family Cirroteuthidae that were feeding on the bottom. Several external characters supporting that identification are visible in our frame grabs. These include (a) the large lobe-shaped fins in Fig. 3B, D, (b) single long web nodules in Fig. 3C, reminiscent of those in *Cirroteuthis muelleri*, and (c) possible narrow "secondary webs" (Vecchione and Young 1997) between the arms and the "primary webs". Cirroteuthids are known to swim far above the bottom, but they have been seen near bottom (Vecchione and Young 2016). They must sometimes associate closely with the bottom because cirrates attach their eggs to deep corals (Vecchione 2019).

The depth extension from abyssal to upper hadal depths of both taxa could be important in terms of geographical distribution. The Pacific and Indian Oceans are largely deep oceanic basins. Although they average ca. 3500–4000 m depths, they also include vast abyssal plains greater than 5000 m, punctuated by large basins of close to, and often exceeding, 6000 m (Jamieson and Stewart 2021; Weston et al. 2021). If depth ranges of bottom-associated cephalopods were limited to 5000 m, then their distribution would be largely confined to the oceanic rims. However, with depth ranges exceeding 6000 m, and assuming both taxa are associated with the seafloor then their assumed habitat may be greatly increased into the expanses of the Pacific and Indian Ocean basins. The next question with regard to distribution is whether these deep populations of squid and cirrate octopods are confined to the equatorial regions and, and if not, how far north and south they are distributed.

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Data availability The data that support the findings of this study are copyright of Caladan Oceanic LLC and restrictions apply to the availability of these data, which were used under licence for the current study, and so are not publicly available. Data are, however, available from the authors upon reasonable request and with permission of Caladan Oceanic LLC.

Declarations

Conflict of interest The authors declare no conflict of interest.

Ethical approval All applicable international, national and/or institutional guidelines for sampling, care and experimental use of organisms for the study have been followed.

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