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Discovery of Dense Aggregations of Stalked Crinoids in Izu-Ogasawara Trench, Japan

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Stalked crinoids are recognized as living fossils that typically inhabit modern deep-water environments exceeding 100 m. Previous records of stalked crinoids from hadal depths (exceeding 6000 m) are extremely rare, and no in-situ information has been available. We show here that stalked crinoids live densely on rocky substrates at depths over 9000 m in the Izu-Ogasawara Trench off the eastern coast of Japan, evidenced by underwater photos and videos taken by a remotely operated vehicle. This is the deepest in-situ observation of stalked crinoids and demonstrates that crinoid meadows can exist at hadal depths close to the deepest ocean floor, in a fashion quite similar to populations observed in shallower depths.

Key words: crinoid, echinoderm, hadal zone, trench, biogeography

INTRODUCTION

Stalked crinoids, often treated as "living fossils," were widely distributed in shallow water in the geologic past, but now are confined to depths exceeding 100 m (Meyer and Macurda, 1977; Oji, 1986). Previous records of stalked crinoids from hadal depths are scarce. Only two records exist: *Bathycrinus australis* collected by the Danish R/V *Galathea* from the Kermadec Trench (8210–8300 m), and *Bathycrinus volubilis* collected by the former Soviet Union's R/V *Vityaz* from at least six stations (8175–9345 m) from the Kamchatka-Kuril, Japan, and Izu-Ogasawara Trenches (Mironov, 2000). These records revealed that stalked crinoids, among other echinoderms, can occur at extreme depths, near the maximum depth of the ocean. However, the crinoids were all collected by trawling, and thus far there has been no information on the habitat, ecology, or lifestyle of these hadal crinoids. This paper confirms the existence of stalked crinoids at hadal depths in the Izu-Ogasawara Trench using underwater photos and video taken by a Japanese remotely operated vehicle, and describes and discusses their mode of life compared with other stalked crinoids living at shallower depths.

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MATERIALS AND METHODS

The Japanese remotely operated vehicle (ROV) *Kaiko* of JAMSTEC (Japan Agency for Marine-Earth Science and Technology) carried out two dives (Nos. 148 and 151) in 1999 into the northern part of the Izu-Ogasawara Trench, located approximately 110 km SE of Tokyo. The dates, coordinates, and depth ranges of the two dives were: Dive 148, 9 Dec. 1999, 34°17.3'N to 34°17.4'N, 141°51.6'E to 141°51.8'E, depth range 8967–9090 m; Dive 151, 12 Dec. 1999, 34°17.1'N to 34°17.2'N, 141°51.8'E to 141°52.0'E, depth range 8994–9102 m.

The diving transects were located on the western slope of the Izu-Ogasawara Trench. We used time-lapse color photos and video images taken during both dives. Unfortunately, as no specimens were captured by the ROV, the sizes of the crinoids were measured from the photos and videos by comparing them to the known size of the manipulator. An enlarged view of crinoids with the manipulator, taken from a video, is shown in Fig. 2. The underwater photos showed an undulating bottom topography with frequent steep slopes, some of which possessed the clear bedding structure of sedimentary rocks. The bottom surface consisted of consolidated sedimentary rocks, cobbles, and boulders, as well as bottoms comprising a thin veneer of mud over the rocks.

RESULTS

The videos and photos revealed high-density populations of stalked crinoids distributed exclusively on rocky substrates near the deepest part of the Izu-Ogasawara Trench (Fig. 1). Stalked crinoids were observed in most frames showing exposed rocky substrates. The depth ranges of the confirmed crinoid distribution were 9019–9090 m for Dive 148, and 8994–9102 m for Dive 151. All individuals were small, and most were of approximately the same size (Fig. 2); the size of only one individual was measured with confidence by comparison with the size of the manipulator. The stalk was about 13 cm, arm length was about 10 cm,

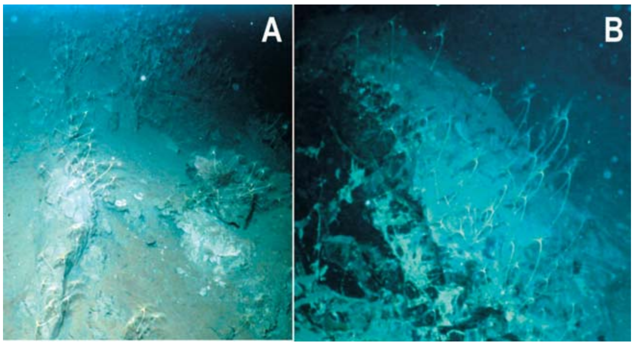

Fig. 1. Stalked crinoids (bathycrinids) observed by ROV *Kaiko* in the northern Izu-Ogasawara Trench. **(A)** Highly dense concentration of stalked crinoids at a depth of 9049 m (Dive 148). Individuals are evident only on hard substrates, not on muddy substrates. **(B)** Specimens erect on a large boulder at a depth of 9063 m (Dive 148). All arms are oriented toward the left (downcurrent) in a typical feeding posture.

Fig. 2. Close-up view of bathycrinid crinoids from a depth of 9087 m (*Kaiko* Dive 148). Note that the crinoids have possibly 10 arms, with long pinnules (appendages on the arms), and slender stalks with slight undulations on the lateral surface. At the right is a part of the manipulator of ROV *Kaiko*.

and there were 10 arms. Although the resolution of the video was not good, the lateral stalk surfaces of some specimens (Fig. 2) show a fine zigzag pattern (undulating, not smooth), suggestive of the synarthrial articulations characteristic of the order Bourgueticrinida (Rasmussen, 1978), a taxon common at bathyal depths. The appearance of these crinoids suggests they might represent *Bathycrinus volubilis*, a species previously described from Kamchatka-Kuril, Japan, and Izu-Ogasawara Trenches (Mironov, 2000).

The stalked crinoids were found only on the rocks that make up topographic relief within the trench; none were seen on muddy substrates. Due to the proximity to a subduction zone, the bottom was dominated by slopes and undulations, both consisting mainly of rocks but partly covered with mud, with occasional large boulders. Crinoids appeared to be attached to rocks, although we could not determine from the photos whether they employed radicular cirri (root-like appendages), typical of *Bathycrinus*, or a terminal attachment disk. Specimens spread their arms in either shallow parabolic fans (Fig. 1A), radial fans (Fig. 1B), or conical fans (Fig. 2). These postures, together with the downcurrent orientation of the oral surface and downcurrent bending of the stalks, all reflect typical feeding postures in a current, as previously documented (Macurda and Meyer, 1974; Messing et al., 1990) (Fig. 1B). When disturbed by the manipulator, crinoids closed their arms inward (adorally). Besides crinoids, only a few frames in one spot showed some scale worms (polychaetes), on a flat surface at a depth of 8967 m in Dive 148.

DISCUSSION

These results represent the deepest in-situ observation of stalked crinoids. Previous records of stalked crinoids from hadal depths, *Bathycrinus australis* from the Kermadec Trench from 8210–8300 m (Gislén, 1956) and *Bathycrinus volubilis* from the Kamchatka-Kuril, Japan, and Izu-Ogasawara Trenches from 8175–9345 m (Mironov, 2000), were based on trawled material. The precise depths of deep-water trawls are difficult to ascertain, especially in steeply sloping areas. Among these stations, only one (*Vityaz* Stn. 5631, central Izu-Ogasawara Trench, 9070–9345 m), might have exceeded the maximum depth confirmed by *Kaiko* (9102 m).

Stalked crinoids clearly occur in abundance at depths greater than 9000 m, and show the same feeding postures (mouths directed downcurrent) as many shallower-water taxa. Similarly dense populations of stalked crinoids, or “crinoid meadows,” have previously been photographed at bathyal depths in the Caribbean (e.g., Messing et al., 1990) and from the Bay of Biscay (Conan et al., 1980). Our observations also show that stalked crinoids are the most abundant macroinvertebrates in the northern Izu-Ogasarawa Trench. The previous records by *Galathea* and *Vityaz* suggested that these bathycrinids might be a major constituent of the fauna in the deepest part of the ocean.

Our discovery also implies that sufficient food supply reaches the crinoids despite the extreme depths. The amount of organic matter generally decreases dramatically with increasing depth, due to bacterial decomposition (Suess, 1988). Mironov (2000) suggested the existence of a hydrothermal or seep condition responsible for an abundance of fauna away from or near the axis of trenches. However, the photos and videos we examined revealed no evidence of a hydrothermal or seep environment near the crinoid habitat. The diving area was near the axis of the trench and located near the Japanese Islands, and organic matter may have been abundant in the narrow trench bottom. In the surface sediments at a hadal site (7800 m) in the Atacama Trench, Danovaro et al. (2003) detected concentrations of organic matter similar to those from shallow coastal seas, and considered that this trench behaved as a deep oceanic trap for organic material. If so, this may explain why there are abundant stalked crinoid populations near the axis of the trench we examined.

We expect that dense crinoid populations are widespread in deep, unexplored trenches where similar conditions prevail. Our discovery also shows that habitats with rock and boulders substrates are a favorable environment for stalked crinoids; it is likely that such trenches located in similarly active tectonic zones have offered appropriate environments for stalked crinoids in the geologic past.

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