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Histioneis (Dinophysiales, Dinophyceae) from the western Pacific Ocean

Fernando Gómez[a]

Station Marine de Wimereux, Université des Sciences et Technologies de Lille, CNRS UMR 8013 ELICO, 28 avenue Foch, BP 80, F-62930 Wimereux, France,
e-mail: fernando.gomez@fitoplancton.com

Abstract

The distribution of the dinoflagellate *Histioneis* was studied in the vicinity of the Kuroshio Current, the Philippine, Celebes, Sulu and South China Seas and the western and central equatorial Pacific Ocean. A total of 65 specimens, assigned to 17 species, was observed. For the first time, photomicrographs of several species are reported. *Histioneis cymbalaria* and *H. longicollis* were the most common. Nearly all specimens were recorded from 0–70 m depth, and the highest abundance was recorded in the Philippine Sea in July (32°N, 138°E, 30 m depth) with a maximum of 32 individuals per litre.

Keywords: dinoflagellates; Dinophysiales; *Histioneis*; Pacific Ocean; phytoplankton.

Introduction

The tropical dinophycean *Histioneis* Stein (Histion=wing, neis=vessel) is characterized by an antero-posteriorly flattened, usually rotund to reniform or subreniform cell body with ornate hyaline list and rib systems. The left sulcal list is highly developed, whereas the right sulcal list is vestigial. The cingulum has a very long dorsal edge, is almost horizontal, and very concave. The epitheca has been reduced to a minute disc (Kofoid and Skogsberg 1928). Chloroplasts are absent and symbiotic cyanobacteria occur between the two robust lists of a large cingular chamber (Hallegraeff and Jeffrey 1984). The genus *Parahistioneis* Kofoid *et* Skogsberg is distinguished from *Histioneis* mainly by the absence of the submarginal cross-rib of the posterior cingular list found in *Histioneis* (Kofoid and Skogsberg 1928). *Parahistioneis*, intermediate between the genera *Ornithocercus* Stein and *Histioneis*, is considered to be congeneric with *Histioneis* (Balech 1971, 1988, Sournia 1986).

Histioneis is a rare genus; its delicacy, transparency, small size and limited investigations in warm/tropical waters in the last decades contribute to the scarce records. Little is known of its ecological and geographical distribution. Records of *Histioneis* from the north-western Pacific Ocean are restricted to a few citations along the coasts of Japan by Okamura (1912) and Abé (1967). Böhm (1936), Rampi (1952) and Balech (1962) reported several species from the tropical waters of the western and central Pacific Ocean. Wood (1963a,b) described several taxa from the surrounding waters of Australia. For the eastern Pacific Ocean, Kofoid and Skogsberg (1928), in the most complete study on *Histioneis* to date, described and well illustrated numerous species.

The present study describes and illustrates the abundance and composition, geographic and vertical distributions of *Histioneis* collected in several regions of the tropical and equatorial western Pacific Ocean.

Materials and methods

Samples were collected during 10 cruises in the western Pacific Ocean (Figure 1).

- Two cruises were carried out on board R/V *Soyo Maru* (13–20 May and 3–10 July 2002) along the meridian 138°E in the vicinity of the Kuroshio Current. Nine stations were sampled from 30°30′N to 34°15′N in May, and 10 stations from 30°0′N to 34°20′N during the July cruise. At each station, 15 depths from 5–200 m were sampled.
- R/V *Hakuho Maru* visited the Celebes, Sulu and South China Seas from 7 November to 18 December 2002. Samples were collected from 10 stations at six depths from 0–150 m.
- A cruise was carried out on board R/V *Mirai* (15–28 January 2003) along the equator from 160°E to 160°W. Samples were collected from 9 stations at 14 depths between 0–200 m. In addition, during the ship transit in returning to Japan, several 5-l samples were collected by pumping from ca. 5 m depth and filtering through 10-μm pore size Nylon mesh.
- Six cruises were completed at station H (41°30′N, 145°47′E) on board R/V *Oshoro Maru* and station A7 (41°30′N, 145°30′E) on board R/V *Wakataka Maru* in the Oyashio area during the spring and summer of 2003.

Samples collected by Niskin bottles were preserved with acidified Lugol's solution and stored at 5°C. Samples of 400 ml were concentrated via sedimentation in glass cylinders. Over five days, the top 350 ml of each sample was progressively and slowly siphoned off with small-bore tubing. Fifty ml of concentrate from 400 ml of water were settled in composite settling chambers. The entire chamber was scanned at 200× with an inverted Nikon (Tokyo, Japan) microscope equipped with a Nikon digital camera and the specimens of *Histioneis* were photographed for further precise identification. Film photographs were taken during a short period when the digital camera was unavailable.

[a] Present address: Department of Zoology, The Natural History Museum, Cromwell Road, London SW7 5BD, UK.

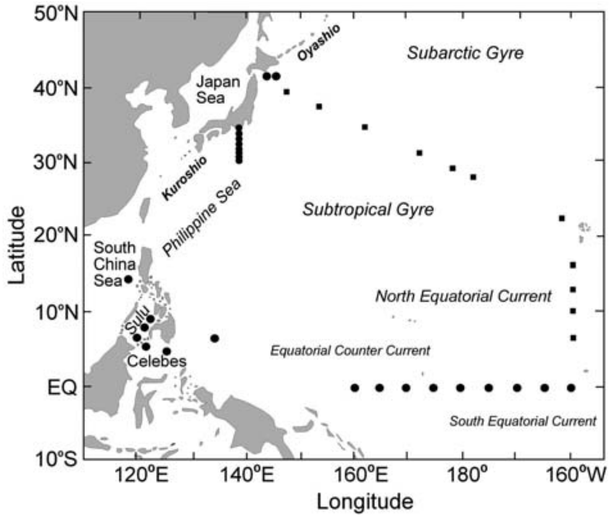


Figure 1 Map of the station locations marked by black circles in the western Pacific Ocean.
The black squares represent surface net sampling.

Results

A total of 65 specimens of *Histioneis* was recorded in the western Pacific Ocean and were tentatively assigned to 17 species (Figures 2–33). All specimens were observed as single cells, never in couplets of dividing cells, triads or tetrads (as occurs in other dinophyceans). *Histioneis cymbalaria* Stein *sec* Balech (1988), with a sulcal list tapering posteriorly to a point, or rounder and with a variable degree of reticulation, was the most common species (Figures 3–4, 9–13). One specimen with a less complexly ribbed sulcal list was tentatively assigned to *H. cleaveri* Rampi, being the first record after the original description (Figure 2). Specimens with a sulcal list with several radiating ribs from the main posterior rib and the posterior sulcal list more dorsally extended that *H. cymbalaria* were tentatively considered as *H. pacifica* Kofoid *et* Skogsberg (Figures 5–7). Figure 8 illustrates a tentatively immature specimen of a species related to the previous taxa. After *H. cymbalaria*, the most abundant species was *H. longicollis* Kofoid, and this species is assumed to show a variable development of the sulcal list (Figures 19–24). Several specimens, with less elongate appearance and shorter sulcal list lacking ornamentation in the posterior rib compared to *H. longicollis*, were considered to be *H. joergensenii* Schiller (Figures 17–18).

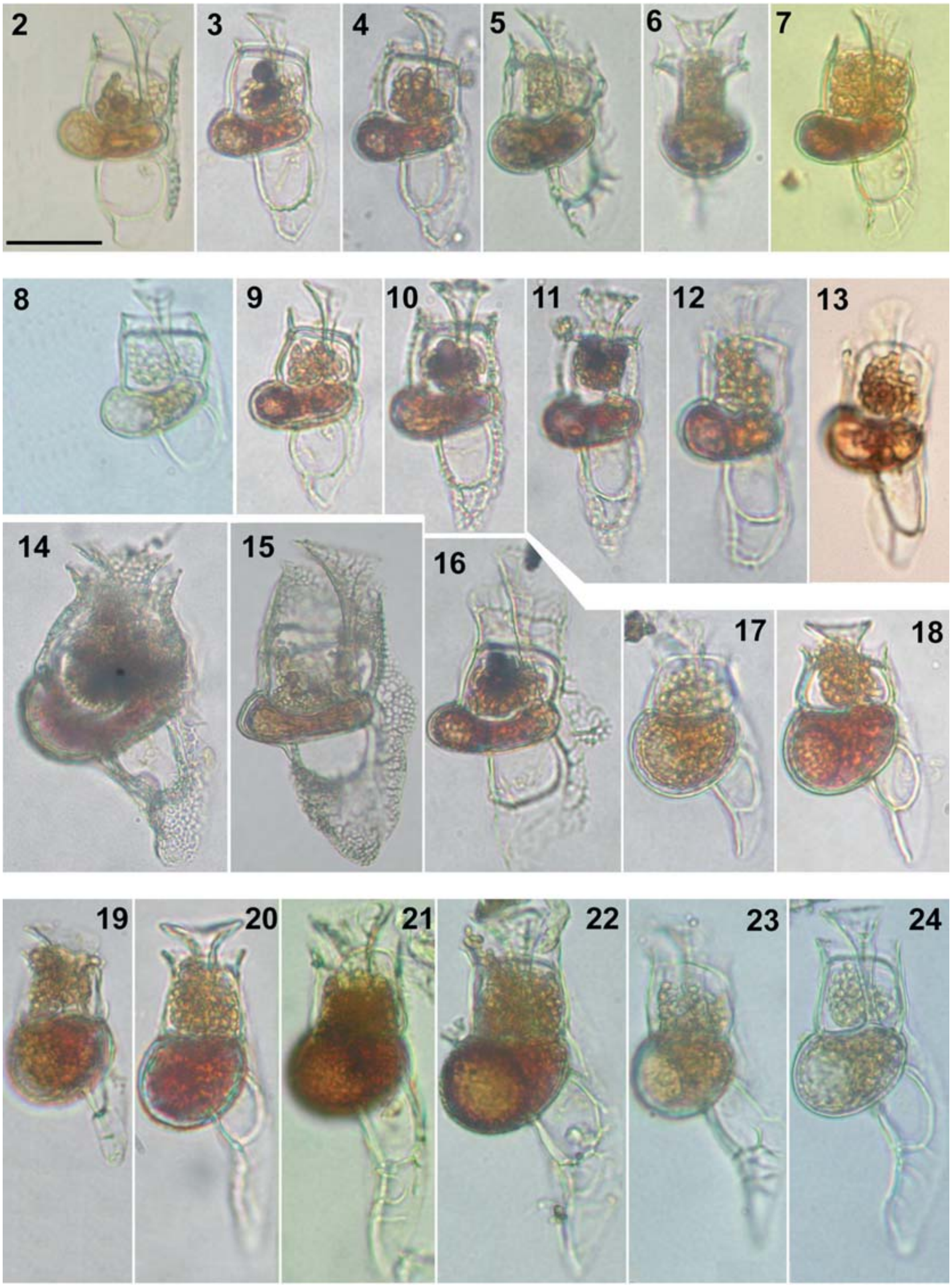
Other species were observed from single or a few specimens, such as *Histioneis pietschmannii* Böhm *in* Schiller from the South China Sea, *H. mitchellana* Murray *et* Whitting and *H. schilleri* Böhm *in* Schiller from the Philippine Sea (Figures 14–16). Two specimens were identified as *H. elongata* Kofoid *et* Michener (Figures 25–26) and another corresponded to *H. costata* Kofoid *et* Michener (Figure 27). One specimen from the Philippine Sea was tentatively assigned to *H. sphaeroidea* Rampi (Figure 29), being the first record beyond the Mediterranean Sea (Gómez 2003). The identification of several specimens of the former genus *Parahistioneis* were more difficult, e.g., *H. para* Murray *et* Whitting or *H. paraformis* (Kofoid *et* Skogsberg) Balech. The specimen in Figure 30 was assigned to *H. para*, and a larger specimen to *H. paraformis* (Figure 31). Another specimen was tentatively assigned to *H. pachypus* Böhm *in* Schiller (Figure 28), and another tentatively identified as *H. oxypteris* Schiller (Figure 32). In one case, the poor quality of the photomicrograph did not allow precise identification (Figure 33).

In the vicinity of the Kuroshio Current (138°E) 10 individuals of *Histioneis* were found from the 131 samples analysed during the cruise in May. Four specimens were collected at 32°N. The maximum abundance was only two specimens per sample (5 cells l^{-1}) (Figure 34). During the cruise in July, the stations were re-visited and 38 specimens were observed from 144 samples. As in May, the higher abundance was recorded in the offshore subtropical waters of the Philippine Sea at 32°N. At this station, 17 individuals were collected, with 13 specimens at 30 m depth (Figure 35). Nearly all the specimens corresponded to *H. cymbalaria*, and a few specimens to *H. longicollis*. During the cruise in the marginal seas of the western Pacific Ocean 9 specimens were recorded from the 81 samples examined. All the specimens were collected in the 0–30 m depth range, except for one individual at 150 m depth in the Sulu Sea (Figure 36). In the western and central equatorial Pacific Ocean, only 8 specimens were observed from the 124 samples analysed. All the specimens were found in the western Pacific warm pool and we have no records in the equatorial upwelling region (Figure 37). Samples from six cruises carried out off Hokkaido (north of Japan) were also analysed during this study. No specimen of *Histioneis* was observed in these cold subarctic waters under the influence of the Oyashio Current.

Discussion

Two species, *Histioneis cymbalaria* and *H. longicollis*, were the most common in the regions of the Pacific Ocean examined. However, previous studies in the area did not report these taxa. In the coastal waters off southern Japan, Okamura (1912) reported *H. highleyi* Murray *et* Whitting, *H. paraformis* (as *H. para*), *H. paulsenii* Kofoid (?*H. carinata* Kofoid or ?*H. elongata*) and *H. reticulata* Kofoid. Abé (1967) reported *H. hippoperoides* Kofoid *et* Michener, *H. pietschmanii* and *H. mitchellana*. These authors collected their samples from surface hauls in coastal waters. Net sampling facilitates collection of rare species of phytoplankton, but the smaller and fragile specimens may be inefficiently retained, and their abundances subsequently underestimated in comparison with larger or resistant congeneric taxa. In the present study, small species such as *H. cymbalaria* (<70 μm length) were more common in offshore oligotrophic waters (Figures 34–37). Iriarte and Fryxell (1995) only reported *H. longicollis* and *H.* cf. *mitchellana* in the central equatorial Pacific Ocean.

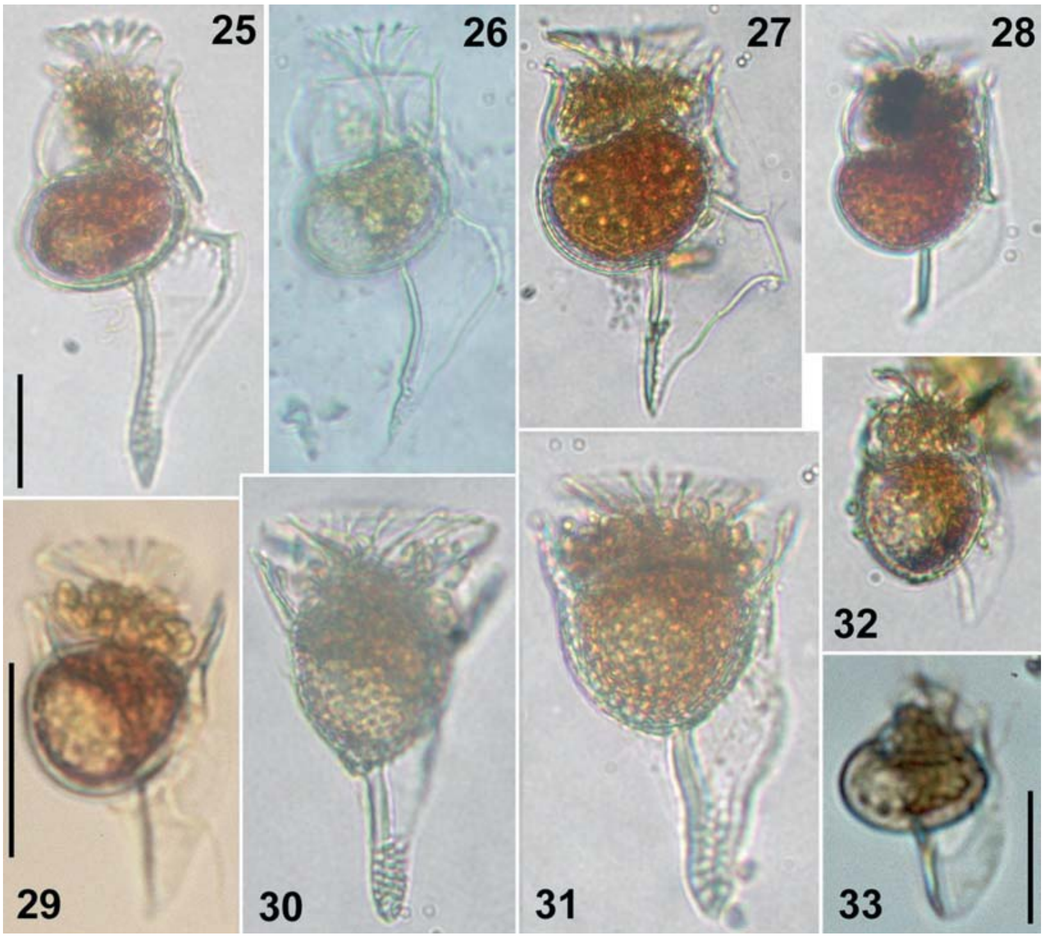
In general, *Histioneis* is a rare genus. Exceptionally, 13 specimens were found in one sample (32 cells l^{-1}). The hydrological and trophic conditions (major nutrients), and



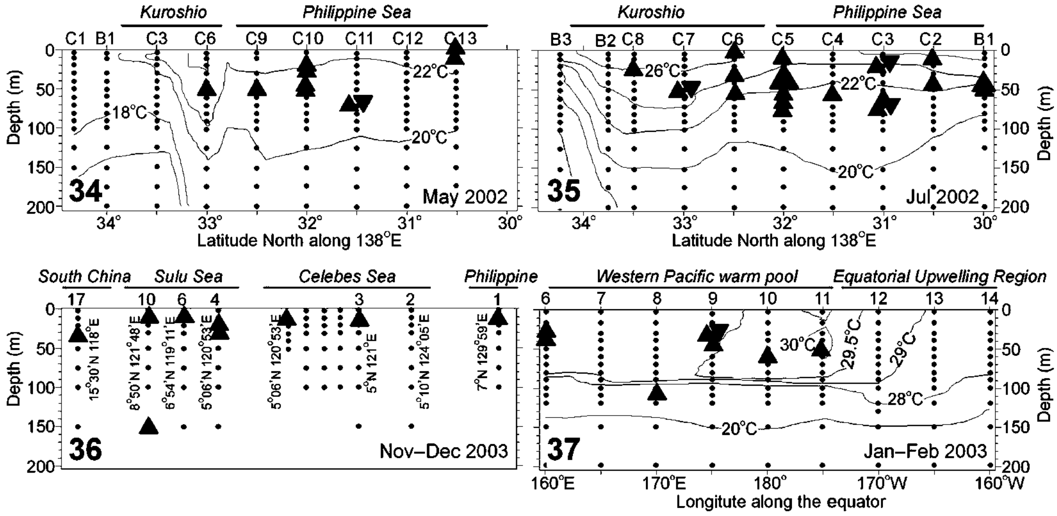
Figures 2–24 Photomicrographs, bright field optics, of *Histioneis* in right lateral view (except Figure 6 in dorsal view). (2) Tentatively *H. cleaveri* (33°N, 138°E; 50 m depth). (3–4, 9–13) Several specimens of *H. cymbalaria* sec Balech (1988). (5–6) Tentatively *H. pacifica* (0°, 175°W; 50 m depth). (7) Tentatively *H. pacifica* (0°, 180°; 60 m depth). (8) Unidentified specimen (0°, 180°; 0 m depth). (14) *H. pietschmannii* (14°30′N, 118°E; 30 m depth). (15) *H. mitchellana* (32°30′N, 138°E; 50 m depth). (16) *H. schilleri* (7°N, 130°E; 30 m depth). (17–18) *H. joergensenii*. (19–24) *H. longicollis*. All at the same magnification, scale bar=20 μm.

the phytoplankton assemblage at the collection site were investigated, and compared to the surrounding stations. Not one of these factors can be inferred as responsible for the higher abundance of *Histioneis* at this location. Along the equator, *Histioneis* was found from 170°E to 175°W, coinciding with high seawater temperatures (>29.5°C) and very oligotrophic conditions during El Niño in January 2003 (Figure 37).

The distribution of *Histioneis* was different from the autotrophic or mixotrophic species of *Dinophysis* that can achieve high abundance in eutrophic coastal waters. The apochlorotic *Histioneis* differs from *Dinophysis* in having a large cingular chamber that seems to be an adaptation for hosting unicellular cyanobacteria. These symbionts, named phaeosomes in early literature, were observed extracellularly in *Ornithocercus* and *Citharistes*



Figures 25–33 Photomicrographs, bright field optics, of *Histioneis* in right lateral view.
(25) *H. elongata* (32°N, 138°E; 50 m depth). (26) *H. elongata* (0°, 180°; 0 m depth). (27) *H. costata* (5°N, 121°E; 10 m depth). (28) Tentatively *H. pachypus* (7°N, 130°E; 10 m depth). (29) Tentatively *H. sphaeroidea* (33°30′N, 138°E; 20 m depth). (30) *H. para* (8°50′N, 121°48′E; 150 m depth). (31) *H. paraformis* (32°30′N, 138°E; 30 m depth). (32) Tentatively *H. oxypteris* (8°50′N, 121°48′E; 150 m depth). (33) Unidentified specimen (30°30′N, 138°E; 50 m depth). All at the same magnification, except Figure 29 and Figure 33; scale bars=20 μm.



Figures 34–37 Section plots of the records of *Histioneis* in the western Pacific Ocean indicated by black triangles (see Figure 1). (34) Records along the meridian 138°E in May. (35) Records from the same location in July. (36) Records from Celebes, Sulu and South China Seas. (37) Records from the western and central equatorial Pacific Ocean. The distribution of temperature is shown.

Stein and intracellularly in *Amphisolenia* Stein (Hallegraeff and Jeffrey 1984, Lessard and Swift 1986). In the present study, nearly all the specimens of *Histioneis* contained symbionts. The few exceptions were probably due to losses through sample treatment or damage to the cingular chamber. Norris (1967) described the rod-shaped, purple/pink cyanobacterium in *Histioneis* as *Synechococcus carcerarius* R.E. Norris. From living material, Lucas (1991) reported the presence of dividing cells in all the populations of symbionts, indicating active growth. He suggested that transmission of the symbiont in *Histioneis* occurs (rather that renewed infection). In the study of Hallegraeff and Lucas (1988), the food contents in *Histioneis* were not recognizable, but resembled cyanobacteria.

During the present study, samples were collected from the surface to 200 m depth. Nearly all the specimens were found in the upper 70 m depth (rarely just in the surface waters) and the highest abundance of *Histioneis* was at 30 m depth (Figures 34–37). If it is assumed that the cingular chamber functions as a greenhouse in which *Histioneis* grows symbionts to supplement its diet, the vertical position of *Histioneis* could be related to the optimal irradiance for the growth of these cyanobacteria. In the upper waters ($<$70 m depth) of the tropical Pacific Ocean, free-living unicellular cyanobacteria such as *Synechococcus* Nägeli are a ubiquitous component of the picoplankton with abundances of $\sim 10 \times 10^6$ cells l^{-1} (Blanchot et al. 2001). The vertical distribution of *Histioneis* could be related to the depth of maximal availability of potential prey and/or the optimal depth (irradiance) for the growth of the symbiont algae.

Histioneis has been reported rarely in the literature of the last three decades, mainly due to the limited taxonomical studies carried out in open waters of tropical oceans. Records at the species level are necessary to investigate the distribution and ecology of this genus.

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