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Dicroerisma (Actiniscales, Dinophyceae) in the open Pacific Ocean, a gymnodinioid dinoflagellate with an endoskeleton*

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Abstract This study is the first to describe and illustrate the dinoflagellate genus *Dicroerisma* in the open Pacific Sea and in the southern hemisphere. Eleven individuals ascribed to *Dicroerisma psilonereiella* were encountered in subsurface waters (>70 m depth) from 34°N to 33°S. Another specimen that differs from the type is also illustrated. These findings reveal that *Dicroerisma* is a widespread genus and that there is tentative existence of another species within the genus.

Keyword: *Dicroerisma psilonereiella*; Actiniscales; axostyle; endoskeleton; Dinophyceae; the Pacific Ocean

1 INTRODUCTION

Dinoflagellates containing an internal skeleton are of great interest in the study of the evolution of dinoflagellates (Taylor, 2004). At present, little is known about the genus *Dicroerisma* Taylor and Cattell with a distinctive inverted Y-shaped endoskeleton, in part resembling that in Ebriids (*Ebria* Borgert, *Hermesinum* Zacharias). To date, *D. psilonereiella* Taylor and Cattell described from Canadian Pacific coastal waters is the only known species within the genus. The species was later reported from the same region (Horner et al., 2005), Canadian Atlantic coasts (Harvey et al., 1997; Bérard-Therriault et al., 1999), Russian Pacific coasts (Simakova and Konovalova, 1995) and Swedish coasts (Kuylenstierna and Karlson, 2000). *Dicroerisma psilonereiella* is the only known from neritic cold waters of the northern hemisphere, with an exception of one individual reported from the warm Indian Ocean (Taylor, 1976). Chrétiennot-Dinet et al. (1993) placed *Dicroerisma* in the order Actiniscales Sournia and Fensome et al. (1993) created the family Dicroerismaceae within the order Gymnodiniales Lemmermann for this single species.

Taylor and Cattell (1969) described the genus as a non-photosynthetic gymnodinioid cell possessing a single, hollow, internal skeletal element, longitudinally orientated and forked in the manner of an inverted Y. Taylor and Cattell (1969) named the endoskeleton as axostyle. Gymnodinioid cells with inverted Y-shaped internal skeleton were found from 11 cruises in several contrasting regions off the open Pacific (Fig.1). Sample collection and light microscopical methods used were described in Gómez and Furuya (2005) and are not repeated here. *Dicroerisma* is regarded as a monotypic genus. This study illustrates a distinctive specimen that differed from the type species. This study reports for the first time the genus in the open Pacific and in the southern hemisphere, and reveals that the geographical distribution of *Dicroerisma* is wider than previously known.

2 OBSERVATION

2.1. Dicroerisma psilonereiella (Fig. 2A-G)

Eleven individuals were found from the temperate waters of the northwest (33°45′N; Fig. 2C) to the southeast Pacific (32°42′S; Fig. 2F), as well as the tropical and equatorial Pacific waters (Fig. 2D) (Table 1). All the specimens were encountered between 70 and 190 m depth, except one record at 10 m depth in an upwelling zone in the north Celebes Sea (Fig.2E).

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These pear-shaped gymnodinioid cells were slightly dorso-ventrally compressed. The episome was conical and sharply pointed. The hyposome was slightly bilobed with two small tips. The deeply impressed cingulum was descending and displaced about 1–1.5 cingulum width. In ventral view, the cingular groove was more apical in the left side of the cell. The sulcus was not discernible. From Lugol-fixed specimens, the maximum length ranged from 25 to 35 μm and the width was 15–21 μm at the cingulum level.

The most distinctive morphological feature was the endoskeleton that extended longitudinally from near the apex and bifurcates at the base of the hyposome. The longitudinal section of the axostyle was leftwards curved (Fig.2A, B). The endoskeleton was secondary branched in the distal ends of the hyposome. It was more difficult to discern whether the axostyle has bifurcated endings in the episome (Fig.2F). The cells showed two large pale areas of ellipsoidal shape located at each hyposomal lobule or apparently only one pale area crossed longitudinally by the axostyle (Fig.2D). At first sight, these pale areas could be attributed to the nucleus. No microfilaments (chromosomes) were observed and the occurrence of two nuclei per cell should be discarded. In some specimens, the two hyposomal lobules appeared stained darker than the rest of the cell body (Fig.2F, G). All the specimens showed a yellow-greenish pigmentation and the occurrence of chloroplasts cannot be confirmed from these Lugol-fixed specimens. The localization and shape of the nucleus and the trophic status of *D. psilonereiella* need further research.

2.2 *Dicroerisma* sp. (Fig. 2H–J)

One distinctive specimen found at 150 m depth in the north Celebes Sea is assumed to belong to the genus *Dicroerisma*, although it differed from the morphology of the type species. This highly dorso-ventrally flattened cell showed a pointed conical episome with slightly concave contours. The deeply impressed cingulum was descending and

Table 1 Records of *Dicroerisma* in the Pacific Ocean. Date; depth (meters); geographic coordinates (latitude, longitude) of each record

Taxon	Date	Depth	Geographic coordinates		Figure
		(m)	Latitude	Longitude	
D. psilonereiella	11/05/2002	125	32°30′N	138°E	Fig. 2A
D. psilonereiella	13/05/2002	70	31°30′N	138°E	Fig. 2B
D. psilonereiella	07/07/2002	125	33°45′N	138°E	Fig. 2C
D. psilonereiella	15/01/2003	110	0°	160°E	Fig. 2D
D. psilonereiella	22/01/2003	100	0°	175°W	-
D. psilonereiella	18/11/2002	10	5°19′N	120°40′E	Fig. 2E
D. psilonereiella	08/11/2004	170	20°27′S	122°53′W	-
D. psilonereiella	23/11/2004	160	30°02′S	98°23′W	-
D. psilonereiella	02/12/2004	70	32°42′S	84°04′W	Fig. 2F
D. psilonereiella	27/11/2004	125	31°52′S	91°24′W	Fig. 2G
D. psilonereiella	27/11/2004	190	31°52′S	91°24′W	-
Dicroerisma sp.	18/11/2002	150	5°N	121°E	Fig. 2H–J

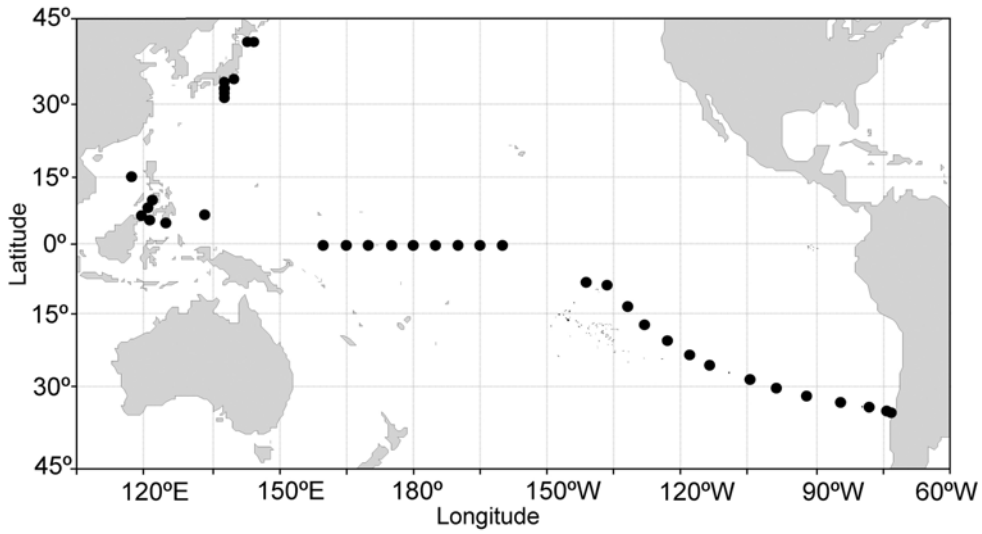

Fig. 1 Map of the station locations in the Pacific Ocean (marked by solid circles**)**

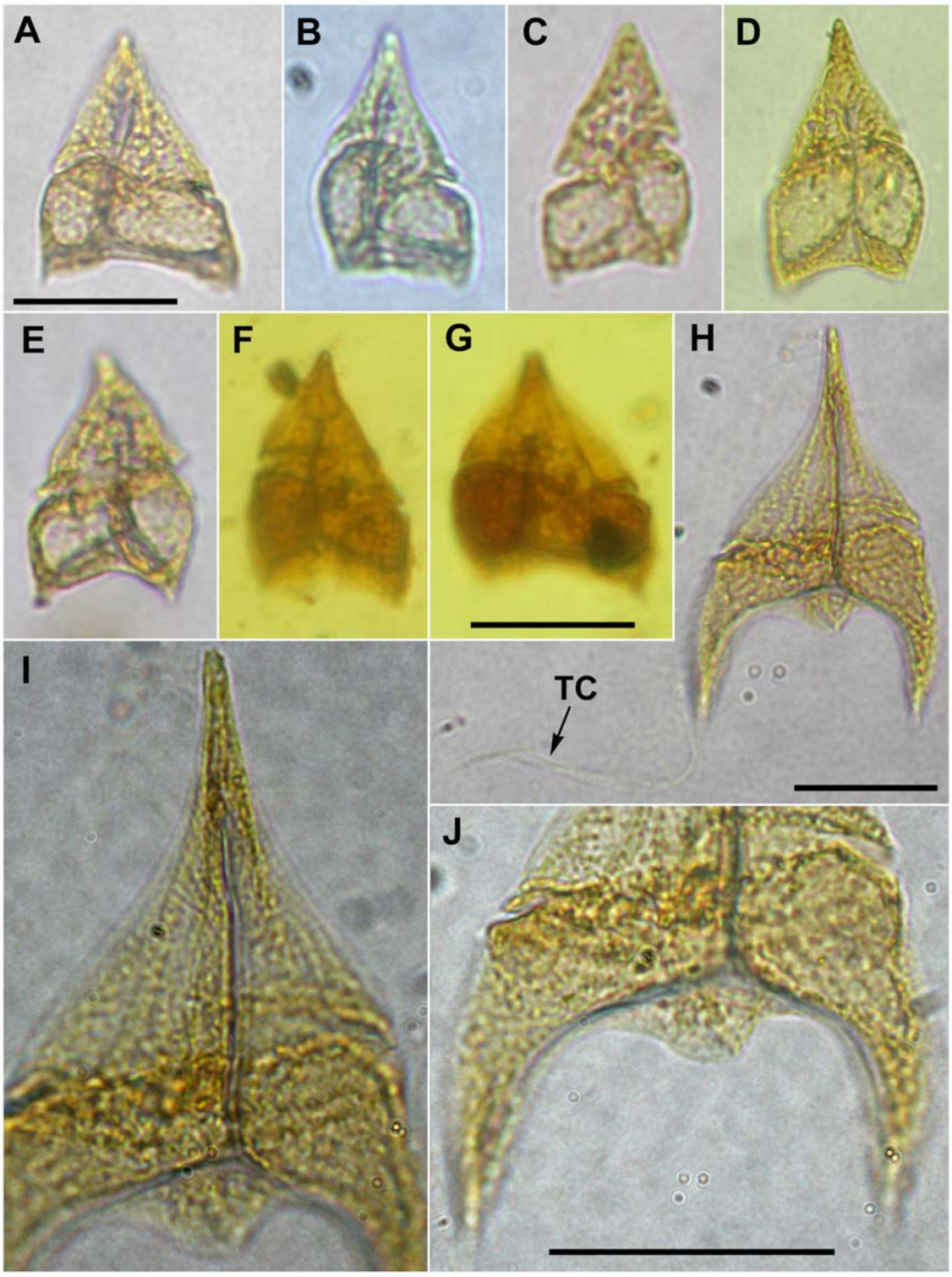

Fig.2 Photomicrographs of *Dicroerisma*, bright-field optics

See Table 1 for the location of the records. A–G: *Dicroerisma psilonereiella*; H–J: *Dicroerisma* sp.; Ventral view: C–E, H–J. Dorsal view: A–B, F–G. A–G at the same scale. TC= Trichocysts. Scale bars 20 μm

displaced about two cingulum widths. The base of the hyposome diverged into two equal elongate pointed extensions (Fig.2H–J). The maximum length was 60 μm and the width was 28 μm at the cingulum level. The width of the hyposome increased antapically. A flattened semicircular protrusion was observed at the middle of the base of the hyposome. From the end of one of the right antapical extension was visible a cluster of trichocysts (Fig.2H). The longitudinal section of the

inverted Y-shaped endoskeleton was slightly displaced leftwards. The bifurcation of the axostyle in the hyposome was more antapically located than in the type species. The two hyposomal branches extended along the inner margin of the antapical extensions. It was not observed any secondary branching in the distal ends of the axostyle. A rounded pale area appeared in the left hyposome (Fig.2H, 3D). It is uncertain whether this pale area corresponded to the nucleus or other organelle.

Dicroerisma sp. differed from the type species in the occurrence of two antapical extensions and a semicircular protrusion at the base of the hyposome. For the type species, Taylor and Cattell (1969) described large pale areas that occupied the lobules as vesicular cavities of an unknown function. The pale region in the left hyposome of *Dicroerisma* sp. may correspond to the nucleus. For example in *Ceratoperidinium* Margalef, another highly flattened unarmoured cell, the pale region in the hyposome corresponded to the nucleus (Gómez et al., 2004). These differences suggest that *Dicroerisma* sp. is a second species for this monotypic genus, requiring further research to be established as a new species.

All previous records were restricted to cold boreal neritic waters, with the exception of one single individual identified as *D. psilonereiella* from the open tropical Indian Ocean by Taylor (1976) (Fig.3B). This author illustrated his formalin-preserved individual with the terminal points of the axostyle blunter than in the original description (Fig.3C, D). The vesicular cavities were hardly visible in the Taylor's illustration. These differences may be due to the preservation protocols. The origin and nature of the endoskeleton in *Dicroerisma* are of great interest in the phylogenetic evolution of dinoflagellates (Taylor, 2004). This study reveals that the gymnodinioid dinoflagellates with an inverted Y-shaped endoskeleton are more widespread than previously known.

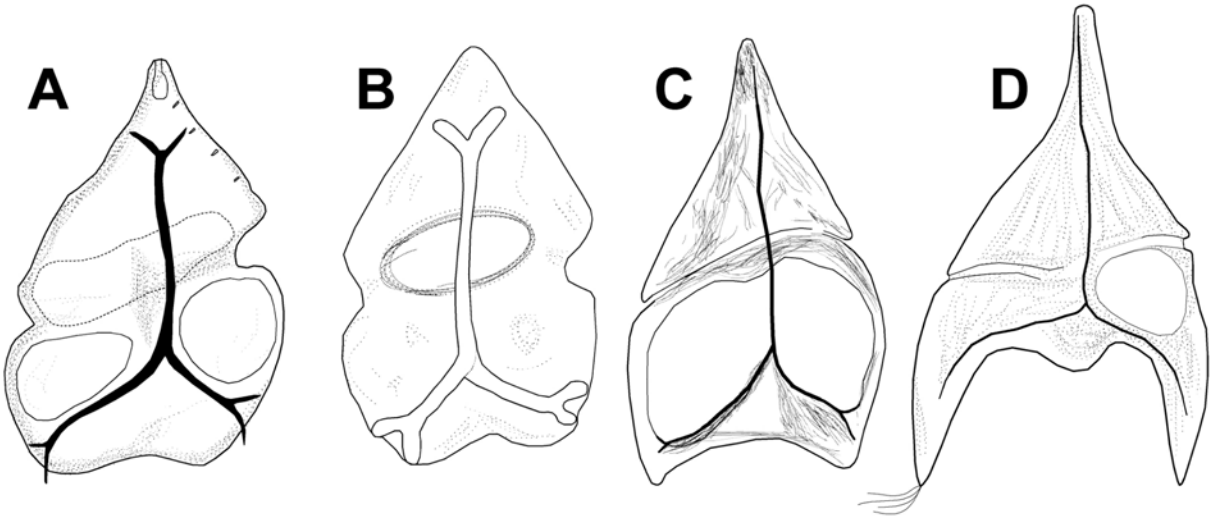

Fig.3 Line drawings of *Dicroerisma* in ventral view

A, *D. psilonereiella* adapted from Taylor and Cattell (1969); B, *D. psilonereiella* adapted from Taylor (1976); C, *D. psilonereiella*; and D, *Dicroerisma* sp. from the open Pacific.

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