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## Short Communication

Luis Castro-Cera, Darío Vega-Díaz, Ruth S. Eriksen, Karine Leblanc and Gustaaf M. Hallegraeff\*

# New observations on the rarely reported tropical dinoflagellates *Tripes lanceolatus* and *T. schroeteri* from the Colombian Caribbean, South Pacific and Indian Oceans

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**Abstract:** We report the circumtropical dinoflagellate *Tripes lanceolatus* (Kofoid) F. Gómez from the Colombian Caribbean, provide a new record from the tropical western Pacific off Tonga, and the first record from the Australian sector of the Indian Ocean. We present the first scanning electron micrographs of thecal ornamentation and apical pore structure which show its morphological similarities to *T. furca* (Ehrenberg) F. Gómez within the subgenus *Biceratium*. We also report the more widely distributed tropical species *T. schroeteri* (B. Schröder) F. Gómez from the Colombian Caribbean, and compare it to the first scanning electron micrographs of the morphologically similar *T. digitatus* (F. Schütt) F. Gómez within the subgenus *Archaeceratium*.

**Keywords:** biodiversity; phytoplankton; taxonomy; *Tripes digitatus*; *Tripes lanceolatus*; *Tripes schroeteri*.

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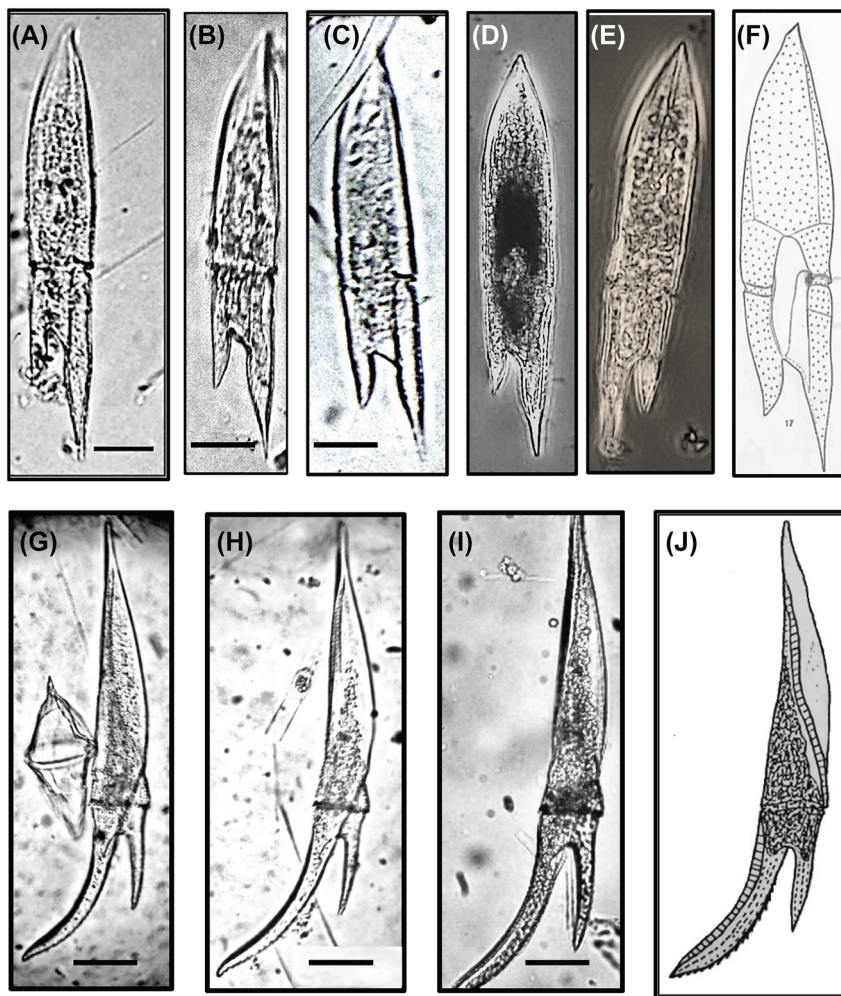
The distinctive dinoflagellate genus *Tripes* Bory occurs widespread in marine waters. Members were previously included in *Ceratium* Schrank, a genus name now restricted to freshwater (Gómez et al. 2010), while all marine species have been transferred to the genus *Tripes* (Gómez 2013). Various studies on the distribution of *Tripes* have demonstrated their use for biogeography, as ecological indicators of the dynamics of ocean currents, and monitors of global climate change (Dodge and Marshall 1995; Hallegraeff et al. 2020; Tunin-Ley et al. 2007). While some *Tripes* species exhibit cosmopolitan distributions such as *T. fusus* (Ehrenberg) F. Gómez, *T. furca* (Ehrenberg) F. Gómez and *T. muelleri* Bory, with 123,000, 90,000 and 81,000 records, respectively, listed in OBIS (Ocean Biodiversity Information System 2022), a number of tropical species are rarely reported. One such taxon is the lanceolate-shaped *T. lanceolatus* (Kofoid) F. Gómez, with only 2 OBIS records listed. This species was first described by Kofoid (1907) as *Ceratium lanceolatum* from two stations in the eastern tropical Pacific off Peru. A second more widely distributed tropical species is *T. schroeteri* (B. Schröder) F. Gómez, first described from the Arabian Sea by Schröder (1906), currently with 17 OBIS records listed. We here confirm these two tropical dinoflagellates from the Colombian Caribbean Sea, provide new records from the tropical western Pacific off Tonga, as well as presenting the first scanning electron micrographs of *T. lanceolatus* from the Australian sector of the Indian Ocean and of a close morphological relative of *T. schroeteri*, *T. digitatus* (F. Schütt) F. Gómez from the tropical Pacific.

*Tripes lanceolatus* from Colombian waters had a flat lancet-shaped epitheca with parallel sides tapering gently to form a pointed, slightly oblique apical horn (Figure 1A–C). The short hypotheca was approximately the same width as it was long and projecting from it were two pointed antapical horns with the left one thicker and about twice as long as the right one. Cell dimensions were 130–141 µm long and

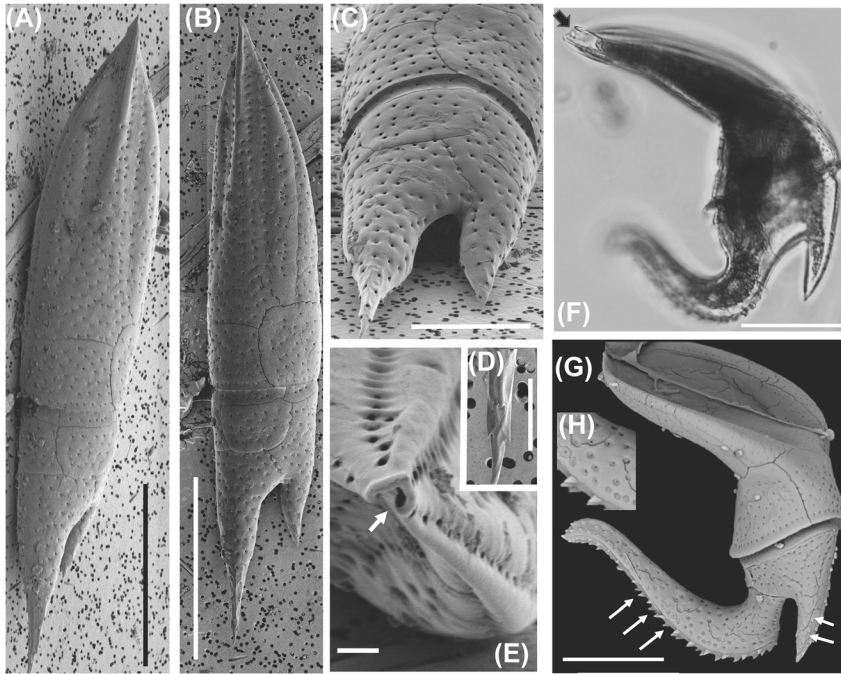
25–27  $\mu\text{m}$  wide, with the left antapical horn 38  $\mu\text{m}$  long and 10  $\mu\text{m}$  wide, while the right antapical horn was 15  $\mu\text{m}$  long by 5  $\mu\text{m}$  wide. The two cells from Tonga exhibited a more distinct strictly terminal apical horn (Figure 1D, E). The line drawing of the type specimen by Kofoid (1907) from off the Galapagos Islands is reproduced in Figure 1F for comparison. Supplementary Table S1 summarizes published records for this species.

We hereby present as far as we know the first scanning electron micrographs of *T. lanceolatus* and also the first report from the Australian sector of the Indian Ocean (Figure 2A–D). This single individual was 139  $\mu\text{m}$  long and

26  $\mu\text{m}$  wide. Unfortunately, we were unable to resolve the ventral view of this cell. The lanceolate epitheca was bent dorsally and dorso-ventrally compressed approximately 26  $\mu\text{m}$  deep (Figure 2A). The cellulose wall was finely poroid, with the poroids occasionally arranged in linear rows notably towards the apical tip (Figure 2B). The epitheca was enforced by lateral longitudinal ridges and constricted towards the tip. The hypotheca was low, with short stout antapical horns, of which the right horn was 60% the length of the left horn (Figure 2C). The horns carried a very fine serrated, teeth-like ornamentation, most prominently on the left antapical horn but barely visible on the right



**Figure 1:** Light micrographs and line drawings of *Triplos lanceolatus* and *T. schroeteri*. (A–F) *Triplos lanceolatus*: (A–C) cells from the Colombian Caribbean; (D, E) cells from Tonga; (F) Kofoid (1907) type illustration from eastern Pacific. (G–J) *Triplos schroeteri*: (G–I) cells from the Colombian Caribbean in dorsal view; (J) type illustration by Schröder (1906) from the Arabian Sea (dorsal view). The Caribbean samples were part of an environmental impact study between July and August 2014 for exploratory drilling in front of the coast of Colombia at water depths of 200–3000 m. A conical plankton net of 20- $\mu\text{m}$  mesh, 48-cm mouth diameter and 2.5-m length was used from surface to 50 m, samples preserved in 2% formalin and examined with an Olympus CH and Nikon Eclipse E2000 microscope. The Tonga samples were collected from 31 October to 6 December 2010 in the western Tropical Pacific on board *RV L'Atalante*. Samples were collected with a phytoplankton net (35- $\mu\text{m}$  mesh) from 0 to 200 m depth, fixed with 0.3% Lugol's iodine solution using a Nikon TE-200 inverted light microscope. Scale bars: (A–C) = 20  $\mu\text{m}$ ; (G–I) = 50  $\mu\text{m}$ .



**Figure 2:** Light and scanning micrographs of *Triplos lanceolatus* and *T. digitatus*. (A–E) Single individual of *T. lanceolatus* from the Australian sector of the Indian Ocean: (A) left lateral view showing dorso-ventrally compressed epitheca curved dorsally; (B) dorsal view; (C) hypothecal view with left apical horn 60% longer than right apical horn; (D) detail of serrated, teeth-like ornamentation of right apical horn; (E) detail of triangular apical pore (arrow). (F–H) *Triplos digitatus* from Tonga waters: (F) light micrograph of cell showing open apical horn (arrow); (G) cell with swollen, dorsally curved epitheca with flattened ventral surface, and rows of spines on strongly dorsally curved left antapical horn and (H) finely poroid thecal ornamentation; minute spines are also visible on the nearly straight right antapical horn. The Indian Ocean sample (IIOE-2) was collected on *RV Investigator* between 15 May and 10 June 2019, along a 110°E latitudinal transect off Western Australia. Net samples (20- $\mu$ m mesh) from surface to 20 m depth were preserved in 2% formalin, filtered gently onto Nuclepore filters, rinsed with 10 ml deionised water to remove salt crystals and gently air-dried. Filters were mounted on aluminium stubs, coated with platinum and examined with a Hitachi SU70 scanning microscope. The Tonga sample was filtered onto polycarbonate filters for SEM, rinsed with milliQ water, dried at room temperature and mounted on SEM stubs for imaging on a Phenom-Pro benchtop scanning electron microscope. Scale bars: (A–B) = 50  $\mu$ m; (C) = 20  $\mu$ m; (D) = 10  $\mu$ m; (E) = 2  $\mu$ m; (F, G) = 30  $\mu$ m.

antapical horn (Figure 2D). The cingulum was shallow (Figure 2C) but fully developed. The apical horn terminated in an easily overlooked minute (2  $\mu$ m diameter) triangular apical pore (Figure 2E). The apical pore closing plate was missing, almost certainly lost during preparation.

Our Colombian Caribbean, Tongan and Indian Ocean cells of *T. lanceolatus* agree with the type description by Kofoid (1907) from the Eastern Pacific (Figure 1F), except for subtle differences in size. The cell illustrated as *C. lanceolatum* by Gaarder (1954) (with ventral pore), as pointed out previously by Gómez (2021), almost certainly represents a mistaken identification of *T. praelongus* (Lemmermann) F. Gómez. Gómez (2021) discussed morphological similarities between *T. lanceolatus* and *T. praelongus*, but the latter has a distinct ventral ring pore on the epitheca which has never been observed in *T. lanceolatus*. Gómez (2021) provisionally created its own section *Lanceolata* to accommodate *T. lanceolatus*, because it did not fit in either the section

*Poroceratium* (to which *T. praelongus* and *T. gravidus* (Gourret) F. Gómez belong) nor the section *Digitata*. We agree with Kofoid's (1907) suggestion that *T. lanceolatus* is morphologically similar to *T. furca* (Ehrenb.) F. Gómez in the subgenus *Biceratium*. This is also reflected in the feature of serrated, teeth-like thecal ornamentation of the antapical horns (Figure 2D).

*Triplos schroeteri* can be recognised in lateral view because its ventral profile shows a sigmoid appearance. We observed three cells from Colombian waters (Figure 1G–I). The Colombian cells were 340–344  $\mu$ m long and 40–41  $\mu$ m wide. The left antapical horn was 104  $\mu$ m long and 22  $\mu$ m wide at its base and the right antapical horn 57  $\mu$ m long and 12  $\mu$ m wide. The right antapical horn was more or less straight in dorsal view, while the left antapical horn was almost twice as wide and long as the right horn, and was strongly curved dorsally. Both antapical horns were pointed, but the right one was smooth while the left horn was

stronger, more robust and carried a series of spinules on its inner side (just visible in Figure 1G, H). The hypothecae of the three Colombian cells of *T. schroeteri* were almost twice as wide as they were long. The illustration of the type specimen by Schröder (1906) from the Arabian Sea is reproduced in Figure 1J. Supplementary Table S2 summarizes published records for this species.

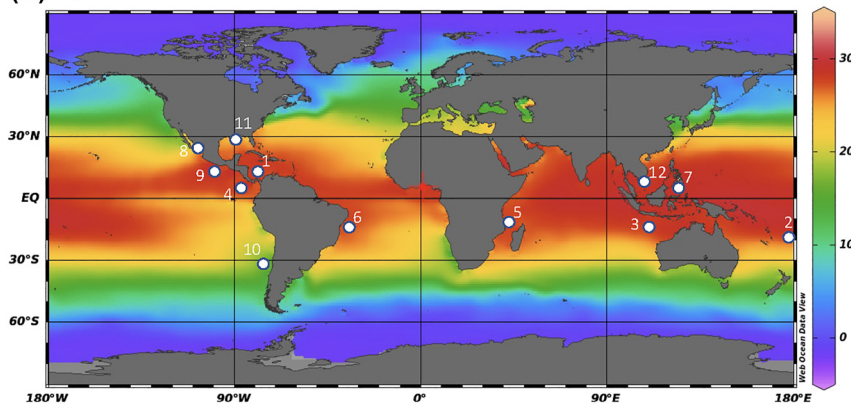
Unfortunately, we have not succeeded so far to produce a scanning electron micrograph for *T. schroeteri*. Instead we present the first known scanning micrographs of a close morphological relative of *T. schroeteri*, the subtropical-tropical dinoflagellate *T. digitatus* (F.Schütt) F. Gómez from Tonga waters (Figure 2F–H). This distinctive species has an apical pore arising from a short projection at the apex (Figure 2F, arrow), its epitheca is swollen, and dorsally curved with a flattened ventral surface, and the strongly dorsally curved left antapical horn bears rows of strong spines. Minute spines are also visible on the nearly straight right antapical horn (Figure 2G) and the cell has a finely poroid thecal ornamentation (Figure 2H).

Our Colombian and Tongan cells of *T. schroeteri* agree with the type description by Schröder (1906), except for

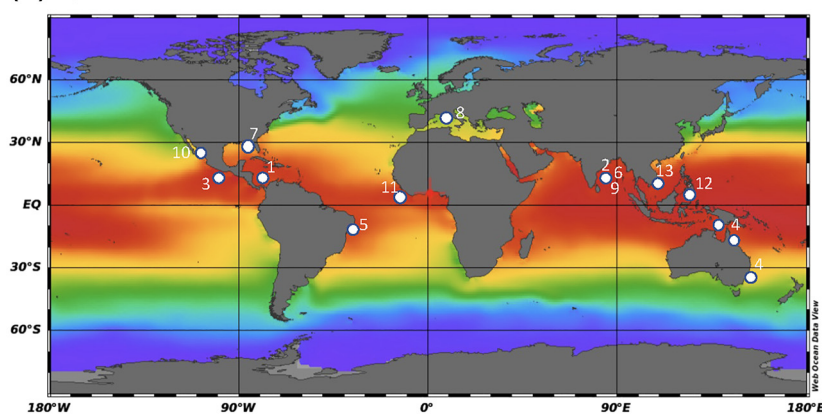
differences in size. This species sometimes can be confused with *T. incisus* (G. Karsten) F. Gómez which however has parallel antiapical horns. Schröder (1906) suggested that *T. schroeteri* occupied a position between *T. furca* and *T. digitatus*. *Triplos schroeteri*, in its feature of the left antapical horn being strongly curved towards the dorsal side with a strongly thickened wall and ornamented with small spinules, is morphologically closest to *T. digitatus*, as argued also by Kofoid (1907) and Taylor (1976). Gómez (2021) classified *T. schroeteri* in the subgenus *Archaeceratium*, section *Digitata*, with which we concur.

A compilation of a total of 16 validated records of the rare dinoflagellate *T. lanceolatus* demonstrates a stenothermal circumtropical distribution in the Pacific, Caribbean and Indian Oceans (Figure 3A). Where surface seawater temperature records are available, they are all in the range 25–30 °C. By comparison, *T. schroeteri*, which is more widely reported, has a more widespread warm-water distribution including the Mediterranean (Figure 3B; Supplementary Table S1). Tropical species at the upper range of seawater temperature limits deserve careful attention in monitoring for climate change impacts.

#### (A) *Triplos lanceolatus*



#### (B) *Triplos schroeteri*



**Figure 3:** Summary of confirmed distribution records of *Triplos lanceolatus* and *T. schroeteri*, based on the present study as well as literature. (A) *Triplos lanceolatus*: <sup>1, 2, 3</sup>present work; <sup>4</sup>type description by Kofoid (1907); <sup>5</sup>Silva (1956); <sup>6</sup>Wood (1968); <sup>7</sup>Borja (2002); <sup>8</sup>Okolodkov and Gárate-Lizárraga (2006); <sup>9</sup>Gárate-Lizárraga (2008); <sup>10</sup>Gomez et al. (2008); <sup>11</sup>Steidinger et al. (2009); <sup>12</sup>Nguyen-Ngoc et al. (2012). (B) *Triplos schroeteri*: <sup>1</sup>present work; <sup>2</sup>type description by Schröder (1906); <sup>3</sup>Kofoid (1907); <sup>4</sup>Wood (1963); <sup>5</sup>Wood (1968); <sup>6</sup>Subrahmanyam (1968); <sup>7</sup>Steidinger & Williams (1970); <sup>8</sup>Léger (1972); <sup>9</sup>Taylor (1976); <sup>10</sup>Okolodkov and Gárate-Lizárraga (2006); <sup>11</sup>Koffi et al. (2014); <sup>12</sup>Omura et al. (2012); <sup>13</sup>Nguyen-Ngoc et al. (2012). Isotherms courtesy Ocean Data view (World Ocean Atlas 2018, Annual surface temperatures, all available years 1955–2018).

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**Conflict of interest statement:** The authors declare no conflicts of interest regarding this article.

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