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# FIRST RECORD OF THE CILIATE EUTINTINNUS APERTUS WITH THE ATTACHED DIATOM CHAETOCEROS TETRASTICHON IN NERITIC WATERS OF SOUTHWESTERN ATLANTIC

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## ABSTRACT

The ciliate *Eutintinnus apertus* (Kofoid and Campbell, 1929) was found in 18 of the 20 stations sampled near the São Sebastião region (São Paulo State). In 17 of these stations 63 (81.85%) of the total lorica were colonized by the diatom *Chaetoceros tetrastichon* Pavillard. Although the association between these species is common, it has not been reported for neritic waters from Southwestern Atlantic before. The loricas showed a relatively constant form, but the dimensions were very variable, mainly the total lenght. Water temperature and salinity fluctuated between 23.09 $^0$C and 25.03 $^0$C and between 34.98 and 35.17, respectively, at the 20 sampling stations. Maximum quantities of *E. apertus* with *Chaetoceros* cells adhered were found in temperatures ranging from 24.0 $^0$C to 24.5 $^0$C.

**Keywords:** Tintinnina, Diatoms, *Eutintinnus apertus*, *Chaetoceros tetrastichon*, epizoic association, morphometry.
**Descritores**: Tintinnina, Diatomáceas, *Eutintinnus apertus*, *Chaetoceros tetrastichon*, associação epizóica, morfometria.

## INTRODUCTION

Despite their importance in marine food chains and in the carbon cycle, the Tintinnina are poorly studied in Brazilian waters. According to SASSI and MELO (1989) only 14 papers were referred to Brazilian species, six of which dated from the beginning of present century (from 1899 to 1918) and eight were carried out during the last 25 years. With the exception of the paper of BRESSLAU (1906), who documented details of the reproduction of *Stenosemella ventricosa* (=*Tintinnopsis ventricosa*) from Guanabara Bay, all these papers have focused only the systematic aspects. Neverthless, not one had shown specimens with on associated diatoms.

Although the literature on ciliate and diatom associations is too scarce in examples concerning marine microplankton, TAYLOR (1982) states that this phenomenon occurs as much in ciliates living over diatoms (many sessile peritrich ciliates) as with diatoms attached to ciliates (Tintinnina).

*Eutintinnus apertus* studied herein is known to possess attached diatoms from the genus *Chaetoceros*. It is a neritic and widely distributed species which was referred scarcely and without diatoms in their lorica for Southwestern Atlantic (SOUTO, 1970; BALECH, 1971).

## MATERIAL AND METHODS

Twenty plankton samples were gathered in surface waters from São Sebastião region (São Paulo State, Southeastern Brazil) from 10/27/91 to 10/29/91, between 45°21'30" and 45°24' W and between 23°46' and 23°49'30" S, using a standard plankton net with 30 μm mesh size. The material was preserved with 4% neutralized formaldehyde and analysed under a phase contrast microscope in several magnifications. All specimens of *Eutintinnus apertus* were measured with a calibrated micrometer eyepiece. Selected specimens were drawn with a *camera lucida* and microphotographed.

## RESULTS

*Eutintinnus apertus* was found in 18 of the 20 sampled stations and in 81.85% of these stations the diatom *Chaetoceros tetrastichon* was attached the loricas. The highest frequencies of the loricas with the adhered diatoms were registered in stations 13 and 18. The temperature and salinity data from the studied region fluctuated between 23.09 °C to 25.03 °C and between 34.98 to 35.17, respectivelly (Tab. 1).

The following systematic treatment is presented for this Tintinnina.

Family Tintinnidae Kofoid and Campbell

Genus *Eutintinnus* Kofoid and Campbell

*Eutintinnus apertus* (Kofoid and Campbell, 1929)

(Figs. 1, 2)

*Tintinnus inquilinus* CLAPÁRÈDE and LACHMANN, *partim*, 1858, p. 196, pl. 8, fig. 2; DADAY, 1887a, p. 164, pl. 2, fig. 8; DADAY, 1887b, p. 528, pl. 18 (2, 10-13); JÖRGENSEN, 1924, p. 12, fig. 7; 1927, p. 9, figs. 10, 33; ENTZ, Jr., 1909, pp. 107, 217, pl. 13, fig. 11; HOFKER, 1931, p. 386, figs. 82-83; DURÁN, 1951, p. 106, fig. 3; CUPP, 1943, p. 109, fig. 64 (**non** *Tintinnus inquilinus* (Muller) Schranck).

*Tintinnus apertus* KOFOID and CAMPBELL, 1929, p. 331, fig. 648; MARSAHLL, 1934, p. 659; HADA. 1935, p. 247; HADA, 1938, p. 182, fig. 98; KOFOID and CAMPBELL, 1939, p. 363, pl. 31; HASLE, 1960, p. 44, fig. 43a, b, (intermediate form between *apertus* and *angustatus*?); **non** SANTAMARIA DEL ANGEL and CEPEDA, 1992, p. 177, fig. fig. 12a, b (= *Eutintinnus lususundae*). For complete synonymy see KOFOID and CAMPBELL (1929).
*Eutintinnus apertus* var. *curta* KOMAROVSKY, 1959, p. 24, fig. 70.
*Eutintinnus* sp. SILVA, 1953, p. 114, Est. 3, fig. 7.
*Eutintinnus pacificus*, SILVA, 1954, p. 232, Est. 7, fig. 13.
*Tintinnus inquilinus*, JÖRGENSEN, 1924, p. 12, fig. 7a, b; DURÁN, 1951, p. 106, fig. 3; 1953 (only citation).

**Table 1** – Number of *E. apertus* with and without diatoms found in the studied stations.

| Stn. N. | Lat. (S) | Long. (W) | °C | Salinity | Total of *E. apertus* | Total with diatoms |
|---|---|---|---|---|---|---|
| 1 | 23°46'48" | 45°22'43" | 23.09 | 35.11 | 1 | 1 |
| 2 | 23°46'42" | 45°22'36" | 23.31 | 35.11 | 3 | 2 |
| 3 | 23°46'32" | 45°11'54" | 23.57 | 34.98 | 6 | 5 |
| 4 | 23°46'42" | 45°21'54" | 23.59 | 35.15 | 1 | 0 |
| 5 | 23°46'46" | 45°22'48" | 23.64 | 35.17 | 3 | 3 |
| 6 | 23°46'06" | 45°22'48" | 23.56 | 35.09 | 4 | 3 |
| 8 | 23°47'06" | 45°22'42" | 23.85 | 35.13 | 4 | 3 |
| 7 | 23°47'30" | 45°22'34" | 23.80 | 35.17 | 3 | 2 |
| 9 | 23°47'14" | 45°22'00" | 24.11 | 35.10 | 9 | 8 |
| 10 | 23°47'12" | 45°21'54" | 24.37 | 35.14 | 5 | 1 |
| 11 | 23°48'18" | 45°22'06" | 24.48 | 35.05 | 3 | 2 |
| 12 | 23°48'09" | 45°22'30" | 24.49 | 35.16 | 5 | 5 |
| 13 | 23°47'57" | 45°22'42" | 24.42 | 35.13 | 8 | 7 |
| 14 | 23°47'49" | 45°22'54" | 24.66 | 35.15 | 4 | 4 |
| 15 | 23°47'48" | 45°23'07" | 25.03 | 35.19 | 0 | 0 |
| 16 | 23°49'17" | 45°23'02" | 24.20 | 35.11 | 3 | 3 |
| 17 | 23°49'18" | 45°23'21 | 24.32 | 34.99 | 5 | 4 |
| 18 | 23°49'11" | 45°23'37" | 24.20 | 35.06 | 6 | 5 |
| 19 | 23°49'00" | 45°23'51" | 24.21 | 35.02 | 5 | 5 |
| 20 | 23°48'46" | 45°23'53" | 25.20 | 35.12 | 0 | 0 |
| **TOTAL** | | | | | **78** | **63(=81.58%)** |

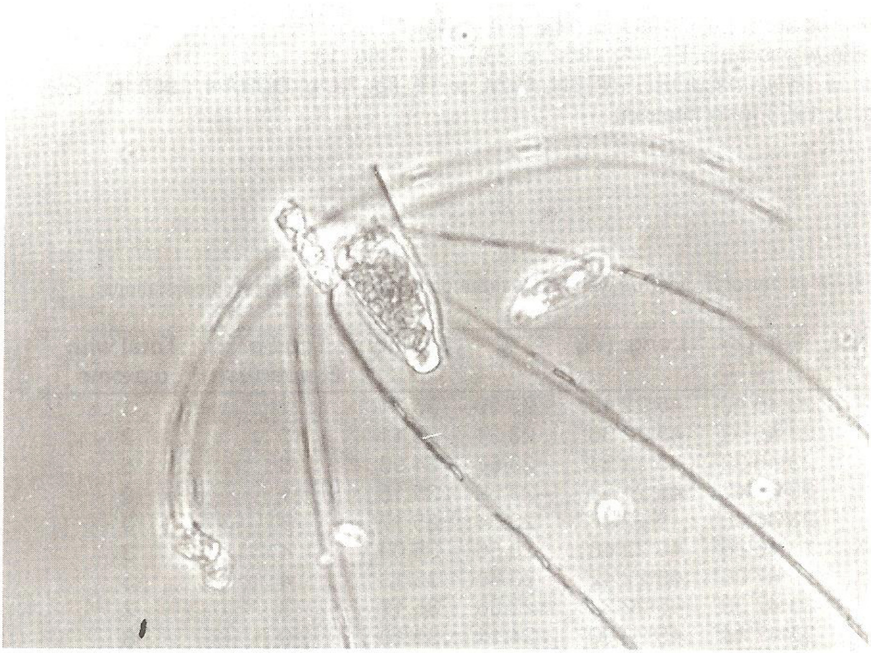

**FIGURE 1** – *Eutintinnus apertus* with attached *Chaetoceros tetrastichon* chain collected in São Sebastião region. Magnification: approx. 265x.

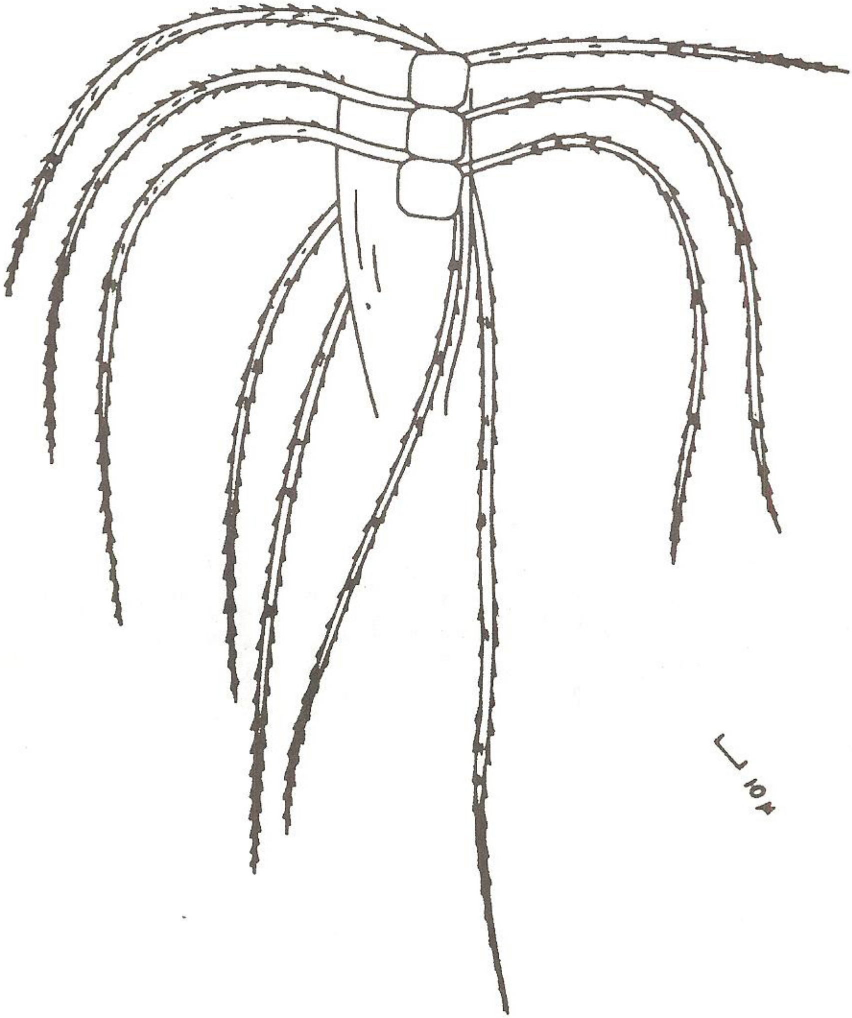

FIGURE 2 – Sketch of *Eutintinnus apertus* lorica with attached *Chaetoceros tetrastichon* chain collected in São Sebastião region.

**Description:** Lorica tubular, hyaline, frequently with the diatom *Chaetoceros tetrastichon* attached to it and with thin wall without evident primary structure. Aboral end strongly narrow and oral region slightly larger.

**Dimensions: based on the literature** (Figs. 3, 4): total length, 54-189 μm; oral diameter, 22-39 μm; aboral diameter, 12.3-22 μm (normal forms). *Eutintinnus apertus* forma *curta* from KOMAROVSKY (1959) has total length = 55 μm, oral diameter = 27.5 μm and aboral diameter = 12.5 μm. The fig. 43b presented by HASLE (1960) as a probable intermediate form between *E. apertus* and *E. angustatus* has total length = 52 μm, oral diameter = 14 μm and aboral diameter = 3 μm (dimensions estimated from her drawing). **Present study** (Figs. 5, 6, 7): total length, 66.5-106.6 μm (usually between 78.2 to 95.6 μm); oral diameter, 24.9-39 μm (usually between 28.2 to 31.3 μm); aboral diameter, 10.4-20.8 μm (usually between 13.4 to 16.4 μm).

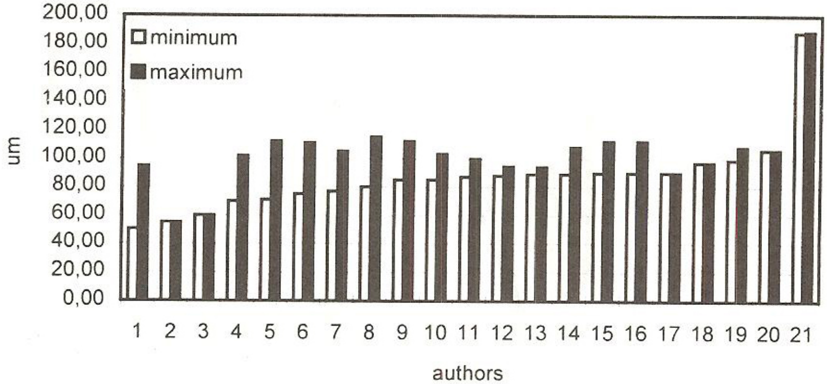


**Figure 3** – Total length measurements of *E. apertus* according to various authors (1 = Hasle, 1960; 2 = Komarovsky, 1959; 3 = Entz, Jr., 1904; 4 = Kofoid and Campbell, 1939; 5 = Zeitschell, 1969; 6 = Balech, 1962; 7 = Calderón-Aragón and López-Ochoterena, 1973; 8 = Souto, 1970; 9 = Marshall, 1969; 10 = Marshall, 1934; 11 = Komarovsky, 1959; 12 = Hasle, 1960; 13 = Jörgensen, 1924; 14 = Kofoid and Campbell, 1929; 15 = Yamaji, 1984; 16 = Hada, 1938; 17 = Krsinic, 1980; 18 = Durán, 1951; 19 = Daday, 1887; 20 = Silva, 1958; 21 = Balech, 1959).

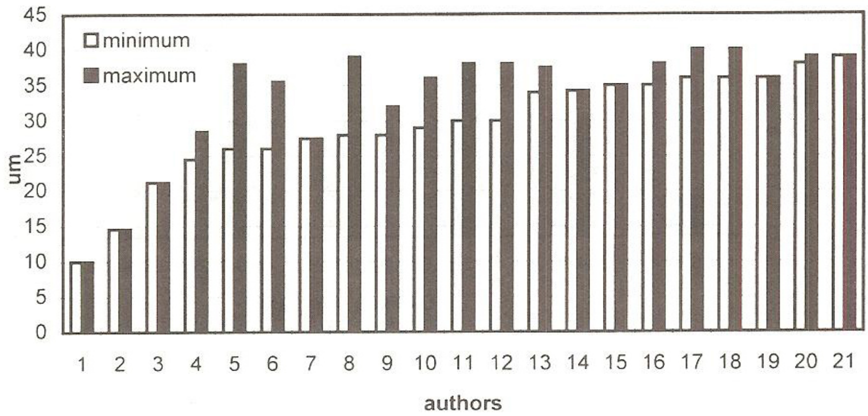


**Figure 4** – Oral diameter measurements of *E. apertus* according to various authors (1 = Hasle, 1960; 2 = Entz, Jr., 1909; 3 = Hasle, 1960; 4 = Calderón-Aragón and López-Ochoterena, 1973; 5 = Zeitschell, 1969; 6 = Balech, 1962; 7 = Komarovsky, 1959; 8 = Marshall, 1969; 9 = Marshall, 1934; 10 = Kofoid and Campbell, 1939; 11 = Yamaji, 1984; 12 = Hada, 1938; 13 = Komarovsky, 1959; 14 = Durán, 1951; 15 = Kofoid and Campbell, 1929; 16 = Souto, 1970; 17 = Jörgensen, 1924; 18 = Daday. 1887; 19 = Silva, 1958; 20 = Balech, 1959; 21 = Krsinic, 1980).

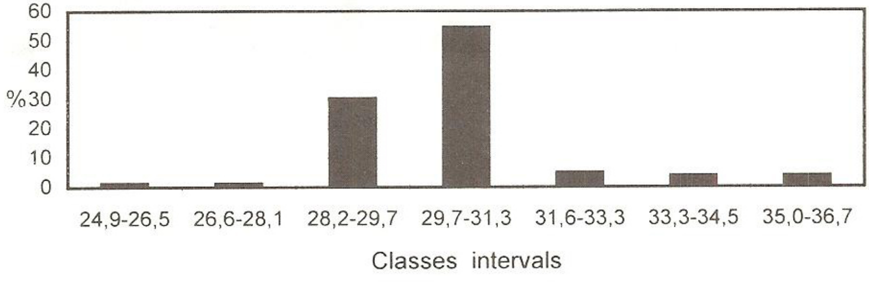


**Figure 5** – Oral diameter from the studied specimens.

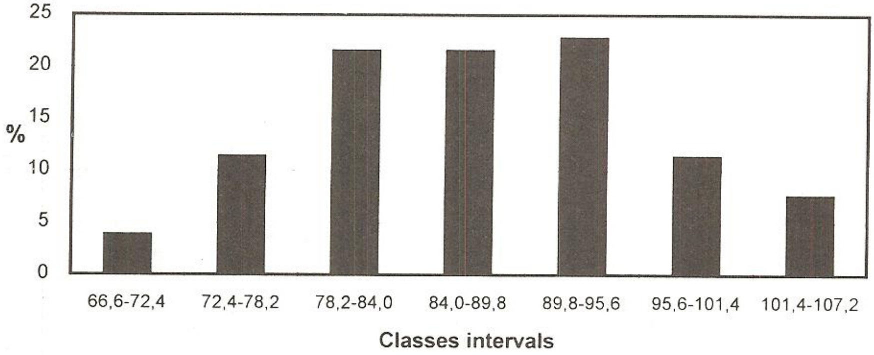


**Figure 6** – Total length from the studied specimens.

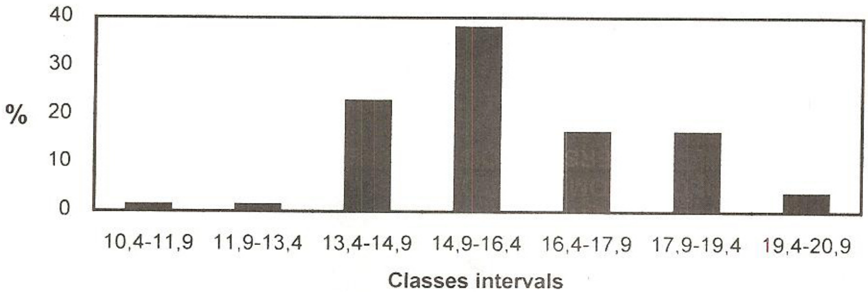


**Figure 7** – Aboral diameter from the studied specimens.

**Distribution**: Neritic waters from Southeastern Brazil (new occurrence); Northeast Brazil Current (BALECH, 1971); Equatorial Atlantic Waters (CAMPBELL, 1942); Gulf of Mexico (BALECH, 1967; CALDERÓN-ARAGÓN and LÓPEZ-OCHOTERENA, 1973; LUBEL, 1974); Sargasso Sea (CAMPBELL, 1942; GAARDER, 1946); Damariscota River estuary, Maine, USA (SANDERS, 1987);

Irminger Sea (GAARDER, 1946); North Sea and Irish Sea (CLAPÁRÈDE and LACHMANN, 1858; JÖRGENSEN, 1927); Baltic Sea (JÖRGENSEN, 1927; SCHWARZ, 1961); north and south coast of Europa, Northwest of Africa, North Atlantic and Central Atlantic, including Canaries, Azores and Gulf Stream (MARSHALL, 1969); Óbidos lagoon, Portugal (SILVA, 1953); Southeastern Atlantic off Angola (SILVA, 1954, 1958); Mediterranean Sea (DADAY, 1887a, b; JÖRGENSEN, 1924; HOFKER, 1931; NAVARRO and MASSUTI, 1940; RAMPI, 1939, 1950; DURÁN, 1951, 1953; BALECH, 1959;TRAVERS and TRAVERS, 1971; KRUGER, 1980); Adriatic Sea (KRSINIC, 1980); Gulf of Eylath, Aqaba, Red Sea (KOMAROVSKY, 1959); Izmir Bay, Aegean Sea, Turkey (KORAY and ÖZEL, 1983; KORAY, 1987); Tulear region, Madagascar (TRAVERS and TRAVERS, 1965); Mozambique Channel (TRAVERS and TRAVERS, 1965); Indian Ocean off western Arabian Sea (ZEITZSCHEL, 1969); Arabian Sea (ZEITZSCHEL, 1969); Southwestern of Indian Ocean (KRUGER, 1980); Philippines Sea (TANIGUCHI, 1977); Celebes Sea (TANIGUCHI, 1977); Sulu Sea (HADA, 1935, 1938); Japan Sea (YAMAJI, 1984); Great Barrier Reef (MARSHALL, 1934); North Polynesian Waters (South Equatorial Current) (KOFOID and CAMPBELL, 1939; RAMPI, 1952); Pacific North Equatorial Current Waters (CAMPBELL, 1942; RAMPI, 1952; HASLE, 1960); Pacific central girals Waters (BALECH, 1962); California Waters (CAMPBELL, 1942; CUPP, 1943; BALECH, 1962); Western Mexican and Panamic Waters (KOFOID and CAMPBELL, 1929, 1939; BALECH, 1962); South Equatorial Pacific Waters (BALECH, 1962); Peru-Galapagos Waters (KOFOID and CAMPBELL, 1939; CAMPBELL, 1942; BALECH, 1962); South Pacific Waters at 44°33' S, 131°50' W (BALECH, 1962); Uruguay Waters (33°04' S, 51°00' W; 33°06' S, 50°28' W) (SOUTO, 1970).

## DISCUSSION

Apparently LAACKMANN (1909) commited a mistake regarding the presence of *E. apertus* in his samples from Southwestern Atlantic because the station where he found this species was not located in Brazil current (as he had also pointed out) but in the Benguela Current (as he had also pointed out). From a tentative reconstruction of the route of the "Deutschen Südpolar-Expedition 1901-1903", we concluded that this station was located in the Benguela Current.

*E. apertus* is considered a neritic species (JÖRGENSEN, 1924; MARSHALL, 1934; HADA,1938) with a wide geographic distribution and was found also inside salps stomachs (JÖRGENSEN, *op cit.*). The few quantitative data available for Tintinnina show low densities for this species; the maximum (4000 ind.$m^{-3}$) was reported by KRISINIC (1980) in the Adriatic Sea.

This species is very similar to *E. pinguins* but is smaller and has a stronger aboral constriction. BALECH (1962) also considered *E. pacificus* Kofoid and Campbell as another close species. *Eutintinnus angustatus* Daday seems to be only another variable form *of E. apertus* which shows a slight dilatation in the middle portion of the lorica.

*Eutintinnus apertus* has been confused with *Tintinnus inquilinum* (O.F.Müller) since both species have very similar general form and dimensions. However, *T. inquilinum* is generally sessile, with the aboral end closed, and generally without *Chaetoceros* adhered to the lorica. The confusion between these two species is due to the presence or absence of the attached diatoms (CLAPÁRÈDE and LACHMANN, 1858; DADAY, 1887b; ENTZ, Jr., 1908, 1909; JÖRGENSEN, 1924; DURÁN, 1951, 1953).

There is no doubt that the specimen identified by SILVA (1954) in Angola waters (Africa) as *E. pacificus* is *E. apertus*. Her fig. 13 (plate 7) is very similar to *E. apertus* both in dimensions and general form of the lorica, although it does not have diatoms attached. Even SILVA (*op. cit.*) has recognized that the specimens of *E. pacificus* she found exceeded the dimensions of *E. pacificus* provided by KOFOID and CAMPBELL (1939).

In our opinion, the two specimens of *Eutintinnus* sp found by SILVA (1953) in Óbidos lagoon (Portugal), also seem to be *E. apertus*, despite the arguments invoked by her.The general dimensions of Silva's specimens (total lenght: 100 μm; oral diameter: 21 μm; aboral diameter: 14 μm) clearly fall within those established for *E. apertus*.

We do not see any reason to consider valid the variety *curta* of *E. apertus*, proposed by KOMAROVSKY (1959) (*E. apertus* var. *curta* Komarovsky), since the single character which distinguishes it from the main species is the total length, as stated that author "*Lorica similar in shape to that of main species except for its being considerably smaller*". Since the characteristics of the loricas are very variable. it seems probable that Komarovsky's specimen (*op. cit.*) is a smaller form, possibly younger. This argument is reinforced by the sizes provided by that author for the oral and aboral diameters, which are similar to within the limits established for *E. apertus*. Small specimens of *E. apertus*, probably all of them are young forms, were also found in the Mediterranean Sea (BALECH, 1959), in the Tropical Pacific (HASLE, 1960) and in the Phillipine and Celebe Seas (TANIGUCHI, 1977).

Both species *E. apertus* and *E. pinguins* may show diatoms from the genus *Chaetoceros* attached to their loricas. Generally *Chaetoceros dadayi* is associated with *E. apertus* and *C. tetrasticon* with *E. pinguins* (TAYLOR, 1982). These associations probably are never obligate nor specific however, since loricas of *E. pinguins* and *E. apertus* were found without diatoms (KUZMINA and ROGACHENKO, 1980; MARSHALL, 1934; HADA, 1938; HASLE, 1960; SOUTO, 1970), as well as both species of diatoms were observed growing to *E. apertus* (RAMPI, 1939, 1952). Furthermore, the presence of diatoms adhered to the lorica is not exclusive of *E. apertus*. Within the Tintinnina this association has been found between *E. lususundae* and *E. medius* with *Pseudoeunotia doliolus* (BALECH, 1962). KOFOID and CAMPBELL (1939) also mention one lorica of *E. lususundae* with 7 frustules of an unidentified diatom (probably belonging to the genus *Isthmia*). PAVILLARD (1935) found one lorica of *E. apertus* (= *E. tenuis* according to BALECH, 1962) with *Pseudoeunotia doliolus*. The latter was also found attached to the bowl of *Codonellopsis indica* Kofoid and Campbell. BALECH (1964) also found in Mar del Plata region (Argentina), some loricas of *E. medius* associated with diatoms of the genus *Hemiaulus*. This diatom genus was also recorded attached to *Tintinnus lusus undae* (= *Eutintinnus lususundae*) (PAVILLARD, 1916, p. 44, according to JÖRGENSEN, 1924). *Planktoniella sol* also has been observed adhered to *E. lususundae* (RAMPI, 1952). MARSHAL (1969) also commented that occasionally *E. lususundae* and *E. fraknoi* could be found in association with *Chaetoceros*. This symbiotic relationship also was found by FOL (1884) in *Rhabdonella elegans* (according to KOFOID and CAMPBELL, 1939).

Other species of the genus *Eutintinnus* can also be found with stranger materials attached to their lorica. This fact was referred to *E. lususundae* by DURÁN (1953), MARSAHLL (1969) and SASSI and MELO (1989).

Although the association between diatoms and Tintininna is known since last century (EHRENBERG, 1834; DADAY, 1887, among others), this phenomenon had been scarcely studied, so that the advantages and disadvantages to the majority of the animals involved in this kind of association is not known. Probably, this association results in reciprocal benefits, in spite of the fact that it has not been scientifically confirmed.

It is probable that *Eutintinnus* reduces its energy expenses to maintain itself in buoyancy when in symbiosis with *Chaetoceros*; the diatom increases its chances to obtain nutritional resources since it is transported by the ciliate. Living material observed by TAYLOR (1982) in the Adaman Sea and Caribbean Sea, indicated that Tintinnina is able to swim fast, even carrying diatoms attached to the lorica, although commenting that "*although one can infer that the diatom may benefit from the added flow of water over its surface [...], it seems doubtful that the tintinid benefits in any way*".

Many genera with agglutinated loricas (e.g. *Codonella*, *Codonaria*, *Tintinnidium*, *Tintinnopsis*, *Stenosemella* and *Laackmaniella* ) also have foreign particles adhered to their loricas (fragments of diatoms frustule, spicules of sponges, cocoliths and sand grains). Although the particle agglutination may result in an additional energetic expense to keep the organisms in the euphotic zone, it seems to be a strategy adopted by many species in order to increase their weight and consequently their sinking rate, increasing the possibility to scape of predators (CAPRIULO,1982; SASSI and MELO, 1989).

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