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Thecate dinoflagellates (Dinophyceae) from Bahía Fosforescente, Puerto Rico

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Abstract: Bahía Fosforescente, Puerto Rico, is well-known because of bioluminiscence caused by high concentrations of dinoflagellates. However, the specific composition of dinoflagellates has not been studied in detail. Several samples taken during 1975-1987 with net were analysed to study the dinoflagellates in the bay. Twenty-six taxa were identified, including 19 species, 3 varieties, and one form, together with three species not fully identified, all of them thecate. The valid, currently recognized names, as well as some synonyms are given, together with references, illustrations and distribution data. This study shows the constant presence of the species responsible for the bioluminiscence in the bay, *Pyrodinium bahamense*. The taxa *Ceratium hircus* and *Dinophysis caudata* var. *ventricosa* also occurred in all seasons. The genus *Protoperidinium* is represented by the greatest number of species in the bay (15). The unique hydrographic characteristics registered in the bay, such as the tidal and wind-driven mechanisms make possible the diversity of typically planktonic dinoflagellates in a shallow environment, although one benthic form was also found.

Key words: Dinoflagellates, phytoplankton, Bahía Fosforescente, Puerto Rico, taxonomy.

Bahía Fosforescente of La Parguera, Lajas, Puerto Rico, has been, for many years, one of the most atractive places for tourism and science in the southern part of the island. The bioluminiscence phenomenon is observed in the bay waters, which is caused by high concentrations of dinoflagellates.

Some physiological, chemical and ecological studies have been made in the bay (Burkholder & Burkholder, 1958). Recently, Seixas (1988) provided an account of the investigations made in the bay, mainly by researchers of the University of Puerto Rico, Mayagüez (Department of Marine Sciences) (Cintrón 1969, Cintrón *et al.* 1970), and also by foreign researchers visiting this interesting place (Gold 1965, Seliger *et al.* 1971).

There is no study especially devoted to the dinoflagellate fraction in the bay. Most of the studies have only mentioned or listed them. Margalef's (1957, 1961) works on phytoplankton composition in Puerto Rico involved many dinoflagellates. Margalef (1965) also gave a list of dinoflagellates, including some drawings, from the Caribbean Sea in front of Venezuela. New modern techniques have contributed to the dinoflagellates taxonomy, and present revisions are still necessary in the bay.

This paper deals with the dinoflagellates collected during 1975-1987, providing the valid, present names, synonyms and taxonomic comments in some cases, references, illustrations, and distribution.

MATERIAL AND METHODS

The area of Bahía Fosforescente, located in La Parguera, southwestern Puerto Rico, has already been described in various papers (Cintrón *et al.* 1970, Seixas 1988). Samples for this study were obtained from a central point within the bahia, with a phytoplankton net (80 µm mesh, 50 cm diameter), by hauls from a small boat. They were observed *in vivo* at the laboratory and then preserved with 5 % formalin.

Observations, measurements and micrographs were made with an inverted Nikon microscope, equiped with camera and videorecorder.

The material (in liquid) is deposited in an informal collection at the Departamento de Biología, Universidad Católica de Puerto Rico, Ponce, Puerto Rico, with Dr. N. Navarro R.

Terminology and present taxonomy followed Sournia (1973), Dodge (1975) and Balech (1974, 1988). The typical measurements are: total length (L), width (W), transdiameter (T), mean (x), and number of specimens measured (n).

RESULTS

Twenty-three dinoflagellates taxa were identified, and three remained not fully identified, all of them are thecate forms. The taxa are listed alphabetically and some comments are added. Table I shows the temporal distribution of the dinoflagellates.

TABLE I

Dinoflagellates in Bahia Fosforescente, Puerto Rico

Species	1	2	3	4	5	6	7
Ceratium declinatum f. *normale*			X				
C. furca var. *furca*		X					
C. fusus var. *fusus*			X				
C. hircus	X	X	X	X	X	X	X
Dinophysis caudata var. *ventricosa*	X	X	X	X		X	X
Gonyaulax cf. *digitale*		X					
Gonyaulax verior			X				
Prorocentrum gracile	X	X	X	X	X		
P. mexicanum		X					
Protoperidinium brochi		X	X	X	X	X	X
P. conicum	X						
P. crassipes	X	X					
P. depressum	X	X		X	X		X
P. divergens	X			X			
P. murrayi	X		X	X	X		
P. oceanicum	X	X		X			
P. pallidum			X				
P. pellucidum				X			
P. punctulatum				X			
P. steidingerae	X		X	X		X	
P. venustum		X				X	
P. sp. (aff. *wiesneri*)		X					
P. sp. (aff. *decollatum*)				X			
Protoperidinium sp.	X						
Pyrodinium bahamense	X	X	X	X	X	X	X
Pyrophacus steinii	X	X	X		X		

1= October, 1975; 2= October, 1976; 3= June, 1977; 4= October, 1977; 5= February, 1978; 6= July, 1984; 7= June, 1987

Ceratium declinatum f. normale Jörgensen Fig. 1

Sournia, 1967, p. 439, fig. 66, pl. 2, fig. 8; Hernández-Becerril, 1989, p. 43, fig. 22.

Scarse and rare in Bahía Fosforescente (BF). It was present only in June, 1977. Taxon distributed in temperate and tropical waters.

Measurements: L= 180 µm, W= 38 µm, n= 1.

Ceratium furca (Ehr.) Claparéde et Lachmann var. *furca* Fig. 4

Sournia, 1967, p. 396, fig. 20; Hernández-Becerril, 1989, p. 35, figs. 4, 45.

Rare in BF; it occurred in October, 1976. This variety shows world-wide distribution, being very common in the Caribbean Sea (Halim, 1967).

Measurements: L= 184-210 µm (x= 196 µm), W= 28-32 µm (x= 30 µm), n= 4.

Ceratium fusus (Ehr.) Dujardin var. *fusus* Fig. 5

Sournia, 1967, p. 409, fig. 32; Hernández-Becerril, 1989. p. 38, fig. 15.

It is also rare in BF, present only in June, 1977. The type (var. *fusus*) is cosmopolitan in temperate and tropical waters.

Measurements: L= 435 µm, W= 36 µm, n= 1.

Ceratium hircus Schröder Fig. 2

Jörgensen, 1911, p. 18, fig. 27; Carbonell, 1979, p. 26, pl. 1, figs. 3 a-f.

= *Ceratium furca* var. *hircus* (Schröder) Margalef ex Sournia

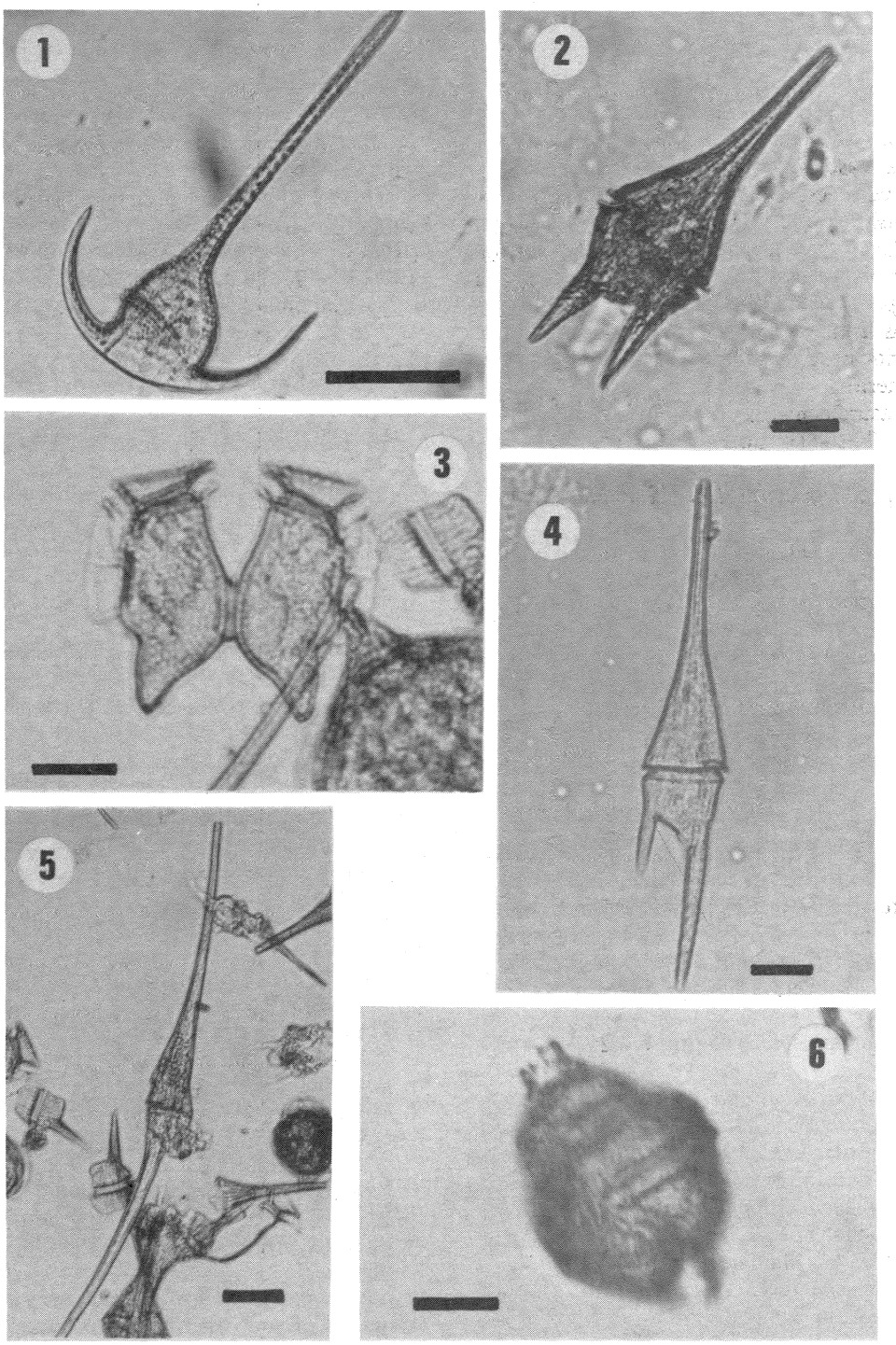
Sournia, 1973, p. 9.

This species is common and abundant all seasons in BF. It has been cited often for the Caribbean Sea (Margalef, 1961, 1965; Halim, 1967; Carbonell, 1979, 1982; López Baluja, 1980), with a typical distribution from tropical areas (López-Baluja, 1980; Balech, 1988).

The taxonomy of this species has been discussed, whether it should be considered as a separate, valid species, or it is a form of *C. furca* (Carbonell, 1979). Here it is referred to as a separate species, because transition was not found and populations in other places are stable.

Measurements: L= 128-149 µm (x= 134.3 µm), W= 40-44 µm (x= 41.8 µm), n= 21.

Dinophysis caudata var. *ventricosa* Pavillard Figs. 3, 7, 8



Figs. 1-6. Fig. 1. *Ceratium declinatum* f. *normale*, Fig. 2. *Ceratium hircus*, Fig. 3. *Dinophysis caudata* var. *ventricosa*, two cells, Fig. 4. *Ceratium furca* var. *furca*, Fig. 5. *Ceratium fusus* var. *fusus*, Fig. 6. *Gonyaulax* cf. *digitale*. Scale bars: Figs. 1, 5 = 50 µm, Figs. 2-4, 6= 20 µm.

Margalef, 1957, p. 45, fig. 1 d.

Common and abundant in BF, encountered in all the samples.

The type species, *Dinophysis caudata* Saville-Kent, shows a high degree of variation, for such a reason many authors have proposed several varieties, including the valid species *D. diegensis* Kofoid y *D. tripos* Gourret. The var. *ventricosa* does not develop the characteristic posterior process properly and is thinner than the type. Balech (1988) mentioned that the specimens from coastal waters are coarser with the posterior process shorter. This variety is typically neritic.

Measurements: L= 51-56 µm (x= 52.7 µm), W= 35-38 µm (x= 36.5 µm), n= 15.

Gonyaulax cf. *digitale* (Pouchet) Kofoid Fig. 6

Kofoid, 1911, p. 214, pl. 9, figs. 1-5; Hernández-Becerril, 1988, p. 429, figs. 20, 43.

Very rare species in BF, encountered only in October, 1976. Species distributed in temperate and subtropical waters.

Measurements: L= 62 µm, W= 46 µm, n= 1.

Gonyaulax verior Sournia Fig. 9

Sournia, 1973, p. 34; Balech, 1988, p. 167, pl. 74, figs. 5, 6.

= *Gonyaulax diacantha* (Meunier) Schiller

Schiller, 1937, p. 300, fig. 309 (non *Gonyaulax diacantha* Athanossopoulos, 1931)

Rare species in BF, only found in October, 1976. It is characteristic from warm-waters and relatively high salinities. It has been previously reported for Puerto Rico as *G. diacantha* (Margalef, 1961).

Measurements: L= 48 µm, W= 25 µm, n= 1.

Prorocentrum gracile Schütt Fig. 10

Dodge, 1975, p. 114, fig. 3 D, pls. 2 D, 3 E; Hernández-Becerril, 1988, p. 424, fig. 2.

This is a fairly constant species in BF. It shows a wide distribution in temperate and tropical waters. Species also reported earlier for the Caribbean (Margalef, 1965).

Measurements: L= 49-55 µm (x= 52.2 µm), W= 21-24 µm (x= 22.8 µm), n= 7.

Prorocentrum mexicanum Osorio-Tafall Fig. 11

Osorio-Tafall, 1942, p. 440, pl. 34, figs. 3, 8; Faust, 1990, p. 549, figs. 5-10.

= *Prorocentrum rathymum* Loeblich, Sherley et Schmidt

Fukuyo, 1981, p. 968, figs. 5-7, 47.

It is very rare, with just one specimen found in BF. Distributed in temperate and tropical waters, inhabiting benthic habitats.

This species has been apparently confused with others like *P. maximum* (Gourret) Schiller (from which was placed as synonym by Dodge, 1975, p. 117) and the same *P. rathymum.*

Measurements: L= 29-31 µm (x= 30 µm), W= 22-23 µm (x= 22.5 µm), n= 2.

Protoperidinium brochi (Kofoid et Swezy) Balech Fig. 15

Balech, 1974, p. 70; Balech, 1988, p. 108, pl. 41, fig. 4-7.

Is is fairly constant in BF. This is basically a neritic species, in temperate and subtropical waters.

Measurements: L= 90-94 µm (x= 92 µm), W= 68-69.8 µm (x= 68.9 µm), n= 6.

Protoperidinium conicum (Gran) Balech Fig. 22

Balech, 1974, p. 58; Balech, 1988, p. 87, pl, 26, figs. 1-4.

This species was found only in October, 1975 in BF. It is widely distributed in all temperate to tropical waters.

Measurements: L= 94-98 µm (x= 96.2 µm), W= 88-91 µm (x= 89.6 µm), n= 5.

Protoperidinium crassipes (Kofoid) Balech Fig. 28

Balech, 1974, p. 60; Balech, 1988, p. 110, pl. 43, figs. 5-7.

This species occurred in October, 1975, 1976 in BF. Species commonly present in subtropical and temperate waters.

Measurements: L= 100-104 µm (x= 102.2 µm), W= 86-92 µm (x= 89 µm), n= 6.

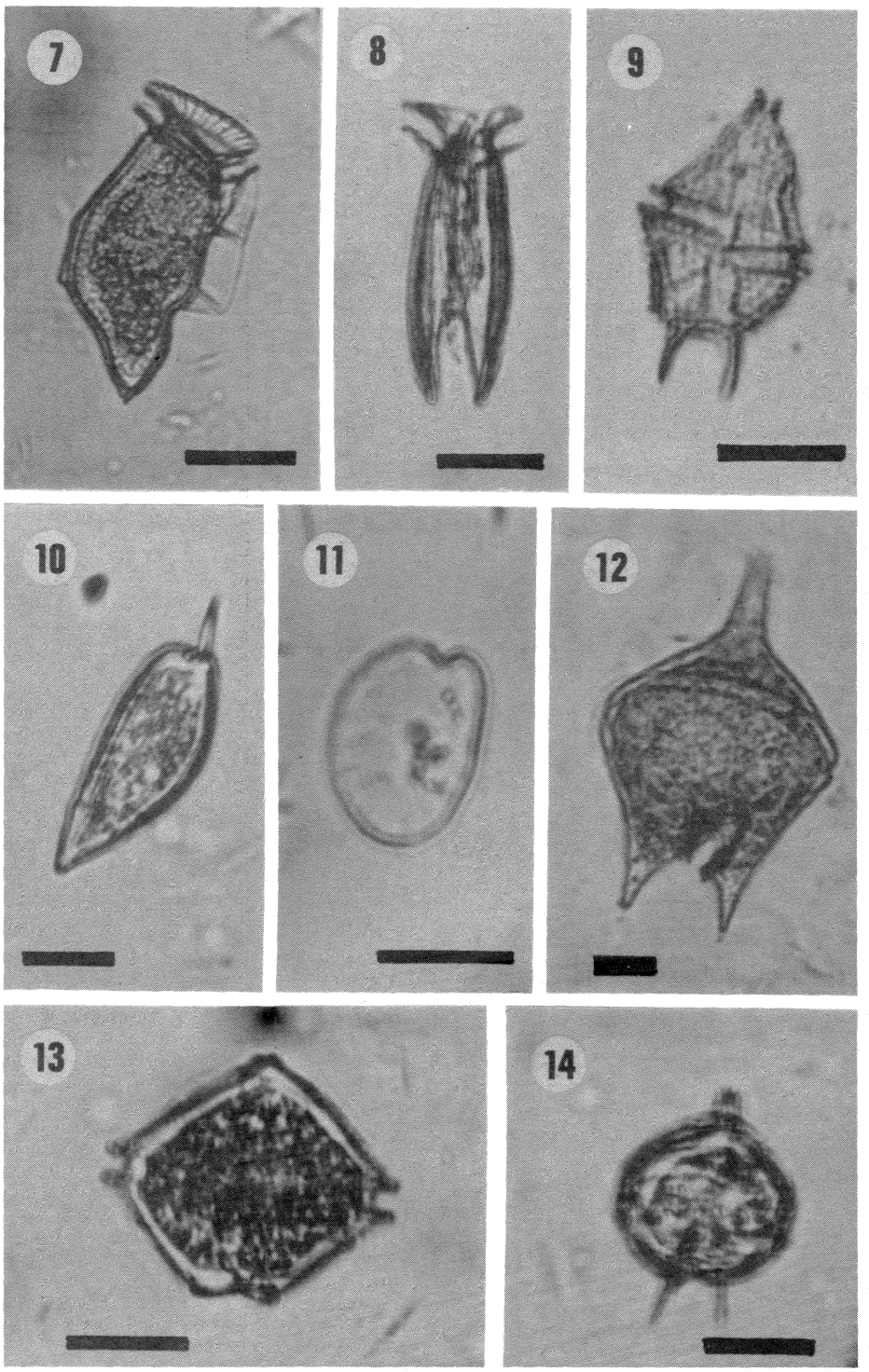
Protoperidinium depressum (Bailey) Balech Fig. 16

Balech, 1974, p. 57; Balech, 1988, p. 87, pl. 25, figs. 4-8.

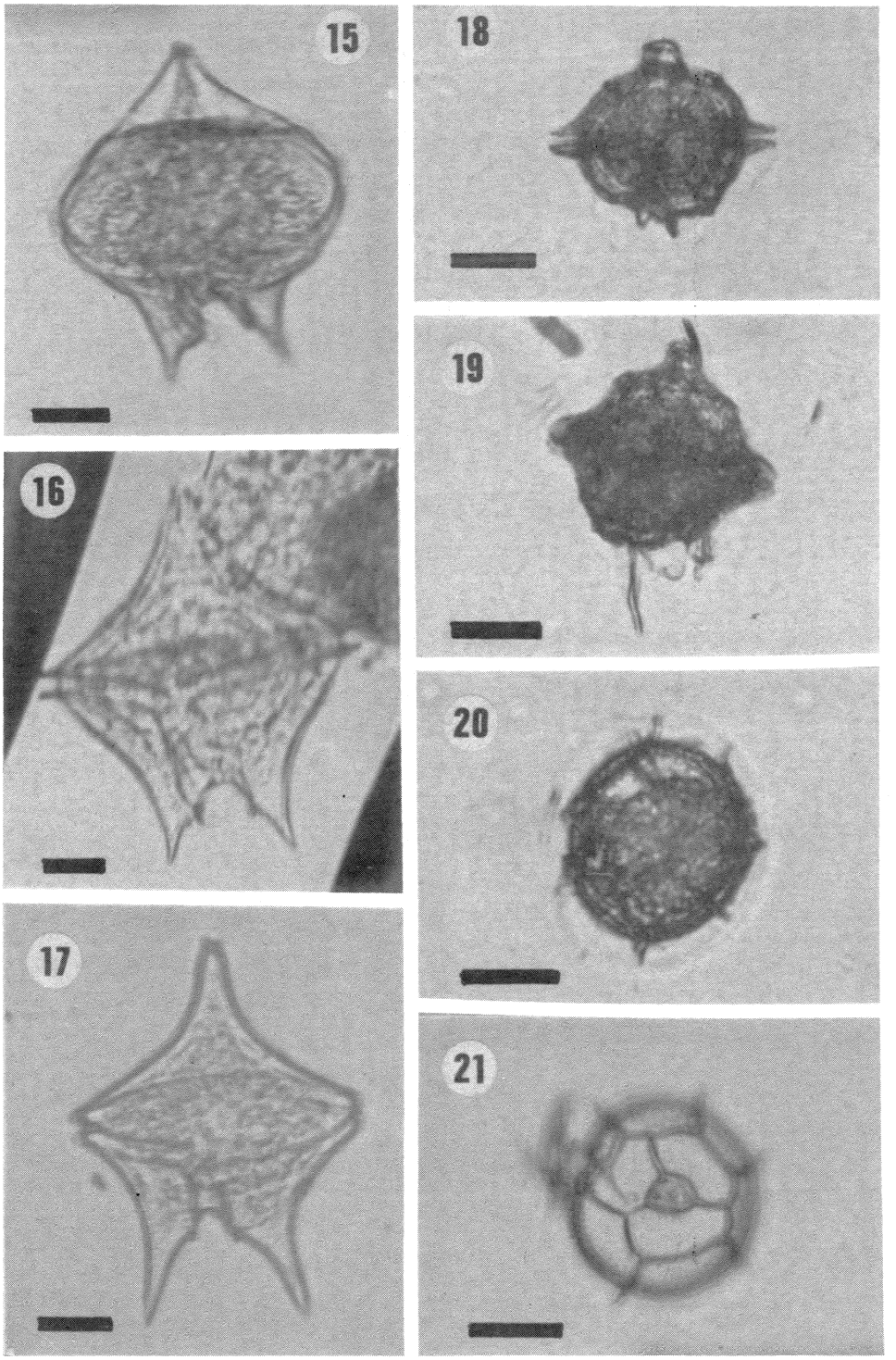
It is present in most of the samples from BF. A species of wide distribution, common in all the seas, except in polar areas.

Measurements: L= 104-112 µm (x= 107.6 µm), W= 82-87 µm (x= 84.6 µm), n= 5.

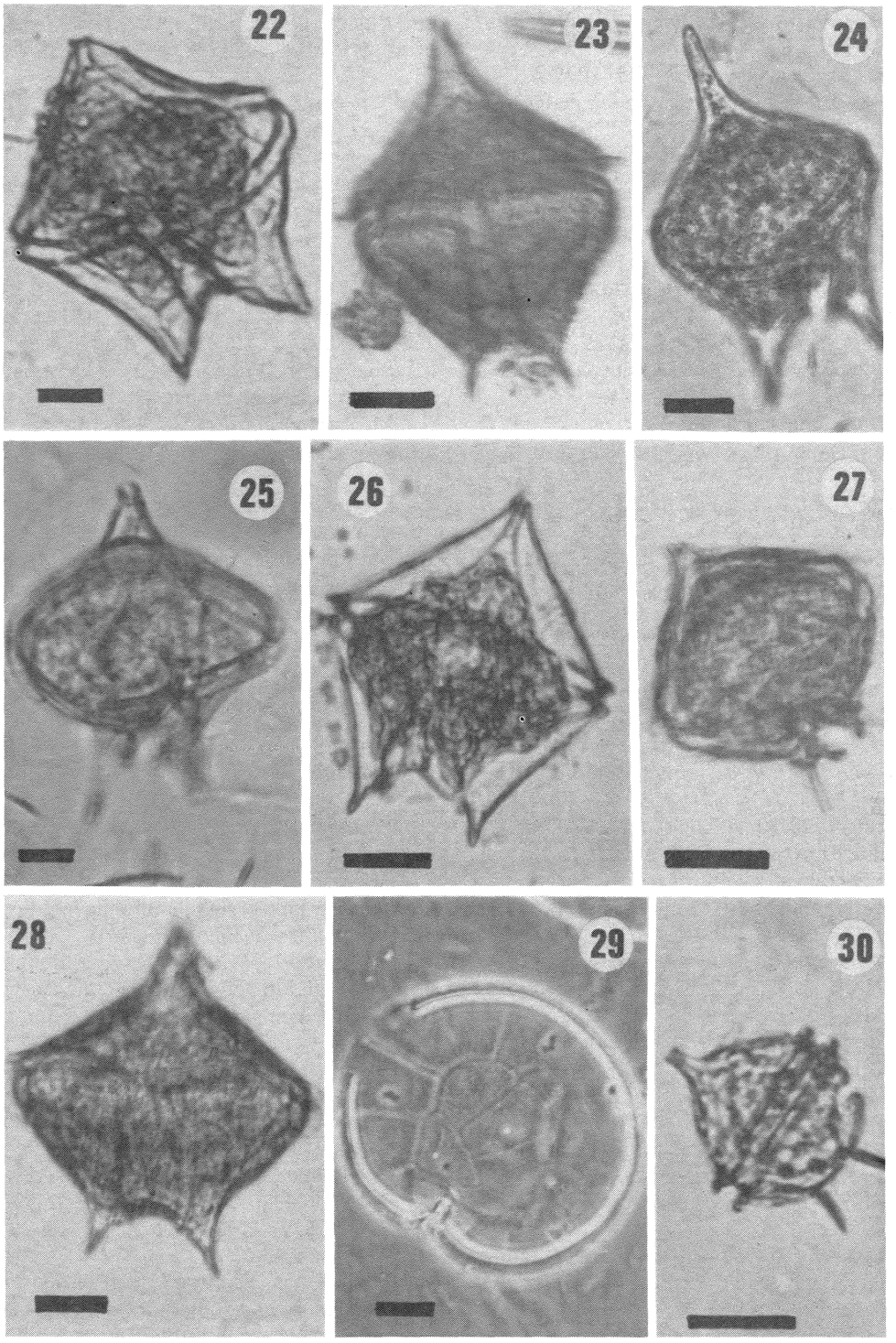
Protoperidinium divergens (Ehrenberg) Balech Fig. 25



Figs. 7-14. Figs. 7, 8. *Dinophysis caudata* var. *ventricosa*, lateral and ventral views, respectively, Fig. 9. *Gonyaulax verior*, Fig. 10. *Prorocentrum gracile*, Fig. 11. *Prorocentrum mexicanum*, Fig. 12. *Protoperidinium oceanicum*, Fig. 13. *Protoperidinium punctulatum*, Fig. 14. *Protoperidinium pellucidum*. Scale bars: 20 µm.



Figs. 15-21. Fig. 15. *Protoperidinium brochi*, Fig. 16. ***Protoperidinium depressum***, **Fig. 17.** ***Protoperidinium venustum*, Figs.** 18-21. *Pyrodinium bahamense,* (Fig. 18- specimen with no spines, Fig. 19- specimen with long spines, Figs. 20, 21- **apical** view of specimens, showing the plates). Scale bars: 20 µm.



Figs. 22-30. Fig. 22. *Protoperidinium conicum,* Fig. 23. *Protoperidinium pallidum,* Fig. 24. *Protoperidinium* ***steidingerae,*** Fig. 25. *Protoperidinium divergens*, Fig. 26. *Protoperidinium* sp. (aff. *decollatum*), Fig. 27. *Protoperidinium* sp. (aff. *wiesneri*), Fig. 28. *Protoperidinium crassipes*, Fig. 29. *Pyrophacus steinii*, Fig. 30. *Protoperidinium* sp. Scale bars: 20 µm.

Balech, 1974, p. 60; Balech, 1988, p. 109, pl. 41, figs. 11-13.

It occurred in October, 1975, 1977 in BF. Widely distributed in warm and temperate waters.

Measurements: L= 94-110 µm (x= 102 µm), W= 80-83 µm (x= 81.5 µm), n= 2.

Protoperidinium murrayi (Kofoid) Hernández-Becerril

Hernández-Becerril, 1991, p. 79, figs. 6, 27.

= *Peridinium murrayi* Kofoid

Kofoid, 1907, p. 176, pl. 5, fig. 29.

It is uncommon in BF. Distributed in tropical waters.

Measurements: L= 113-121 µm (x= 117.2 µm), W= 75-85 µm (x= 80.4 µm), n= 5.

Protoperidinium oceanicum (Vanhöffen) Balech Fig. 12

Balech, 1974, p. 57; Balech, 1988, p. 85, pl. 23, figs. 7-10.

Species scarse and rare in BF. It exhibits a wide distribution in temperate and subtropical seas.

Measurements: L= 109-113 µm (x= 111 µm), W= 76-78 µm (x= 77 µm), n= 2.

Protoperidinium pallidum (Ostenfeld) Balech Fig. 23

Balech, 1973, p. 365, pl. 6, figs. 101-110.

Species not common in BF. It is typical from temperate and cold waters.

Measurements: L= 91 µm, W= 58 µm, n= 1.

Protoperidinium pellucidum Bergh Fig. 14

Dodge, 1982, p. 202, figs. 23 J, K, pl. 5 c; Hernández-Becerril, 1991, p. 82, fig. 43.

Rare species in BF, present in October, 1975. Temperate to subtropical.

Measurements: L= 41 µm, W= 30 µm, n= 1.

Protoperidinium punctulatum (Paulsen) Balech Fig. 13

Balech, 1974, p. 58; Balech, 1988, p. 90, pl. 30, figs. 1-5.

Present only in October, 1975. Species common in temperate and tropical waters.

Measurements: L= 38-42 µm (x= 40 µm), W= 42-46 µm (x= 44 µm), n= 2.

Protoperidinium steidingerae Balech Fig. 24

Balech, 1979, p. 55, pl. 1, figs. 1-6, pl. 2, figs. 1-10; Balech, 1988, p. 188, pl. 85, figs. 1-7.

It is common in the Gulf of Mexico and is also present in Caribbean waters (Colombia). It is a warm-water form.

Measurements: L= 110-116 µm (x= 111.7 µm), W= 66-71 µm (x= 68.7 µm), n= 5.

Protoperidinium venustum (Matzenauer) Balech Fig. 17

Balech, 1974, p. 57; Balech, 1988, p. 86, pl. 24, figs. 1-4.

Species uncommon in BF. It is apparently typical of subtropical waters.

Measurements: L= 104-106 µm (x= 105.6 µm), W= 76-77.8 µm (x= 76.9 µm), n= 3.

Protoperidinium sp. aff. *wiesneri* (Schiller) Balech Fig. 27

Balech, 1976, p. 40, fig. 6.

Species rare in BF. Its general shape, arrangement of plates and measurements agree with Balech's (1976) description, but later Balech (1988) provided some drawings which are different from the specimens found in BF. The species is common in temperate and tropical waters.

Measurements: L= 58 µm, W= 26 µm, n= 1.

Protoperidinium sp. (aff. *decollatum* Balech ?) Fig. 26

Also very rare in BF. It resembles *P. conicum*, but its size is smaller and the length:width ratio is higher in this species. It is most probably related to *P. decollatum*, although that species is distributed in rather cold waters.

Measurements: L=88 µm, W= 68 µm, n= 1.

Protoperidinium sp. Fig. 30

Species unidentified, scarse in BF.

Measurements: L= 48 µm, W= 31 µm, n= 1.

Pyrodinium bahamense Plate Figs. 18-21

Plate, 1906, p. 411, pl. 18; Balech, 1985, p. 19-29, fig. 1, pl. I, figs. 1-17, pl. II, figs. 18-41, pl. III, figs. 42-56.

This species is constant in all seasons, being very abundant and sometimes dominant in BF. It is the species responsible for the bioluminiscence in the bay. The specimens found do not form chains, but are solitary. It is very common in the Caribbean Sea (Margalef 1957; Halim

1967), and is distributed in tropical and subtropical regions.

P. bahamense is also associated to the production of toxic "red tides" (Steidinger 1983), especially in areas of the Pacific Ocean (MacLean 1977). Balech (1985) studied and discussed the morphologic variations of the species from many places around the world, which had been considered taxonomic varieties (depressed forms, without spines: var. *compressa* (Böhm) Steidinger, Tester et Taylor), concluding that there is only one valid species.

Measurements: L= 52-78 µm (x= 66.2 µm), W= 42-45 µm (x= 43.3 µm), n= 28.

*Pyrophacus steinii (*Schiller) Fig. 29

Wall et Dale, 1971, p. 234, figs. 1 B, 26-36; Hernández-Becerril, 1988, p. 429.

Frequent in all samples, but it is not abundant in BF. Distributed in temperate and subtropical waters. It has also been cited for the Caribbean Sea (Margalef 1965).

Measurements: T= 110-113 µm (x= 111.6 µm), n= 6.

DISCUSSION

The dinoflagellate assemblages encountered in this study contain a great majority of planktonic forms, with only one benthic species. The hydrographic conditions in the bay (*e.g.* tidal and wind-driven variations in convergence of oceanic, bay and fresh-water mechanisms), as well as the behaviour of the dinoflagellates (*e.g.* upward taxis of the organisms) are thought to be the factors that support the planktonic populations in a rather shallow environment (Seliger *et al.* 1971).

The species *Pyrodinium bahamense* is present in all samples, together with *Ceratium hircus* and *Dinophysis caudata* var. *ventricosa*, and they presumibly occurr all seasons along the year, although their abundance may vary. *Pyrodinium bahamense* appears in solitary forms, as found in other places in the Caribbean Sea (Hernández-Becerril, in prep.) and is apparently non toxic.

It is important to recognize the relatively high number of *Protoperidinium* species detected in the bay (15), which are all truly planktonic. In contrast, the genus *Ceratium*, which traditionally exhibits a great species diversity in both neritic and oceanic waters, is poorly represented here (by only 4 taxa). The only benthic species recorded here, *Prorocentrum mexicanum*, is sometimes associated to toxic blooms events.

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RESUMEN

Bahía Fosforescente, Puerto Rico es un área bien conocida debido al fenómeno de bioluminiscencia, el cual es ocasionado por altas concentraciones de dinoflagelados. La composición de los dinoflagelados no se ha estudiado en detalle. En este estudio se analizaron diversas colectas con red efectuadas en dicha bahía durante 1975-1987, para investigar la fracción de los dinoflagelados. Se encontraron 26 taxa: 19 especies, 3 variedades y 1 forma identificados, además de 3 especies sin identificar completamente, todas son formas tecadas. Se anotan los nombres reconocidos actualmente, así como sus sinónimos conspicuos, referencias, ilustraciones y datos de distribución. Es notoria la presencia constante de la especie responsable de la bioluminiscencia en la bahía, *Pyrodinium bahamense,* a lo largo del período estudiado, lo mismo que *Ceratium hircus* y *Dinophysis caudata* var. *ventricosa.* El género *Protoperidinium* estuvo representado por el más alto número de especies (15). La diversidad de formas típicamente planctónicas, donde sólo se detectó una especie bentónica, está sustentada en las singulares condiciones hidrográficas de un ambiente somero como es esta bahía.

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