

# *Dotyophycus pacificum* I. A. Abbott (Liagoraceae, Rhodophyta) a new record for the Atlantic Ocean

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Recebido em 21/05/2010. Aceito em 16/03/2011

## RESUMO

(*Dotyophycus pacificum* Abbott (Liagoraceae, Rhodophyta) nova referência para o oceano Atlântico). Durante estudo sobre as rodofíceas do litoral do estado da Bahia foram encontrados exemplares de *Dotyophycus pacificum* Abbott em coletas realizadas a 23-36 metros de profundidade. Os espécimes foram estudados detalhadamente e comparados a espécies morfológicamente semelhantes. Esta é a primeira ocorrência de *D. pacificum* para o oceano Atlântico.

**Palavras-chave:** Bahia, Brasil, diversidade, infralitoral

## ABSTRACT

(*Dotyophycus pacificum* I. A. Abbott (Liagoraceae, Rhodophyta) a new record for the Atlantic Ocean). Specimens of *Dotyophycus pacificum* I. A. Abbott were found during a survey of Rhodophyta on the coast of Bahia state. The samples were taken from 23-36 meters depth and the specimens found were studied in detail and compared to other morphologically similar species. This is the first time that the genus *Dotyophycus* is cited for the Atlantic Ocean.

**Key words:** Bahia, Brazil, diversity, subtidal

## Introduction

The majority of rhodophycean species from the Bahian coast are largely distributed in the western American tropical region and in the tropical area of the Indo-Pacific in a smaller fraction. According to Horta *et al.* (2001), the Brazilian and Caribbean seaweed flora have both originated in the Indo-Pacific region.

A detailed exploration of the subtidal zone has revealed many little-known and previously unreported taxa that are new for the Brazilian coast and the Atlantic Ocean (Nunes *et al.* 2008a, b; Nunes & Guimarães 2008).

The genus *Dotyophycus* was described by Abbott (1976) based on the details of origin of the carpogonial branches, the manner of initiation of gonimoblast and the subsequent fusion cells of the carpogonial branch with the lower gonimoblastic cells. According to Abbott and Yoshizaki (1981), this genus is described as having a calcified thallus, brittle when dry and a cylindrical-compact axis. The thallus is multiaxial, branching dichotomous to subdichotomous,

and the cortical or assimilatory filaments present terminal cells of different forms. The carpogonial branch originates from the medullar region through a modified cortical filament, producing 3 to 4-celled carpogonial branches, with 8-10 sterile cells located below. These cells can form 1-13 short lateral filaments (subsidiary carpogonial filaments). Gonimoblasts are formed after transverse division of the zygote, giving rise to radial filaments with terminal cells that become carposporangia. Dioecious and monoecious plants, spermatangia originating in groups on peduncles.

Three species of *Dotyophycus* are recognized at present: *D. abbottiae* Kraft, *D. pacificum* I.A. Abbott and *D. yamadae* (Ohmi *et* Itono) I.A. Abbott *et* Yoshizaki, all occurring in the Indian and Pacific Oceans (Guiry & Guiry, 2009). The species *D. corymbosum* was described by Rishnamurthy & Sundararajan (1985) from the Indian Ocean, but after analyzing the type material, Abbott (1999) considered the species as being synonymous with *D. yamadae*.

*Dotyophycus* was reported by Nunes (2005b) on the coast of Bahia, but due to scarce material available it was

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not possible to observe diagnostic features that separate the species.

The identification of the species is based mainly on their habit, pattern of division of fertilized carpogonium, presence or absence of short lateral filaments on the carpogonial branch and extension of cell fusions in the carpogonial branch.

This work describes the morphology and aspects of the reproduction of *Dotyophycus pacificum*, collected on the Brazilian northeastern coast, thus being the first citation of this species from the Atlantic Ocean.

## Material and methods

The material was collected on Bahia's coast on several beaches of Camaçari and Vera Cruz Counties, being sampled from the subtidal region (23 to 36 m) using a Holme dredge and preserved in 4% formalin/seawater. Stereomicroscope and optical microscope were used to observe the external and internal morphology. Vegetative and reproductive structures were studied through histological hand sections made with a razor blade after decalcification with HCl 5%. Sections were stained in a solution of 1% aniline blue to which a small amount of 1 N HCl was added as a mordant. To characterize the calcification pattern, specimens were air-dried, fractured and mounted on aluminum stubs. The stubs were then coated with gold before viewing in Zeiss Scanning Electron Microscope (SEM) at 15 kV. The material identified was deposited at the Herbarium Alexandre Leal Costa (ALCB) of the Department of Botany, Federal University of Bahia, Brazil.

## Results and discussion

*Dotyophycus pacificum* Abbott, Phycologia 15: 125. 1976.  
Figures: 1-22

Type-locality: Moloka'i, Hawaiian Islands. Holotype: BISH 499995.

Erect terete thallus, 4-6 cm in length, 0.5-1.5 mm in diameter, mildly calcified at the apex heavily calcified at the base, dichotomous to subdichotomously branched, occasionally geniculated at branch angles and sharpened at the tips. Thallus brittle and sometimes powdery when dried. Calcification around medullary core was more conspicuous, with cortical and medullar filaments immersed in a matrix of unbranched aragonite crystals. Thin young medullar filaments 9-17  $\mu\text{m}$  increasing in diameter in older areas to 12-25  $\mu\text{m}$ . Cortical or assimilatory filaments 260-300  $\mu\text{m}$  in length, 3-5 times di-trichotomous with cylindrical cells below and large inflated subterminal cells, each subtending 3-4 smaller obovoid terminal cells 14-20  $\mu\text{m}$  in diameter and 19-38  $\mu\text{m}$  in length. Rhizoidal filaments were arising on inner cortical cells. Primary carpogonial branches originated from medulla through a modified cortical

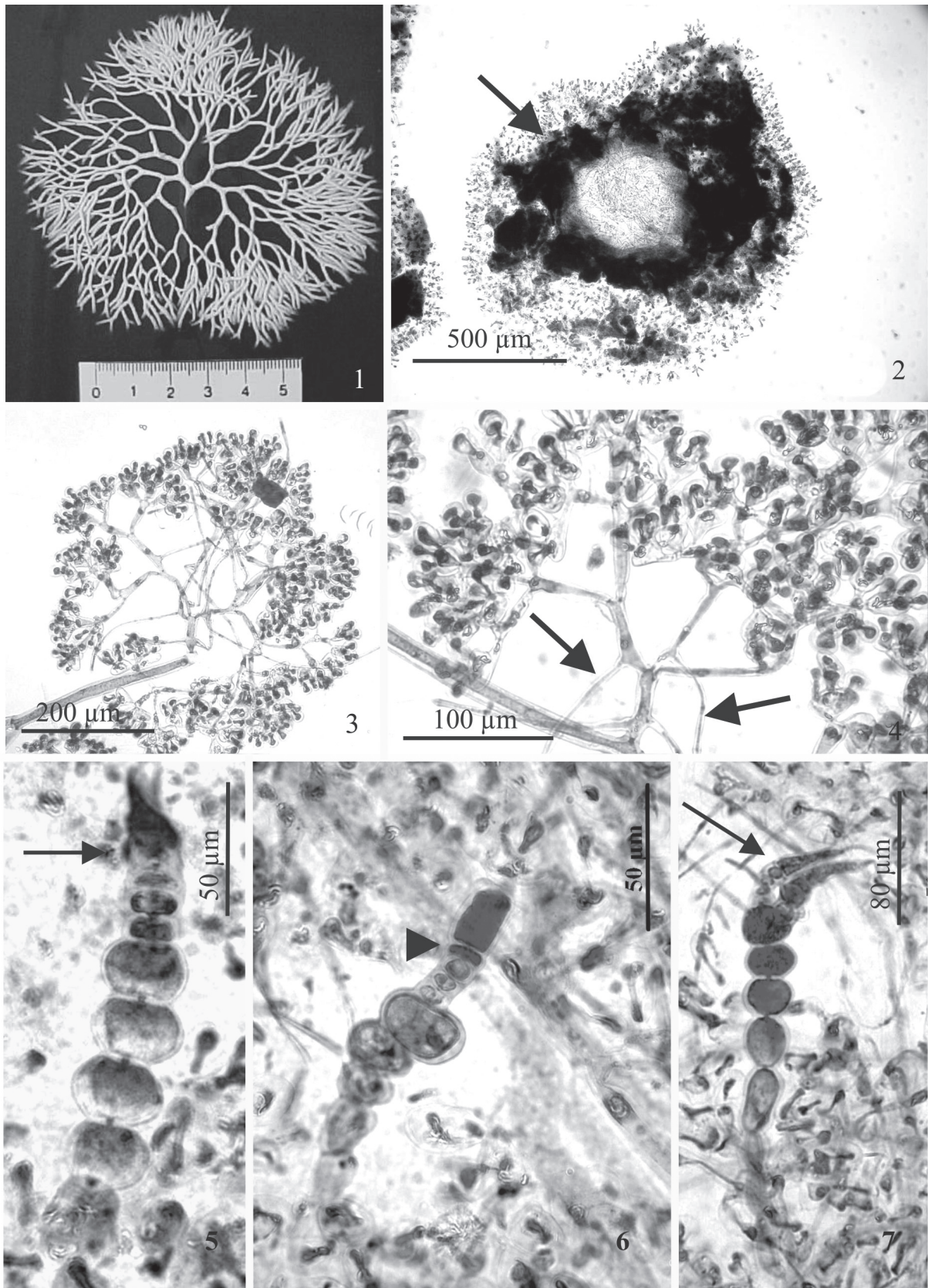
filament, ending with 3 to 4 celled carpogonial branch and having 8-12 sterile cells below. Short filaments varying in number from 1-5 produced laterally from cells of the carpogonial branch. After fecundation, transverse division occurs on the carpogonium base. The upper cell divides successively forming gonimoblastic filaments, which are radially arranged. Terminal cells become carposporangia, carpospores individed, 7-10  $\mu\text{m}$  in width and 16-30  $\mu\text{m}$  in length. Cystocarp prostrate, 410-680  $\mu\text{m}$  in diameter. Carpogonial branch cells and first gonimoblastic cells may fuse. Spermatangial branches were not observed.

Studied material: **BRASIL. Bahia: Camaçari**, Arembepe, Cepemar, 10/XII/1993, (ALCB); 12°44'65"S, 38°21'56"W, Cetrel, 12/I/1997, (ALCB); 12°44'12"S, 38°05'12"W, Cetrel, 19/II/2003, (ALCB); 12°47'04"S, 38°06'38"W, (ALCB); 12°47'31"S, 38°07'58"W, (ALCB); **Vera Cruz**, Cacha-Prego, J.M.C. Nunes, 18/I/2000, (ALCB); Mar Grande, J.M.C. Nunes, 20/I/2000, (ALCB).

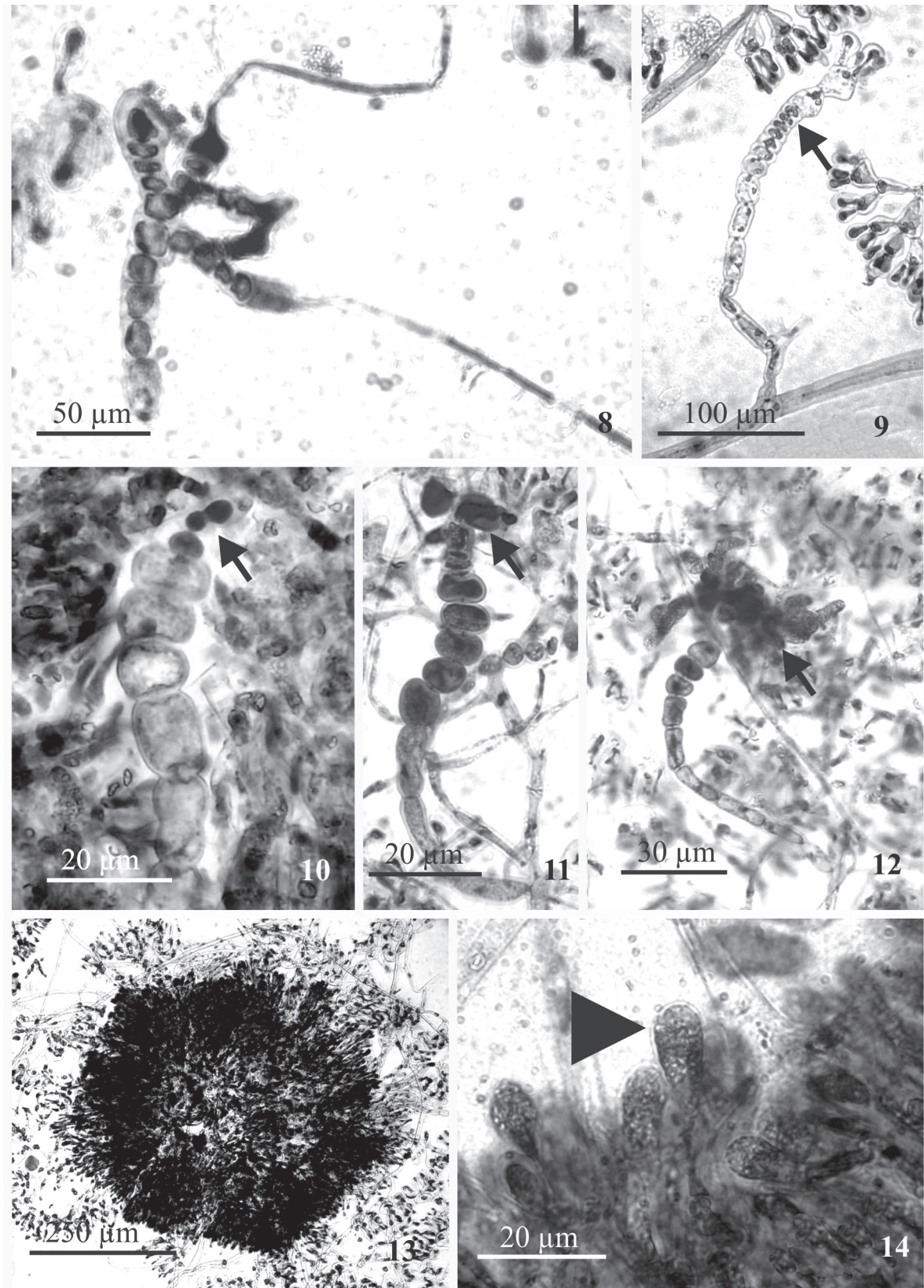
Plants growing on calcareous nodules (rhodolith beds) in the subtidal zone from 23 to 36 meters depth. *Tiffaniella gorgonea* (Mont) Doty et Meñez was usually found as epiphyte.

The studied material was placed in genus *Dotyophycus* since it presents a long carpogonial branch of 13-16 cells that is homologous with an entire assimilatory (cortical) filament and a diffuse, radiating carposporophyte. Also, cells from the primary carpogonial branch can originate other carpogonial branches (polycarpogonial condition). Of the more closely related genera of the family Liagoraceae (Tab. 1), *Liagoropsis* Yamada has some affinity with the Brazilian material. However, in *Dotyophycus* the carpogonial filaments replace an entire cortical lateral, whereas those of *Liagoropsis* replace the primary subdivision of a cortical lateral and are also relatively compact and short (Doty and Abbott 1964; Kraft 1988). Regarding the genus *Yamadaella* I.A. Abbott, we also observed some similarities in relation to the position of the primary carpogonial branch and some of the post-fertilization aspects. However, the presence of uniformly three-celled, non-proliferous carpogonial filaments and carpotetrasporangia represent important distinctive characteristics typical of the genus *Yamadaella*.

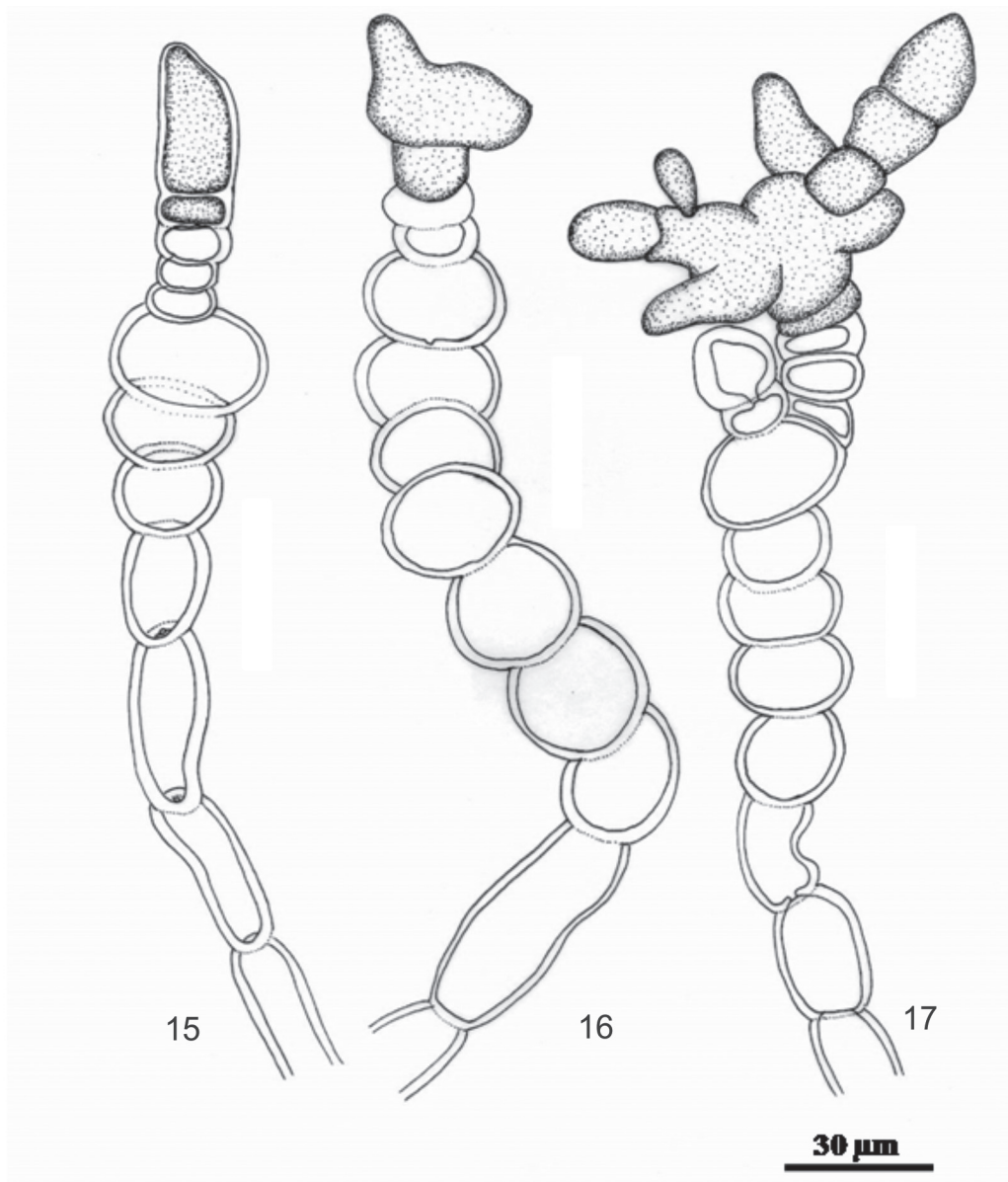
Among the species that belong to the genus *Dotyophycus* (Tab. 2), the studied specimens can be identified as *D. pacificum* since they present the set of features described by Abbott (1976) for this species: brittle cylindrical stem when dry; branches mainly dichotomous; absence of subsidiary cortical filaments; rhizoidal cells present; transverse division of fertilized carpogonia followed by lateral divisions originating the first cells of the diffuse gonimoblast; and fusion of carpogonial branch cells and first gonimoblastic cells. The specimens examined were collected in depths similar to those in which *D. pacificum* from Hawaii is found indicating that this species inhabits deeper waters when compared to the other two species described in the genus.



Figures 1-7. Morphological and reproductive aspects of *Dotyophycus pacificum* I.A. Abbott: 1 - General aspect (scale in cm); 2 - Transverse section showing calcification pattern (arrow); 3 - Cortical cells of assimilatory filaments; 4 - Assimilatory branches with basal rhizoidal cells (arrow); 5 - Aspects of carpogonial branches (arrow); 6 - A transverse division in the base of carpogonia (arrow head). 7 - Two carpogonial branches arising from an assimilatory filament (arrow)



Figures 8-14. Reproductive aspects of *Dotyophycus pacificum* I.A. Abbott: 8 – Four carpoogonial branches arising from assimilatory filaments; 9 – Atypical assimilatory filaments arising from carpoogonial branch (arrow); 10 – early stages of carpoogonial branch formation (arrow); 11 – Lateral division (arrow) of the fertilized carpoogonium giving rise to the gonimoblast initials; 12 – Gonimoblastic filaments producing the base of the diffuse cystocarp (arrow); 13 – Mature prostrate cystocarp; 14 – Detail of carposporophyte showing carposporangia (arrow head).



Figures 15-17. Reproductive aspects of *Dotyophycus pacificum* I.A. Abbott: 15 carpogonial branch before fertilization; 16 and 17 – early stages of development of gonimoblastic filaments after fertilization.

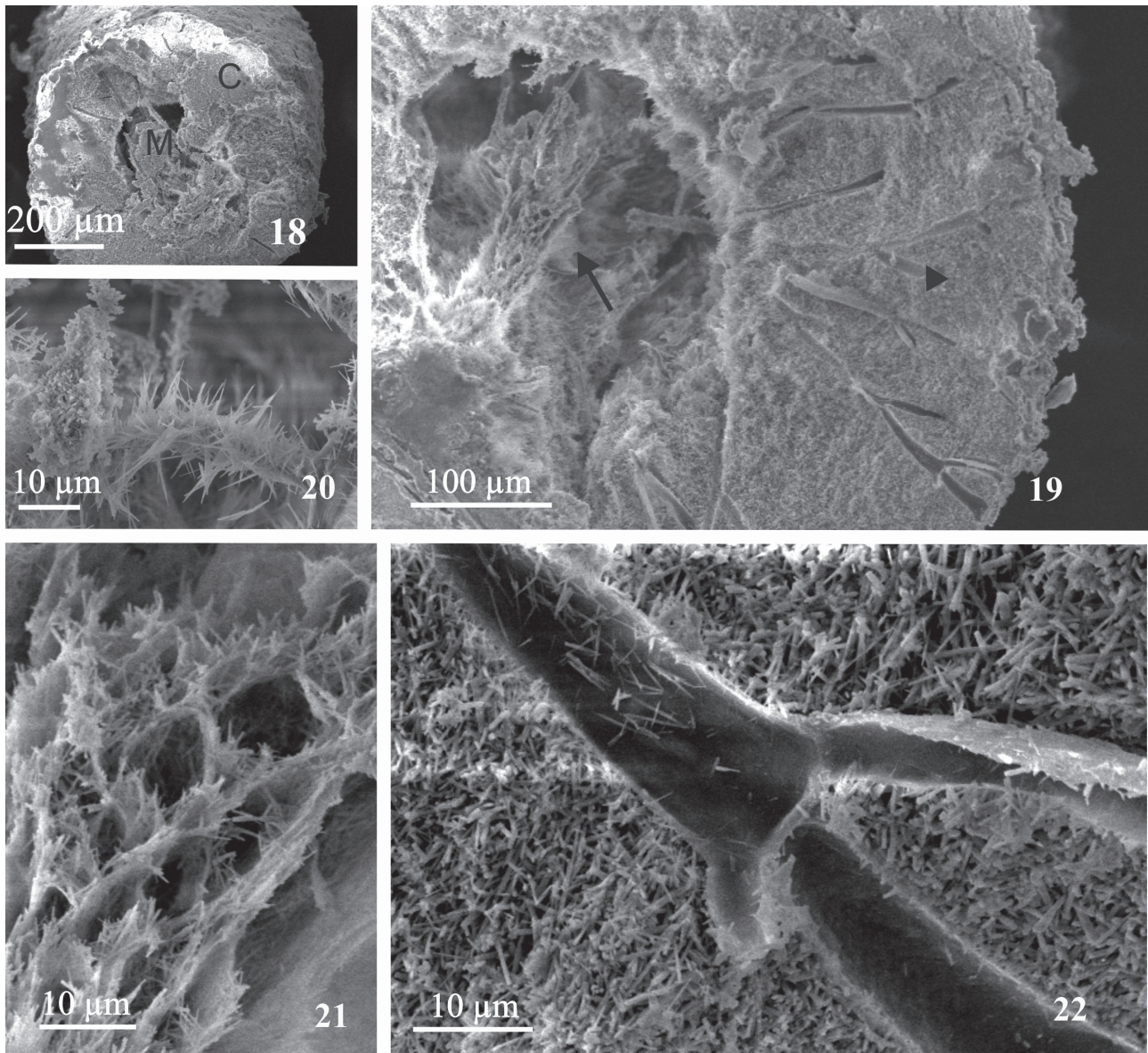
Kraft (1988) points out that only a few characteristics are available to separate the species into the genus *Dotyophycus*. *D. pacificum* differs from the other two species mainly in being monocarpogonial and in becoming geniculated upon drying. *D. abbottiae* and *D. yamadae* have compound carpogonial filaments (Chiang & Chen 1983: Fig. 4 and 5; Kraft 1988: Fig. 7 and 14). Of the studied specimens, the majority of the assimilatory filaments give rise to only one carpogonial branch (monocarpogonial condition, Fig. 5), even branches with four carpogonial branches can occur (polycarpogonial condition, Fig. 6 - 8). Atypical cortical filaments were also observed arising from carpogonial branches (Fig. 9).

As highlighted by Chiang & Chen (1983), the presence of compound carpogonial filaments supports the thesis that

in *Dotyophycus* this female structure is equivalent to an entire assimilatory filament, showing that each carpogonial branch represents a branch homologous to a vegetative branch of an assimilatory filament system.

In the *Dotyophycus* species, the gonimoblastic filaments produce terminal carposporangia which very frequently present their cytoplasm, transverse or obliquely, divided in two or irregularly divided in four. Abbott (1976, Fig. 9) illustrated divided carposporangia for *D. pacificum*, although the specimens described here did not present that characteristic.

*Dotyophycus yamadae* (Ohmi *et* Itono) I.A. Abbott *et* Yoshizaki is the species that is most similar to *D. pacificum* because of the absence of cortical subsidiary



Figures 18-22. SEM view of different aspects of *Dotyophycus pacificum* I.A. Abbott: 18 - Transverse section of thallus in a cylindrical portion with evident medulla (M) and cortex (C); 19 - Detail of transverse section showing medulla (arrow) and cortex with filaments immersed in a matrix of carbonate crystals (arrow head); 20 - Detail of filament joining the medulla and cortex, covered by aragonite crystals; 21 - Medullar filaments covered by aragonite crystals; 22 - Detail of cortical filament immersed in the carbonate matrix.

filaments and the primary division of the fertilized carpogonia. However, the former has the following distinctive characteristics: compact stem, presence of cortical filaments originating from the hypogynous cell of the carpogonial filament (Chiang & Chen 1983, Fig. 2), irregularly branched cortical filaments and extensively spread gonimoblast (Table 2).

*Dotyophycus abbottiae* Kraft is a more distinctive species. The fertilized carpogonium did not divide, and two or three cylindrical gonimoblast initials are formed on its base, having a higher growth rate (Kraft 1988: 135, Fig. 12-13). In *D. pacificum* and *D. yamadae*, fertilization is followed by a transverse zygotic division, and this new cell laterally divides,

giving rise to the gonimoblast primary cells (Fig. 9 and 10). *D. abbottiae* also presents subsidiary cortical filaments and rhizoidal cells (Kraft 1988: 133, Fig. 3) and a compound carpogonial filament bearing up to 13 carpogonia with trichogynes. Another distinctive characteristic is the strong and continuous calcification (Table 1).

The following set of features can be used to separate *Dotyophycus pacificum* from the other two species of the genus: calcification pattern, texture, presence of subsidiary filaments, morphology of the carpogonial filament and the first division of the fertilized carpogonia. However, the presence of aragonite crystal among the medullar filaments (Fig. 25) reinforces the need of SEM use to characterize

**Table 1.** Comparative features of genera of the family Liagoraceae, based on Kraft (1988) and Huisman (2006).

	<i>Dotyophycus</i>	<i>Liagoropsis</i>	<i>Yamadaella</i>	<i>Ganonema</i>	<i>Helminthocladia</i>	<i>Liagora</i>	<i>Nemalion</i>	<i>Trichogloea</i>	<i>Trichogloeopsis</i>
Calcification	present, medulla (mildly) and cortex (heavily)	present, cortex	present, cortex	present, cortex	absent	present, cortex	absent	present, medulla	present, medulla
Subsidiary carpogonial branch (polycarpogonial)	present	present	absent	absent	present	absent	present	present	present
Number of cells in carpogonial branch	10-19 in primary carpogonial branch	5-13 in primary carpogonial branch	3	4	usually 3, some 4, rarely 2	usually 4, 3 or 5	3-10	6-9	4-8
Initial division of fertilized carpogonium	transverse	transverse	absent	transverse	longitudinal	transverse	absent	absent	absent
Sterile subsidiary filaments or cells on cells of the carpogonial branch	present, short, irregularly produced filaments with cells of modified shape	present, long, irregularly produced filaments with cells of normal cortical shape	absent	absent	absent	absent	present as irregularly produced filaments with cells of normal cortical shape	absent	absent
Fusion of cells of the carpogonial branch	present	absent	present	absent	present	present	present	present	absent

**Table 2.** Comparative table with diagnostic characteristic of the species of the genus *Dotyophycus* I.A. Abbott - 1 = Abbott (1976); 2 = Abbott (1999); 3 = Abbott & Yoshizaki (1981); 4 = Ohmi & Itono (1976); 5 = Chiang & Chen (1983); 6 = Kraft (1988).

	<i>D. pacificum</i> <sup>1,2,3</sup>	<i>D. yamadae</i> <sup>3,4,5</sup>	<i>D. abbottiae</i> <sup>6</sup>	Studied material
Depth (m)	27-37	1,5-20	13-18	23-36
Plant size (cm) / thallus habit	7-8 / terete	3-6 / compressed	5-8 / terete	4-6 / terete
Thallus diameter (mm)	0.5-1	1-2,5	1-2	0,5-1,5
Branching pattern	dichotomous / subdichotomous	caespitose or dichotomous / subdichotomous	caespitose / dichotomous	dichotomous / subdichotomous
Medullary filaments – diameter (µm)	4-6 (young), 12 (mature)	10-30	10-25	9-17 (young), 12-25 (mature)
Cortical filaments – length (µm)	150-210	125-385	250	260-300
Subsidiary cortical filaments	absent	absent	present	absent
Number of di/trichotomies – cortical filaments	4-5	2-6	5-6	3-5
Outer cortical cells (µm)	6-34 x 12-52	5.5-11.5 x 11.5-24	4-16 x 10-20	14-20 x 19-38
Fertilized carpogonial division	present	present	absent	present
Cystocarp (µm)	250-350	150-250	up to 500	410-680
Carposporangia (µm)	not found	8 x 17	7,8 x 12-15	7-10 x 16-30

the different Liagoraceae genera and species. The crystal aspect is similar to that observed by Moura *et al.* (1999), in *Trichogloea requienii* (Montagne) Kützing, and by Borowitzka (1977), in others Nemaliales genera.

The seaweed flora from northeastern Brazil has similarities with the marine flora from the Caribbean region (Oliveira 2002). According to Horta *et al.* (2001), these similarities are due to the shared origin of the Brazilian and Caribbean flora in the Indo-Pacific region at distinct periods and routes. Some red algae considered endemic to the Indo-Pacific have already been referred to the southeastern Brazilian coast as *Anotrichium yagii*

(Okamura) Baldock (Horta & Oliveira 2000), *Laurencia venusta* Yamada (Fujii *et al.* 2005) and to the northeastern Brazilian coast as *Gelidiopsis repens* (Kützing) Weber-Bosse (Nunes & Guimarães 2008) and *Tolypocladia* sp. (Nunes 2005a), corroborating this hypothesis.

The uncommon presence of this genus on the coast of Bahia can be attributed to its similarity with plants of the genus *Liagora*, at a non-detailed view, and also to our minimal knowledge about the Brazilian subtidal seaweed flora (Horta and Oliveira 2001). Such examples reinforce the need to invest in the formation of taxonomists and in studies on subtidal Brazilian biodiversity.

## Acknowledgements

Thanks to PICDT/CAPES for the post-graduate grant, to the CNPq for the research grants and to the environmental company CETREL for providing material from the subtidal zone.

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