ABSTRACT
In this paper, we summarize the diversity of Polyphysaceae species in Todos os Santos Bay, in the state of Bahia, Brazil. On the basis of ten years of collections and the analysis of herbarium material, six species have been recorded for the area: Acetabularia caliculus J.V. Lamour.; A. crenulata J.V. Lamour.; A. schenckii Möbius; Parvocaulis myriosporus (Joly & Cord.-Mar.) C.W. N. Moura & J.C. DeAndrade comb. nov.; P. pusillus (M. Howe) Berger et al.; and P. parvulus (Solms). The last has a distribution extending to the southern Atlantic Ocean. Acetabularia myriospora was transferred to Parvocaulis (as P. myriosporus) on the basis of its short corrugated peduncles and lack of a lower corona in the gametangial ray discs, which are diagnostic characters of this genus. In Todos os Santos Bay, Acetabularia species are more widely distributed than are Parvocaulis species, which are currently restricted to Itaparica Island. The most common taxa were A. caliculus and A. schenckii, which were collected from the majority of the study sites. This paper provides detailed descriptions of the morphology, reproductive aspects and geographic distributions of the algae, as well as discussing the taxa studied.

Key words: Acetabularia, Parvocaulis, Parvocaulis myriosporus comb. nov., southern Atlantic Ocean

Introduction
The family Polyphysaceae (Dasycladales, Chlorophyta) is composed of highly differentiated organisms with characteristic unicellular stalks with smooth or corrugated peduncles. The stalks bear two types of lateral whorls that are organized in the following manners: various whorls with ramified hyaline lateral branches and a subterminal or terminal disc or cap of whorls of gametangial rays, which may be lost after reproductive maturity and later replaced; or alternating whorls of hyaline lateral branches and discs of gametangial rays. The gametangial rays have small protuberances (forming the upper corona) on the adaxial face that bear hairs or scars after the protuberances are lost. These rays may have additional protuberances on the abaxial face (lower corona), and they lack hairs when the protuberances are present. Reproduction occurs by gametes that develop in cysts within the gametangial rays (Berger & Kaever 1992; Norris 2010).

Three genera are recognized within the Polyphysaceae: Chalmasia Solms, Acetabularia J.V. Lamour. nom. cons., and Parvocaulis S. Berger, Fettweiss, Gleissberg, L.B. Liddle, U. Richt., H. Sawitsky & Zuccarello. Those genera have traditionally been distinguished on the basis of the characteristics of their peduncles and gametangial ray discs (Valet 1969; Bailey et al. 1976; Berger & Kaever 1992; Berger et al. 2003; Kraft 2007; Norris 2010).

Berger et al. (2003) mapped the morphological characteristics and ontogenies of the Dasycladales through the phylogeny of 18S rDNA and recognized three clades for the Polyphysaceae: clade 1, with the genus Chalmasia, is characterized by the formation of a protuberance on the apex of the cell before the formation of the disc, and pointed gametangial rays; clade 2, including the representatives of Parvocaulis, is characterized by the presence of a corrugated peduncle on adult stalks; and clade 3, containing the taxa Acetabularia (including the genera Acicularia d’Archiac and Polyphysa peniculus [R. Brown ex Turner] C. Agardh [= A. peniculus {R. Brown ex Turner} Solms]), which is characterized by the absence of a velum (a thin, delicate pectic membrane) surrounding the ray discs during the initial stages of development, and by a predisposition to begin forming the disc rays by forming hairs on the upper corona. Berger et al. (2003) observed that the evolution of the lower corona in this group is synapomorphic and that its absence in P. peniculus represents a secondary loss—an observation previously made by Sawitzky et al. (1998). Ac-
According to those authors, the position of *P. peniculus* within *Acetabularia* is supported by the absence of a velum and the non-corrugated peduncle.

According to Berger *et al.* (2003), the genus *Acetabularia* includes two subgenera: *Acetabularia*, containing one species (*Acetabularia acetabulum* [L.] P.C.Silva) and characterized by a cap with congenitally fused gametangial rays; and *Acicularia* (d’Archiac) S. Berger *et al.*, comprising the remaining species of the genus *Acetabularia* and characterized by a cap with unfused gametangial rays.

The Polyphysaceae family has been documented for the past several decades in regional floras of Brazil (Möbius 1889; Taylor 1960; Joly 1965; Oliveira Filho 1977; Pereira 1974; Kanagawa 1984; Martins *et al.* 1991; Pereira & Accioly 1998; Coto & Pupo 2009; Moura 2010), the following species having been identified: *Acetabularia schenckii* Möbius (1889); *Acetabularia caliculus* J.V. Lamour in Quoy & Gaimard (1824); *Acetabularia crenulata* J.V. Lamour. (1816); *Acetabularia myriospora* Joly & Cord.-Mar. in Joly *et al.* (1965); and *Parvocalus pusillus* (M.Howe) Berger *et al.* (2003). However, there have been no detailed studies of these species along the coast of Brazil.

The present study describes the diversity of Polyphysaceae in Todos os Santos Bay. The objective of the study was to make a contribution to the knowledge of marine flora in the state of Bahia and Brazil.

**Material and methods**

**Study area**

As can be seen in Fig. 1, Todos os Santos Bay is located in the state of Bahia, in northeastern Brazil (13°S; 38°W), and is the second largest bay in the country, covering an area of 1,233 km², with 184 km of coastline (Cirano & Lessa 2007). The region around Todos os Santos Bay includes an urban area with more than 3 million residents, including the city of Salvador, and an extensive industrial zone with the largest petrochemical complex in the Southern Hemisphere (Camaçari Petrochemical Complex).

Todos os Santos Bay comprises extensive reef formations and mangrove swamps of great ecological and socio-environmental importance. Due to the environmental damage the bay has suffered over the years, the government of Bahia designated Todos os Santos Bay an Environmentally Protected Area in 1999 (Decree no. 7,595), and the bay is now considered a priority conservation area (MMA 2004). Within the bay, there are 45 islands, with 221 km of coastline (Silva *et al.* 1996).

Todos os Santos Bay has essentially marine characteristics, given that the outflows of the Paraguaçu, Subaé and Jaguaripe rivers are far surpassed by the amount of salt water that enters the bay (Cirano & Lessa 2007). The water column is characteristically well-mixed, and estuarine conditions, which are found only near the mouths of the rivers, show high levels of biodiversity, making them of great ecological and extractive interest.

The tides are semi-diurnal with maximum amplitudes of 2.70 m throughout the majority of the year. Water circulation within Todos os Santos Bay is mostly due to tidal action. The average velocity of the tidal currents in the bay is low (less than 20 cm/s), reaching a maximum of 80 cm/s during intertidal periods (Lessa *et al.* 2001). The salinity of the surface water varies from 28 to 37 practical salinity units (PSU) in the channel between Itaparica/Salvador, and from 35 to 36.2 PSU in the central parts of the bay and Itaparica Channel (Lessa *et al.* 2001; Celino & Queiroz 2006).

**Data collection**

The materials studied were collected from the islands of Itaparica, Frades, Maré, Madre de Deus and Bimbarras, as well as from the municipality of Salinas da Margarida, on the coast of the bay (Fig. 1, Tab. 1). Specimens (fixed to their substrates) were gathered from intertidal regions between 2001 and 2012. We also analyzed material collected from areas of the coast of Bahia other than Todos os Santos Bay. All specimens were preserved in seawater containing 4% formaldehyde.

The specimens were examined using photon microscopy and scanning electron microscopy. For analysis by photon microscopy, the algae were decalcified with 10% hydrochloric acid, stained with 1% toluidine blue O, after which they were analyzed under stereo microscope (BEL Photonics® STM PRO; BEL Engineering, Monza, Milano, Italy) and optical microscope (Leica DM LS2; Leica Microsystems, Wetzlar, Germany). Scanning electron microscopy was performed according to the method described by Berger *et al.* (2003), with the following modifications: the material was washed in distilled water to remove the fixative and then washed for 2 min in an ultrasonic bath to remove impurities. After cleaning, the material was dehydrated in an ethanol series (10-100%, for 15 min at each concentration), ethanol-acetone (1:1, v/v, for 5 min), and in a ketone series (50-100%, for 5 min at each concentration), and then processed by freezing in a critical point dryer (CPD 030; Bal-Tec AG, Balzers, Liechtenstein). Dehydrated specimens were mounted on aluminum stubs using double-sided adhesive tape and subsequently sputter-coated with gold. The specimens were analyzed with a scanning electron microscope (LEO 1430VP; Carl Zeiss AG, Oberkochen, Germany) at 10 kV.

Photographs of the general features of the specimens were taken using a digital camera (Sony Cyber-shot DSC-W7; Sony, Tokyo, Japan), and photomicrographs were obtained using the same digital camera coupled to a binocular microscope (Leica DM LS2; Leica Microsystems, Wetzlar, Germany). Digital images were assembled using the opensource software GNU Image Manipulation Program (GIMP: http://www.gimp.org).

The study material has been deposited in the Herbarium of the (Bahia) State University of Feira de Santana (code, HUEFS).
Polyphysaceae (Dasycladales, Chlorophyta) in Todos os Santos Bay, Bahia, Brazil


![Map of locations in Todos os Santos Bay (TSB), in the state of Bahia, Brazil (based on Lessa et al. 2001). Shaded areas represent intertidal mangrove vegetation. The circles with numbers represent the sampling stations on Itaparica Island (1 – Penha Beach; 2 – Coroa Beach; 3 – Conceição Beach; 4 – Barra Grande Beach; 5 – Enseada do Pedrão Beach)—on Frades Island (6 – Paramana Beach; 7 – Ponta de Nossa Senhora Beach)—on Maré Island (8 – Itamoabo Beach; 9 – Botelho Beach)—on Madre de Deus Island (10)—on Bimbarras Island (11)—and in the municipality of Salinas da Margarida (12).](image)

**Results**

On the basis of ten years of collections and the herbarium material analyzed, two genera were identified in the Todos os Santos Bay: *Acetabularia* J.V.Lamour. nom. cons., a genus widely distributed throughout the study area; and *Parvocaulis* S. Berger *et al.*, restricted to Itaparica Island.

**Division: Chlorophyta Pascher**

**Order: Dasycladales Pascher**

**Family: Polyphysaceae Kütz.**

**Genus: Acetabularia J.V. Lamour. nom. cons.**

The genus *Acetabularia* is represented in the local flora by the subgenus *Acicularia*, with three species that can be identified using the following key.

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### Key to the species of *Acetabularia* subgenus *Acicularia* identified in Todos os Santos Bay, in the state of Bahia, Brazil

1. Flat disc of gametangial rays; gametangia (cysts) surrounded by calcareous masses
   2. Peduncles densely calcified, bearing 1-2(-3) discs; upper corona with 2(-3) hairs; > 100 cysts per gametangial ray
      2. 1. A. schenckii
   3. A. crenulata

2. Calciform disc of gametangial rays
   2. Peduncles somewhat calcified, with 1 disc; upper corona with 3(-4) hairs; < 100 cysts per gametangial ray
      2. 1. A. caliculus
1. *Acetabularia caliculus* J.V. Lamour. in Quoy & Gaimard. Voyage autour du monde...: 621. pl. 90. Figs 6, 7. 1824.

Fig. 2A-H
Thallus 2.0-4.5 cm tall, delicate, lightly calcified, forming groups of cylindrical peduncles, each bearing a terminal disc of light-green gametangial rays, translucent; attached to the substrate by a small, lobed holdfast. Peduncles slightly nodulous, not ramified, whitish due to calcification, 26.0-40.0 mm long × 200.0-440.0 μm diam., the upper third, near the disc of gametangial rays, bearing (2-)4-5(-10) rows of scars left by deciduous hairs. Discs of gametangial rays solitary, cup-shaped when mature, 3.0-7.0 mm diam., composed of 28-36 elongated rays, transparent, united laterally by calcifications; rays 2.0-3.0 mm long, with a diameter of 420.0-510.0 μm at apex and 70.0-120.0 μm at base, apex emarginate to straight, sometimes with two small lateral elevations. Upper corona composed of elongated segments, bearing 3(-4) sterile hairs arranged linearly. Lower corona composed of oblong segments. Fertile gametangial rays bearing 25-60 cysts per ray, spherical to subspherical, not calcified, green, 80.0-160.0 μm diam.

Habitat: Common in Todos os Santos Bay, found in intertidal regions and in shallow waters in protected areas growing in tufts on calcareous algae, the remains of corals (*Millepora* L. and *Mussismilia* Ortmann), and mollusk shells. This species is occasionally partially buried by muddy sediment.

*Acetabularia caliculus* is generally found associated with populations of *A. schenckii* and *A. crenulata*.


Geographic distribution: Essentially pantropical (Berger & Kaever 1992; Kraft 2007; Guiry & Guiry 2013), reported for Brazil along the coasts of the states of Ceará, Paraíba, Pernambuco, Bahia, Rio de Janeiro, São Paulo, and Santa Catarina (*Moura* 2010). Among the species of *Acetabularia* subgenus *Acicularia* cited for the coast of Brazil, *A. caliculus* is morphologically close to *A. crenulata*; it differs, however, in having less calcification, a solitary disc of gametangial rays, and greater numbers of whorls of sterile hairs or scars on the peduncle.

### Table 1. Polyphysaceae sampling stations in and on Todos os Santos Bay, in the state of Bahia, Brazil.

<table>
<thead>
<tr>
<th>Station</th>
<th>Municipality</th>
<th>Locality</th>
<th>Geographic coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vera Cruz</td>
<td>Itaparica Island, Penha Beach</td>
<td>12°59'S; 38°37'W</td>
</tr>
<tr>
<td>2</td>
<td>Vera Cruz</td>
<td>Itaparica Island, Coroa Beach</td>
<td>13°21'S; 38°36'W</td>
</tr>
<tr>
<td>3</td>
<td>Vera Cruz</td>
<td>Itaparica Island, Conceição Beach</td>
<td>13°01'S; 38°38'W</td>
</tr>
<tr>
<td>4</td>
<td>Vera Cruz</td>
<td>Itaparica Island, Barra Grande Beach</td>
<td>13°02'S; 38°40'W</td>
</tr>
<tr>
<td>5</td>
<td>Vera Cruz</td>
<td>Itaparica Island, Enseada do Pedrão Beach</td>
<td>13°03'S; 38°42'W</td>
</tr>
<tr>
<td>6</td>
<td>Salvador</td>
<td>Frade Island, Paramana Beach</td>
<td>12°46'S; 38°37'W</td>
</tr>
<tr>
<td>7</td>
<td>Salvador</td>
<td>Frade Island, Ponta de Nossa Senhora Beach</td>
<td>12°48'S; 38°38'W</td>
</tr>
<tr>
<td>8</td>
<td>Salvador</td>
<td>Maré Island, Botelho Beach</td>
<td>12°47'S; 38°30'W</td>
</tr>
<tr>
<td>9</td>
<td>Salvador</td>
<td>Maré Island, Itamoabo Beach</td>
<td>12°47'S; 38°31'W</td>
</tr>
<tr>
<td>10</td>
<td>Madre de Deus</td>
<td>Madre de Deus Island, Madre de Deus</td>
<td>12°44'S; 38°35'W</td>
</tr>
<tr>
<td>11</td>
<td>São Francisco do Conde</td>
<td>Bimbarras Island, São Francisco do Conde</td>
<td>12°42'S; 38°38'W</td>
</tr>
<tr>
<td>12</td>
<td>Salinas da Margarida</td>
<td>Salinas da Margarida (Mainland)</td>
<td>12°51'S; 38°45'W</td>
</tr>
</tbody>
</table>
The shapes of the apices of the gametangial rays on the specimens analyzed were in accordance with those described by Yoneshigue-Braga (1980), Berger & Kaever (1992), Berger et al. (2003) and Norris (2010). However, their shapes differed from those described by Taylor (1960) and Schnetter (1978), who reported that these rays are mucronate. Gametangial rays with apices flanked by two small elevations, as described by
Kraft (2007), were rarely observed in the specimens studied here.

The shapes of the upper corona in specimens from Todos os Santos Bay were similar to those described by Womersley (1984) and Berger & Kaever (1992), although the linear distribution of their hairs differed from the triangular arrangement reported by Berger & Kaever (1992). The diameters of the cysts of specimens analyzed were in accordance with those described in the literature, although the maximum value found was the largest yet reported for this species.

According to Norris (2010), the original spelling of the species, “caliculus” (J.V.Lamour, in Quoy & Gaimard 1824), does not need to be changed to “calyculus”, because it agrees with the use of the Latin word Calix, a small cup.

2. Acetabularia crenulata J.V.Lamour. Histoire des polypiers corallígenes flexibles...: 249. pl. 8. Fig. 1. 1816. Fig. 3A-H

Thallus 3.0-7.0 cm tall, calcified, forming dense tufts of cylindrical peduncles, each bearing 1-2(-3) terminal discs of light-green gametangial rays. Peduncle straight, cylindrical, 20.0-65.0 mm long × 310.0-680.0 μm diam., upper third bearing verticals of sterile hairs between the discs of gametangial rays; rings of hair scars and deciduous gametangial rays visible on peduncles. Disc of gametangial rays rigid, cup-shaped when mature, (5.0-)8.0-12.0(-14.0) mm diam., formed by the lateral union of 41-67 gametangial rays. Gametangial rays long, cuneiform, with apex apiculate to almost straight, 2.0-6.5 mm long × 210.0-690.0 μm wide at apex and 50.0-120.0 μm wide at base. Upper corona with oblong segments, apex rounded to slightly indented, bearing 2(-3) linearly arranged hairs. Lower corona with elongated segments, bilobate. Fertile gametangial rays bearing 110-270 cysts per ray, not calcified, globose to spherical, 50.0-140.0 μm diam.

Habitat: In Todos os Santos Bay, Acetabularia crenulata predominates on the beaches of Penha and Barra Grande (both on Itaparica Island), where it colonizes extensive areas of reef plates (tidal pools), forming various clusters of peduncles that are often buried by the sandy-muddy sediment or gravel. The species grows on remnants of coral skeletons (Millepora and Mussismilia or, less frequently, Porites Link and Siderastrea Blainville), mollusk shells, and calcareous algae. Stalks densely covered by macroalgae—typically Cladophora dalmatica Kütz., Rhizocladium riparium (Roth) Kütz. ex Harv., Ulva flexuosa subsp. flexuosa Wulfen or Asterolodion rhodochortonoides (Børgesen) Uwai, Nagasato, Motomura & Kogame—and cyanobacteria are common.


Geographic distribution: Largely restricted to the American Atlantic (occurring from Florida to Brazil, including the Caribbean), although specimens have been reported in the Indian and Pacific oceans (India, the Andaman Islands, Sri Lanka, the Philippines and Australia; Guiry & Guiry 2013). In Brazil, Acetabularia crenulata is found predominantly on the northeastern coast, being sparsely distributed throughout the states of Rio Grande do Norte, Paraíba, Pernambuco, and Bahia, although its distribution extends to the state of São Paulo (Moura 2010).

Among the taxa of Polyphysaceae studied, Acetabularia crenulata was the only species with more than one mature disc per peduncle, with whorls of sterile hairs between them. This species also exhibited the greatest variation in peduncle length (3.0-7.0 cm). When mature discs abscise, they leave protuberant scars on the peduncles that are easily distinguished from those left by the thin sterile hairs.

According to Taylor (1960), Schnetter (1978), Littler & Littler (2000) and Berger & Kaever (1992), the shapes of the discs on adult stalks of Acetabularia crenulata are variable, ranging from caliciform to planar. This degree of variation was not observed in the specimens analyzed here, as they were uniformly caliciform, coincident with previous descriptions of material collected along the coast of Brazil (Pereira 1974; Kanagawa 1984).

In a study of the community of epiphytic macroalgae growing on the peduncle of Acetabularia crenulata on Itaparica Island (along the beaches of Penha and Barra Grande), Santos (2010) listed various red acrochaetioid algae, including Colaconema hypneae (Börgesen) A.A.Santos & C.W.N.Moura (Santos & Moura 2010); minute species of Polysiphonia Grev.; Ceramium Roth; Cladophora Kütz.; ectocarpoid brown algae; diatoms; and filaments of cyanobacteria.

3. Acetabularia schenkii Möbius. Hedwigia 28(5): 320. pl. 10., Figs 8-12. 1889 Fig. 4A-I

Thallus up to 3.5 cm tall, light-green when young, becoming whitish at maturity due to dense calcification, forming small groups of peduncles, rarely isolated, bearing a single disc of gametangial rays; attached to the substrate by a small, lobed holdfast. Peduncle cylindrical, smooth, 6.0-28.0 mm long × 200.0-450.0(-600.0) μm diam. Disc of gametangial rays solitary, flat, 4.0-7.0 mm diam., composed of 35-55 rays, densely calcified. Gametangial rays long, cuneiform, with smooth apex or terminating in a small spine, often inconspicuous, 2.0-2.5 mm long × 200.0-350.0 μm wide at apex and 50.0-110.0 μm wide at
Polyphysaceae (Dasycladales, Chlorophyta) in Todos os Santos Bay, Bahia, Brazil

Figure 3. Acetabularia crenulata J.V.Lamour. A. General characteristics of the tuft. B and C. The apex of the peduncle, showing a series of developing discs. D. Disc of gametangial rays, illustrating its characteristic caliciform shape. E. A frontal view of a disc with a large number of rays. F. The bilobate lower corona (arrow) and hair scar on the peduncle (arrowhead), under scanning electron microscopy (SEM). G. The upper corona, under SEM; note the hair scars (arrow) and indented apex. H. The apex of a disc ray, under photon microscopy; note the cysts and mucronate apex.

Habitat: Acetabularia schenckii is common in the intertidal zone and shallow waters in protected areas of Todos os Santos Bay.
Figure 4. *Acetabularia schenckii* Möbius. A. General characteristics of a tuft, together with *A. caliculus*. B. An isolated stalk, associated with *Neomeris annulata*. C. A stalk showing a peduncle and a disc of rays in a characteristic planar arrangement. D. A disc of fertile rays encased in a calcareous mass, as observed under photon microscopy. E. Fertile disc rays after partial decalcification, under photon microscopy; note the calcareous matrix (arrow) enclosing several cysts. F. Disc rays observed after decalcification; note the cysts. G. The ends of the rays, with mucronate apices (arrows). H. The upper corona, under photon microscopy; note hair scar (arrow). I. The lower corona, under photon microscopy.
Santos Bay growing on shells, remnants of hermatypic coral skeletons or calcareous algae, forming small clusters. This species is associated with populations of *A. caliculus*, *A. crenulata*, and *Neomeris annulata* Dickie.


Geographic distribution: *Acetabularia schenckii* is restricted to the Atlantic Ocean, occurring from Florida to Brazil, including the Caribbean (Taylor 1960; Joly 1965; Ganesan 1989; Littler & Littler 2000; Wyss & Kooistra 2003; Sánchez 2005; Dawes & Mathieson 2008). This species shows a non-uniform geographic distribution along the coast of Brazil, having been reported only for the states of Paraíba, Bahia, Rio de Janeiro, and São Paulo (Moura 2010).

*Acetabularia schenckii* was described by Möbius (1889) on the basis of material collected in the region near the municipality of Cabo Frio, in the state of Rio de Janeiro. In 1895, Solms-Laubach included Möbius's species in the genus *Acicularia*, proposed by d'Archiac (1843), and defined the diacritic characteristics of this genus: the presence of cysts surrounded by a calcareous matrix on the disc rays. Therefore, Solms-Laubach (1895) considered *Acicularia schenckii* to be a living representative of the genus *Acicularia*. Egerod (1952) considered the presence of the calcareous matrix surrounding the cysts in *Acicularia* to be an inconsistent taxonomic characteristic. According to the author, with the exception of this characteristic, there was no way to separate *Acicularia schenckii* from the species of *Acetabularia*, and Vallet (1969) agreed. Bailey et al. (1976) considered *Acicularia schenckii* to belong to the genus *Acetabularia* because of the presence of the lower corona, leaving only fossil species in the genus *Acicularia*.

Studies of the morphology and ontogeny of the disc rays in Polyphysaceae, undertaken by Berger et al. (2003), demonstrated that *Acicularia* and *Acetabularia* shared common characteristics, such as the absence of a velum surrounding the disc rays in the initial stages of development, and a predisposition to begin forming disc rays with the formation of hairs on the upper corona. Finding additional support from molecular data (18S rDNA), the authors concluded that *Acicularia* and *Acetabularia* could not be recognized as distinct genera. Therefore, they proposed *Acicularia*, which is characterized by unfused gametangial ray primordia, as a subgenus of *Acetabularia*.

In the study area, *Acetabularia schenckii* is easily separated from other species of *Acetabularia* of the subgenus *Acicularia* due to its small size, the flat discs of gametangial rays, and the calcareous matrix surrounding the cysts on the fertile rays.

The specimens analyzed coincide with the descriptions presented by Joly (1965), Schnetter (1978), Berger & Kaever (1992) and Dawes & Mathieson (2008). However, these specimens were smaller than those described for the Caribbean by Littler & Littler (2000), who reported individuals that were 3.0-8.0 cm in height and had discs up to 2.0 cm in diameter. The adult stalks were very fragile, making them difficult to handle and measure. Joly (1965) stated that this fragility facilitates the release of cysts when the calcified matrix separates from the stalk.

**Division**: Chlorophyta Pascher

**Order**: Dasyycladales Pascher

**Family**: Polyphysaceae Kütz.


The genus *Parvocaulis* is represented in the local flora by three species that can be identified using the following key.

Key to the species of *Parvocaulis* identified in Todos os Santos Bay, in the state of Bahia, Brazil

1. Thallus with peduncle ≤ 2.0 mm in height, disc with free gametangial rays, and < 40 cysts per fertile gametangial ray.................................2

1. Thallus with peduncle > 2.0 mm in height, disc with gametangial rays joined laterally by calcification but free at base, and > 50 cysts per fertile gametangial ray.................................3

2. Discs with 18-23 cuneiform rays with obtuse to emarginated apices, with 50-60 cysts measuring 100.0-120.0 μm in diameter.................................1

3. P. pusillus

3. P. parvulus

2. Discs with (7-)8-9(-11) triangular to obovoid rays with obtuse apices, with ca. 150-200 cysts per fertile ray, measuring 50.0-70.0 μm in diameter.................................

1. P. myriosporus

Thallus up to 1.5 cm tall, dark-green to whitish, narrow, erect, lightly calcified, forming small groups of peduncles, rarely isolated, bearing a single disc of gametangial rays; attached to the substrate by a holdfast with a series of digitate lobes. Peduncle cylindrical transversally corrugated, 3.0-15.0 mm long × 550.0-880.0 μm diam., rows of scars of deciduous hairs sometimes visible on upper third of peduncle. Disc of gametangial rays flat when mature, 3.0-4.5 mm diam., composed of (7-)8-9(-11) rays. Rays triangular to obovate, separated at the disc base but united in its upper third by calcifications, 1300.0-2140.0 μm long × 760.0-1370.0 μm wide at apex and 130.0-260.0 μm wide at base; apex obtuse, smooth. Upper corona rounded, protuberant, situated at base of the rays, 55.0-80.0 μm diam., bearing (5-)6-7(-8) hairs arranged circularly around the corona. Lower corona absent. Fertile gametangial rays bearing approximately 150-200 cysts per ray; cysts spherical, 50.0-70.0 μm diam.

Habitat: In Todos os Santos Bay, Parvocaulis myriosporus was found exclusively on the island of Itaparica, although the taxon occurs in other areas of the coast of Bahia (see additional material analyzed). The species is usually found in locations with breaking waves, generally in small crevices in the substrate, forming diminutive aggregated tufts. It is most likely to be found on rocks and encrusted corals, although it has been reported to grow on the skeletal remains of hermatypic corals and, less commonly, on non-calcareous algae.


Geographic distribution: Restricted to the western Atlantic Ocean and (currently) to the coast of the state of Bahia in Brazil. In addition to the type locality, Parvocaulis myriosporus has been recorded for the Greater Antilles, southern Caribbean, western Caribbean (Littler & Littler 2000), Belize (Norris & Bucher 1982), Cuba (Suárez 2005, as Polyphysa myriospora), Colombia (Bula-Meyer 1982, as Polyphysa myriospora) and Venezuela (García et al. 2003, as Acetabularia myriospora).

The genus Parvocaulis was proposed by Berger et al. (2003) to accommodate the species previously included in Polyphysa Lamark (1816: 151). The following species were recognized as part of the genus: Parvocaulis clavatus (Yamada) S. Berger et al. (2003: 559 as “clavata”; P. exiguis (Solms) S. Berger et al. (2003: 559 as “exigua”; P. polyphysoides (P.Crouan & H.Crouan in Schramm & Mazé) S. Berger et al. (2003: 559); P. pusillus (M. Howe) S. Berger et al. (2003: 560 as “pusilla”); and P. parvulus (Solms) S. Berger et al. (2003: 559 as “parvula”). The last is the type species of the genus.

In the proposal of the new genus, the only species that was not transferred was Polyphysa myriospora (Joly & Cord.-Mar.) Bula-Meyer (= Acetabularia myriospora) because, according to Berger et al. (2003), of a lack of detailed studies on the ontogeny of the gametangial rays to confirm its inclusion in Parvocaulis.

It was possible to follow some of the developmental stages of Acetabularia myriospora under natural conditions in the present study. This species showed the characteristics described for the genus Parvocaulis that justify its transfer as a new combination: Parvocaulis myriosporus C.W.N.Moura & J.C.DeAndrade comb. nov.

The development of the thallus of Parvocaulis myriosporus was accompanied by the appearance of the young peduncles. As the peduncles grow, they develop whorls of sterile hairs at the apex prior to the development of the primary primordium. On each peduncle, more than one whorl of hairs can form, leaving scars after falling.

The primary primordium, which gives rise to the gametangial rays and the upper corona, arises as a corona of 7-11 projections at the apex of the peduncle. The primary primordial rays of the disc, which take on the characteristic form of the species at maturity, are produced concomitantly with the upper corona (Fig. 6B). The upper corona is located at the circular base of the rays. Each upper corona bears approximately 6-7 hairs that leave abscission scars (Fig. 6G,H). The disc rays are covered by a velum (difficult to see in the specimens studied) that is broken at maturity (Fig. 6C). When totally expanded, the disc rays remain joined through the deposition of calcium carbonate between them (Fig. 5G).
After the release of the cysts, the rays fall, leaving scars on the peduncle, and a new disc can form at the apex of the peduncle (Fig. 6F).

The material from Itaparica Island was coincident with the type material and the descriptions and illustrations presented by Joly et al. (1965). The holotype comprises eight envelopes containing material extended on mica. Among the material present in the last envelope, on the left corner of the specimen sheet, are various siphons, some of which bear characteristic corrugated peduncles and a disc of gametangial rays (Fig. 5F).

*Parvocaulis myriosporus* is similar to both *P. parvulus* and *P. polyphysoides* with respect to the presence of disc rays laterally joined by calcifications. However, these species differ with respect to the shapes of the rays, which are cuneiform with a truncated or emarginated apex in *P. parvulus*

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**Figure 5.** *Parvocaulis myriosporus* (Joly & Cord.-Mar.) C.W.N. Moura & J.C. DeAndrade comb. nov. A-E. General aspects of the thallus. F. The holotype (SPF 51). G. The disc, with triangular to ovoid gametangial rays joined by calcifications (arrow), with numerous cysts. H. Scanning electron microscopy image of the disc, showing the upper corona located at the base of the disc rays.
and elongated with a triangular apex in *P. polyphysoides*. The number of rays in the discs of *P. parvulus* and *P. polyphysoides* are greater than those seen in *P. myriosporus* (Valet 1969; Schnetter 1978; Berger et al. 2003).

Until the 1980s, *Parvocaulis myriosporus* was known only from the coast of Brazil. The first description of the species outside the type locality was for the Caribbean coast of Colombia (Bula-Meyer 1982). Littler & Littler (2000) later reported this taxon in other areas of the Caribbean. More recently, García et al. (2003) and Suárez (2005) encountered this taxon along the coasts of Venezuela and Cuba, respectively.

*Parvocaulis myriosporus* is currently restricted to the coast of the state of Bahia in Brazil. In addition to the report

![Figure 6. Parvocaulis myriosporus (Joly & Cord.-Mar.) C.W.N.Moura & J.C.DeAndrade comb. nov. A. Corrugated peduncle, under scanning electron microscopy (SEM); note hair scars. B. SEM image of the disc rays in initial stages of development; note hairs on upper corona. C and D. SEM image of the velum (arrow) enclosing the disc rays. E. Apex of the siphone with sterile hairs, during development. F. Apex of the siphone with sterile hairs and scars left by the abscission of disc rays (arrow). G. SEM image of the rounded upper corona, located at the base of the disc rays; note bases of the free rays (arrows). H. The upper corona, as observed using SEM; note its rounded shape and hair scars.](image-url)
by Joly et al. (1965), there have been a few studies describing the species, including Martins et al. (1991) and Santos (1992). The lack of recent reports for the coast of Brazil led Oliveira (2002) to consider the taxon to be threatened by environmental degradation.

The taxon could possibly have broader geographical distribution along the coast of northeastern Brazil.


Thallus up to 7.0 mm tall, dark-green to whitish, erect, delicate, lightly calcified, composed of a peduncle bearing a single disc of gametangial rays; attached to the substrate by a holdfast with a series of digitate lobes. Peduncle simple, not ramified, cylindrical, transversally corrugated, 3-6 mm long. Disc of gametangial rays, when mature, compound, flat, 3.0–5.0 mm diam., with 18-23 rays. Upper coronas with one or no hairs. In the specimens analyzed the length of the peduncle and the numbers of disc rays. However, the latter differs by having elongated rays with triangular apices and an oval upper corona bearing 6–9 hairs (Valette 1969; Schnetter 1978; Berger et al. 2003).

The specimens of *Parvocaulis parvulus* encountered on the coastal reef at Itaparica Island coincide with the descriptions and illustrations by Valet (1969), Schnetter & Bula-Meyer (1982), Berger & Kaefer (1992), Berger et al. (2003) and Kraft (2007), although the numbers of disc rays were greater in the specimens collected in Brazil. The number of hairs of the upper corona as well as the shapes and terminations of the apices of the disc rays coincide with the descriptions supplied by Schnetter & Bula-Meyer (1982) for specimens found along the Pacific coast of Colombia. Coppejans & Prud’homme van Reine (1989) described specimens from Indonesia as having upper coronas with one or no hairs. In the specimens analyzed here, corrugation of the peduncle was observed in calcified and decalcified materials, coincident with the characteristic pattern for the genus.

It is possible that *P. parvulus* has a broader area of occurrence along the northeastern coast of Brazil, although its small size makes it difficult to locate and recognize in the field.


Thallus erect, dark-green, lightly calcified, diminutive, 1.2–2.0 mm tall, attached to the substrate by a holdfast with a series of digitate lobes. Peduncle, not ramified, cylindrical, short and transversally corrugated, 0.5–1.7 mm long × 240.0–250.0 μm diam. Disc solitary, flat, 1.3–1.6 mm diam., composed of 5–11 rays, unattached, obovate with apices smooth, rounded, 460.0–620.0 μm long × 180.0–260.0 μm wide at apex and 80.0–110.0 μm wide at base. Upper corona located at base of rays, rounded, 39.0–50.0 μm diam., bearing 2 hairs. Lower corona absent. Reproduction by non-calcified cysts, spherical, formed by the division of the protoplast of the disc rays; 25–34 cysts per ray, 60.0–90.0 μm diam.

Habitat: In Todos os Santos Bay *Parvocaulis pusillus* was found exclusively on the island of Itaparica, although the taxon occurs in other areas of the coast of Bahia (see additional material analyzed). These algae generally grow isolated, rarely forming clusters, in small crevices in the substrate in areas with breaking waves. The species grows preferentially on rocks and encrusted corals covered by larger algae.


Geographic distribution: *Parvocaulis parvulus* is largely pantropical (Berger & Kaefer 1992; Kraft 2007; Guiry & Guiry 2013). In the American Atlantic, this species was recorded in the Gulf of Mexico (Berger & Kaefer 1992) and Cuba (Suárez 2005). This is the first report of the taxon in the Southern Atlantic.

Among the recognized species in the genus *Parvocaulis*, *P. parvulus* is similar to *P. polyphysoides* with respect to the length of the peduncle and the numbers of disc rays. However, the latter differs by having elongated rays with triangular apices and an oval upper corona bearing 6–9 hairs (Valet 1969; Schnetter 1978; Berger et al. 2003).

Material examined: **Brazil. Bahia**: Ilha de Itaparica, Vera Cruz, Praia da Penha, 01/III/2003, Moura s.n. (HUEFS...
Carlos Wallace do Nascimento Moura, Wellington Romualdo de Almeida, Alana Araújo dos Santos, Juarez Cosme de Andrade Junior, Aigara Miranda Alves and Kátia Lidiane Moniz-Brito


Figure 7. Parvocaulis parvulus (Solms) S.Berger et al. A. General aspect of the thallus. B. Disc showing rays joined by calcifications (arrow). C. The terminations of the rays, with emarginated apices. D. Calcified stalk showing a corrugated peduncle (arrow) and disc rays joined by calcifications. E. Disc with cuneiform rays and emarginated apices, under scanning electron microscopy (SEM). F. SEM image of the rounded upper corona (arrow), located at the base of the disc rays. G. SEM image of hair scars on the upper corona; note the bases of the free rays (arrow). H. Disc rays with cysts.
Polyphysaceae (Dasycladales, Chlorophyta) in Todos os Santos Bay, Bahia, Brazil

Geographic distribution: *Parvocaulis pusillus* is a tropical species (Guiry & Guiry 2013), with records from the Atlantic Ocean (Florida to Brazil, as well as Liberia), Indian Ocean (Al-dabra Islands and the Seychelles) and Pacific Ocean (Japan and Vietnam). Within Brazil, it has been reported from the states of Paraíba, Pernambuco, Bahia, and Espírito Santo (Moura 2010). According to Berger et al. (2003), *Parvocaulis pusilla* is the smallest representative of the genus, with a delicate thallus and a small peduncle (1.0-3.0 mm in length).

Among the species described for the genus, *P. pusilla* is similar to *P. clavata* (Yamada) S. Berger et al. in terms of its size, the number of rays per disc, and the rounded and

![Image of Parvocaulis pusillus](image-url)

**Figure 8. Parvocaulis pusillus** (M. Howe) S. Berger et al. A. Stalk with peduncle and disc of gametangial rays (arrow). B. Disc rays with cysts; note the corrugated peduncle (arrow), under photon microscopy. C. Disc with clavate rays with obtuse apices, under SEM. D. SEM image of a rounded upper corona (arrow), located at the base of the disc rays; note the bases of the free rays. E. SEM image of the hair scars on the upper corona. F. Calcified stalk showing a corrugated peduncle (arrow), under SEM.
diminutive shape of the upper corona. The former differs from the latter by having a slightly larger peduncle, disc rays of uniform diameter and fewer cysts per fertile ray (Berger et al. 2003). According to Valet (1969), P. pusilla and P. clavata are the smallest representatives of the genus in the tropical Atlantic and tropical Pacific, respectively.

The material described and illustrated by Taylor (1960) and Valet (1969) from Florida, the Bahamas and Jamaica, was similar to that found on Itaparica Island but differed by having slightly tapered apices and greater numbers of cysts (ca. 20-60) per ray.

The first reference to P. pusillus for Brazil was made by Labanca (1967-69), who cited its occurrence on the coast of Pernambuco. Kanagawa (1984) and Pereira & Accioly (1998) tentatively reported this taxon along the coasts of Paraiba and Pernambuco, respectively. Judging from the descriptions and illustrations provided by those authors, principally with respect to the numbers and shapes of the disc rays and the number of cysts, it is likely that those specimens were in fact P. pusillus. The material described by Barata (2004) as Acetabularia cf. pusilla for the coast of Espirito Santo is really a representative of Parvocaulis. Although that author did not present detailed information about the specimens, Figure 42 provided in the study displays characteristics similar (in terms of the numbers of rays and their shapes) to those of P. pusillus. However, the length of the stalk specified by the author distinguishes it from the material analyzed from Itaparica Island, and new analyses of the materials will be necessary to ensure its correct identification. The remaining reports of this species along the coast of Brazil are difficult to evaluate because they are simple species lists (Oliveira Filho 1977; Santos 1992; Nunes 1998; Pereira et al. 2002; Oliveira-Carvalho et al. 2003).

**Discussion**

In the present study, we distinguished among the species of Polyphysaceae by using combinations of the following characters: morphology and dimensions of the peduncle; morphology of the gametangial ray disc; the presence/absence and shapes of the upper and lower coronas; and the numbers and diameters of the cysts.

Analyses of the peduncles of the specimens studied here proved to be useful in the characterization of the genera. The peduncles are corrugated in Parvocaulis and smooth in Acetabularia. In contrast to what is seen in Parvocaulis, the lower third of the peduncles of Acetabularia species are smooth. In Acetabularia, the upper third of the peduncle, close to the disc, has annular protrusions of scars from sterile hairs and fallen discs of gametangial rays. The lengths of the peduncles were observed to differ among the species of Acetabularia studied. The smallest peduncles were seen in A. schenckii, whereas A. cremolata had the largest. The latter species has been described in the literature as polymorphic, with peduncles that vary between 2.0 and 1.0 cm in length (Berger & Kaeber 1992; Berger et al. 2003).

The discs in the species of Polyphysaceae studied here were either caliciform or planar. All species of Parvocaulis showed planar discs, as did Acetabularia schenckii, whereas those of A. cremolata and A. caliculus were caliciform. According to Taylor (1960), Schnetter (1978) and Little & Little (2000), the shapes of the discs on adult stalks of A. cremolata are variable, caliciform to planar forms both occurring.

Although Todos os Santos Bay is considered to have oceanic characteristics, Acetabularia species are widely distributed in the area, as compared with Parvocaulis species, which are currently restricted to Itaparica Island and generally occur in environments with breaking waves. The most common taxa in the study area (reported at the majority of collection sites) were A. caliculus and A. schenckii.

The analysis of additional material suggests that Parvocaulis species are broadly distributed along the coast of Bahia. Parvocaulis parvulus has been reported from the northern coast (Itacimirim Beach, in the Municipality of Camaraço) to the central-south coast (Mucugê Beach, Arrail d’Ajuda, in the Municipality of Porto Seguro), and P. pusillus has been identified from Itaparica island, in the municipality of Vera Cruz (within the greater metropolitan area of Salvador), to Coroa Vermelha Beach, in the municipality of Santa Cruz Cabrália (central-south coast). However, P. parvulus was reported only from the metropolitan region of Salvador and the northern coast of the state. These reports contradict Oliveira (2002), who suggested that the taxa were threatened by environmental deterioration and tourist activities. The absence of records for Parvocaulis from some states along the northeastern coast of Brazil is probably related to the small size of the representatives of the genus, which makes them difficult to recognize in the field.

The data obtained in the present study has helped broaden our knowledge of Parvocaulis parvulus, the geographic distribution of which can now be expanded to include the southern Atlantic Ocean.

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