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Diversity and ecology of Trentepohliales (Ulvophyceae, Chlorophyta) in French Guiana

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Abstract – The subaerial green algal order Trentepohliales has its centre of abundance and diversity in the tropics. However, very few detailed investigations on the taxonomy of this group are available for tropical regions. Collections made in the course of a fieldtrip to French Guiana in June 2006 have revealed a very high diversity of the Trentepohliales in the region. Twenty-eight taxa were recorded; many of them were associated with humid and shaded rainforest habitats. Two undescribed species (*Trentepohlia chapmanii* and *T. infestans*) were found and five taxa represented new records for the Americas (*Phycopeltis irregularis*, *Printzina bosseae*, *Trentepohlia cucullata, T. diffracta* var. *colorata*, *T. dusenii*). On the basis of these results and literature data, the trentepohliacean flora of French Guiana amounts to twenty-nine taxa. Comparison with other tropical areas shows that this is a particularly high number; French Guiana can be therefore considered a biodiversity hotspot for the Trentepohliales. The combination of a highly humid and rainy climate with a high richness of habitats provides very suitable conditions for the development of these algae. Combined with evidence from other studies, the results indicate that tropical rainforests represent a major repository of unexplored microalgal diversity and that extensive investigations on the microalgal flora of these environments are urgently needed.

***Cephaleuros* / Diversity / French Guiana / *Phycopeltis* / *Printzina* / *Trentepohlia* / Trentepohliales**

Résumé – Diversité et écologie des Trentepohliales (Ulvophyceae, Chlorophyta) dans la Guyane française. Les Trentepohliales, ordre subaérien d'algue verte, a son centre d'abondance et de diversité dans les tropiques. Cependant, très peu d'investigations détaillées sur la taxonomie de ce groupe est disponible pour les régions tropicales. Les récoltes faites lors d'une excursion en Guyane française en juin 2006 a révélé une très haute diversité des Trentepohliales dans la région. 28 taxa ont été identifiés ; beaucoup d'entre eux sont associés aux habitats des forêts tropicales humides et ombragées. Deux espèces non décrites (*Trentepohlia chapmanii* et *T. infestans*) ont été trouvées et 5 taxa sont nouveaux pour les Amériques (*Phycopeltis irregularis*, *Printzina bosseae*, *Trentepohilia cucullata*, *T. diffracta* var. *colorata*, *T. dusenii*). Sur la base de ces résultats et des données de la littérature, la flore des Trentepohliacées de Guyane française s'élève à 29 taxa. En comparaison avec d'autres aires tropicales, cette flore est particulièrement riche ; la Guyane française peut donc être considérée comme un hotspot de biodiversité pour les Trentepohliales. La combinaison d'un climat très humide et pluvieux avec une très grande

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richesse d'habitats procure des conditions optimales pour le développement de ces algues. Les résultats de cette étude ajoutés à ceux déjà connus indiquent que les forêts tropicales humides représentent un dépôt majeur de la diversité microalgale inexplorée et qu'il est urgent d'intensifier les investigations de la flore microalgale de ces environnements.

***Cephaleuros* / Diversité / Guyane française / *Phycopeltis* / *Printzina* / *Trentepohlia* / Trentepohliales**

INTRODUCTION

The Trentepohliales is an order of subaerial green algae widespread in tropical and temperate regions with humid climates, where they occur as epiphytes on wood, tree bark, leaves, rock and artificial substrata, as endophytes in leaves and, less frequently, epizooic on some animals (Chapman, 1984; Ettl & Gärtner, 1995; Thompson & Wujek, 1997). These microchlorophytes are characterized by a combination of morphological and ultrastructural characters unique among the green algae and are easily recognizable for their yellow, orange or red colour, produced by the accumulation of ß-carotene and haematochrome (Chapman, 1984; López-Bautista *et al*., 2002). As presently circumscribed, the order includes five genera: *Cephaleuros* Kunze ex Fries 1832, *Phycopeltis* Millardet 1870, *Printzina* Thompson & Wujek 1992, *Stomatochroon* Palm 1934 and *Trentepohlia* Martius 1817. The taxonomic validity of a sixth genus, *Physolinum* Printz 1920, is highly dubious, and in the recent literature the only species included in it (*Physolinum monile* (De Wildeman) Printz) has been usually ascribed to *Trentepohlia* (Cribb, 1970).

There is general agreement that the Trentepohliales have their centre of distribution in tropical regions (Fritsch, 1907; John, 1988; López-Bautista *et al*., 2002). In these areas, trentepohliacean algae represent the main green algal component of the subaerial vegetation; the red, orange, and yellow patches produced by these organisms represent a striking contrast to the grey-blackish colour of the cyanobacterial assemblages that are normally dominant in these habitats (Fritsch, 1907). Some species are well-known practical nuisances; for example, species of *Cephaleuros* are common pathogens on leaves of many flowering plants, including some of commercial interest (Chapman & Good, 1983; Chapman & Waters, 2001; Brooks, 2004), and streaks of *Trentepohlia odorata* (Wiggers) Wittrock produce unsightly discolorations on walls of buildings in Singapore (Wee & Lee, 1980). It is therefore remarkable that the information available on the taxonomy and distribution of the Trentepohliales in tropical regions is still generally fragmentary. Detailed floristic accounts of this group are available only for a few regions, such as the area of Bogor, Java, Indonesia (De Wildeman, 1891, 1900), India and Bangladesh (Brühl & Biswas, 1923; Islam, 1960; Saxena, 1961; Jeeji-Bai, 1962; Randhawa & Venkataraman, 1962; Islam, 1972; Jose & Chowdary, 1980; Panikkar & Sindhu, 1993; Krishnamurthy, 2000), Queensland, Australia (Cribb, 1958a, 1963, 1967, 1968, 1970) and the Hawaiian Islands (Rindi *et al*., 2005). At present, the information available for other regions of the tropical Indo-Pacific area is limited and almost nothing is known for the rainforests of the Amazonian basin and equatorial Africa, two regions for which the diversity of this order might be enormous.

The information available on the terrestrial algal flora of French Guiana is limited to a few fragmentary remarks reported as part of more general

contributions (e.g., Montagne, 1850; Hariot, 1889a, 1890a). Recently we had the opportunity to visit this region, and in the course of a fieldtrip in June 2006 we made extensive collections of Trentepohliales from many different sites and habitats. The survey showed the group to be very diverse and led to several records of great interest; the observations provided also important insights into the ecology of these algae. Two of the entities collected have been described separately as new species (Rindi & López-Bautista, 2007). Here we provide a detailed floristic account, discussing also the factors affecting the distribution of these algae in French Guiana. This study represents one of the most detailed reports on the diversity and ecology of the Trentepohliales currently available for tropical regions. The observations presented here will be of great value for similar future studies on these algae elsewhere in the tropics.

MATERIALS AND METHODS

French Guiana is located on the North-western shore of South America, between approximately 2° and 6° N and 52° and 54° W. With a surface area of 84,000 km^2, it represents the largest Département d'Outre-Mer (Overseas Department) of France. French Guiana consists of two main geographical zones: a coastal strip where the majority of the population is based, and a dense, mostly inaccessible rainforest that covers about 80% of the territory. The region is affected by a zone of atmospheric circulation running from East to West, produced by two subtropical anticyclonic belts, called the Intertropical Zone of Convergence (Barret, 2004). This produces a climate with warm and humid conditions throughout the year. Temperatures range between 18 and 36°C, with an annual average of 26.5°C (Barret, 2004). Annual rainfall ranges between 1,700 mm per year in the North-western part of the region and 4,000 mm per year in the area of the Montagne de Kaw, where the base camp for the present survey was located. The climate is characterized by a cycle of four seasons; the rainy season extends from late March to mid June (Barret, 2004).

Collections of Trentepohliales were made in the period 19 June 2006-1 July 2006 from many different sites and a large variety of substrata, including tree bark, tree leaves, woodwork, concrete walls, metal surfaces and plastic sheeting. For material collected from tree bark and leaves, an attempt was made to identify the host plants; however, due to the largely exotic nature of the host plants to the authors, this was possible only for relatively few collections. Samples were collected mainly in the area of the Montagne de Kaw, in particular near the Floramazone Lodge (N 4° 33.578', W 52° 12.459'; 278 m above sea level), which served as base camp for the survey. Large collections, however, were also made at sites located in the coastal strip, mainly along the main road of the region (that extends from St. Laurent-du-Maroni to St. Georges). Collections were made from sites where yellow, orange or red patches recognizable as Trentepohliales were observed with the unaided eye. The specimens were placed in plastic collection bags and mailed or carried back to the laboratory at the University of Alabama, where the material was examined microscopically and identified at the best possible level of taxonomic discrimination. Microphotographs were taken with an Olympus BX51 Microscope equipped with DIC and a QColor 3 digital camera, and mounted in plates using Adobe Photoshop CS2. Voucher specimens were deposited in GALW, PC and UNA.

RESULTS

Cephaleuros virescens Kunze

Thallus ramulated, forming rounded discs more or less closed, with incised margin, up to 1 cm wide, one- or multilayered, subcuticular on tree leaves. Ramuli with two central filaments. Cells 9-15 µm wide, 1-3 times as long as wide. Erect sterile filaments gradually tapering, with pointed tips. Sporangiate laterals occurring at the top of erect filaments, in clusters of 4-8; zoosporangia elliptical, 22-30 µm wide and 30-38 µm long.

This species was epiphytic on leaves of unidentified trees at Crique Gabrielle, Mana and in the gardens of the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD) in Kourou. It has long been recognized that this species, as traditionally circumscribed, is morphologically variable and may represent a complex of closely similar species rather than a single entity (Printz, 1939). Recently, this possibility has received strong support from molecular data (López-Bautista *et al.*, 2006). A detailed morphological reassessment is necessary for a correct circumscription of *Cephaleuros virescens*. Since Suriname is the type locality, the material from French Guiana is likely to be correctly attributed to the species.

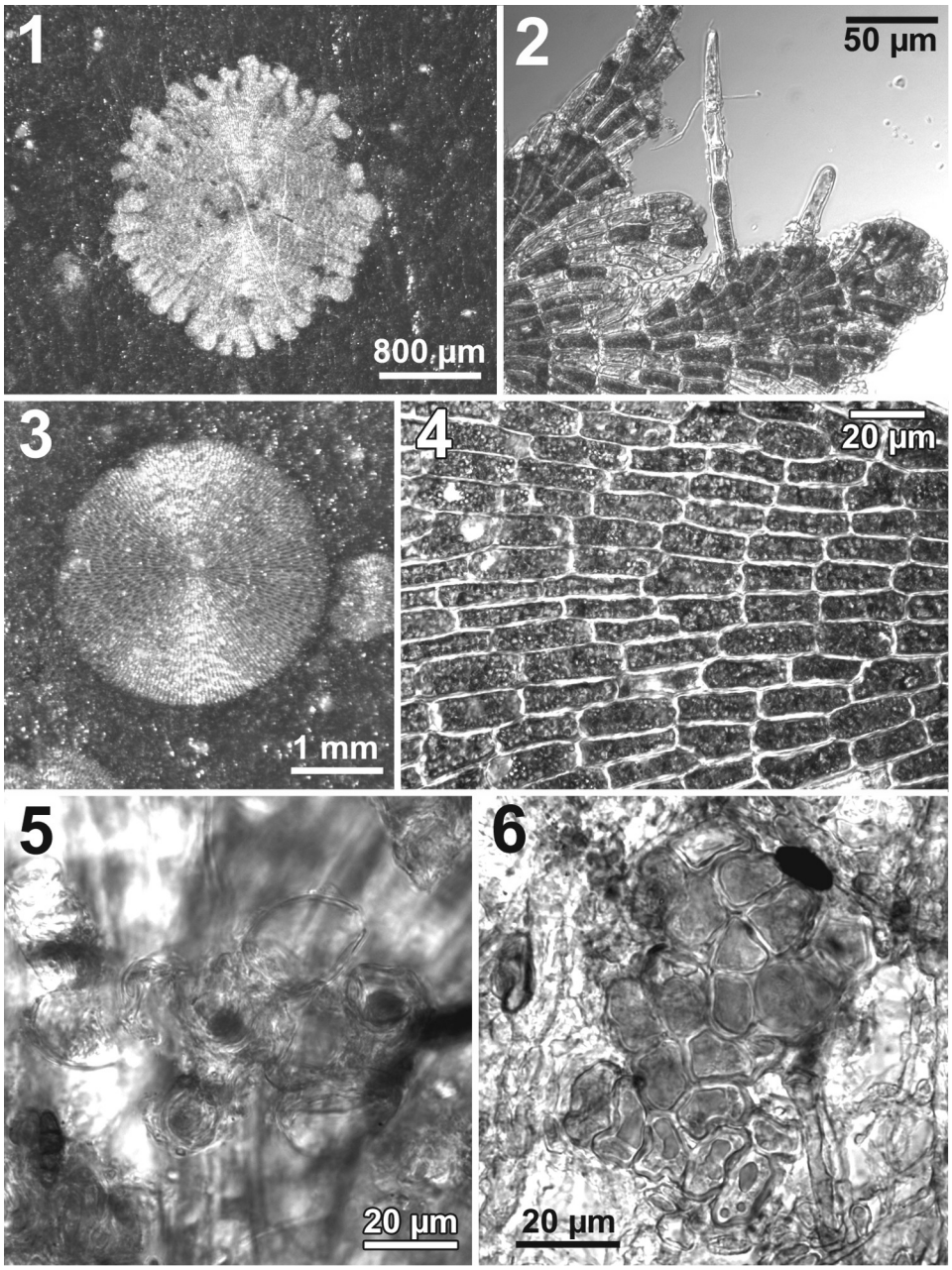
Phycopeltis cfr. *amboinensis* (Karsten) Printz (Figs 1-2)

Thallus consisting of spreading ramuli, converging more or less closely to form a disk with dentate margin, up to 2 mm in diameter (Fig. 1). Ramuli formed by 1-2 central dichotomizing filaments. Cells 7-10 × 18-30 µm in size. Erect sterile filaments abundant, unbranched, 150-250 µm tall (Fig. 2), sometimes bearing lateral glandular cells with thickened, laminated wall. Cells of the erect filaments cylindrical, 7.5-10 µm wide, about two times as long as wide. Gametangia developing from apical cells along the margins of the ramuli. Sporangiate laterals not observed.

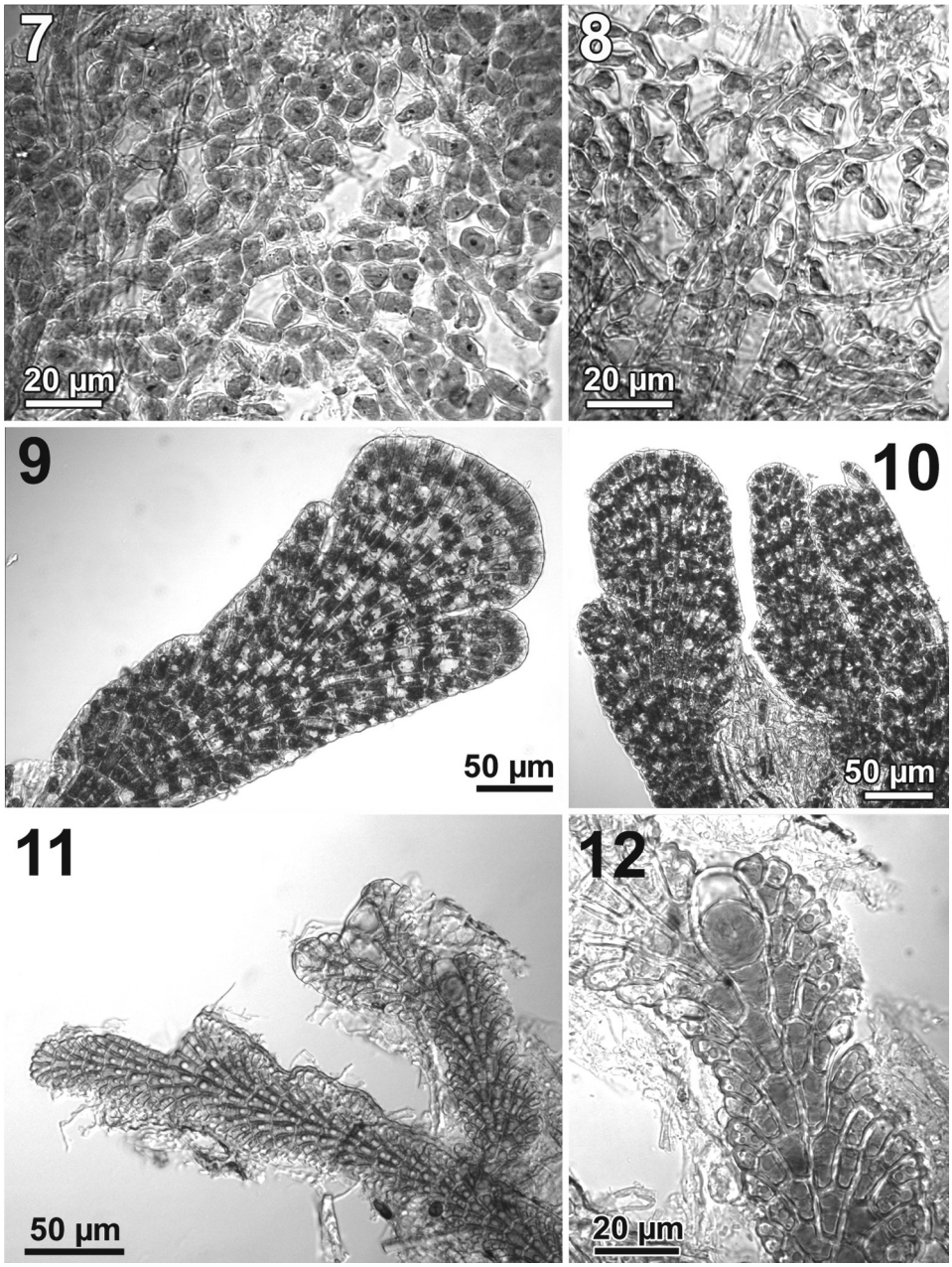
A population of this alga was mixed with *Phycopeltis* cfr. *arundinacea* on leaves of a *Magnolia* sp. near the Floramazone Lodge, on the Montagne de Kaw, on 29 June 2006. The specimens are in general agreement with the circumscription of *Phycopeltis amboinensis* given by Printz (1939) and Thompson & Wujek (1997). More frequently, however, *P. amboinensis* produces open-branched, ramulated thalli rather than circular discoid specimens (Neustupa 2003). Furthermore, sporangiate laterals, which are usually common in this species, did not occur in our material. For these reasons, the identification of our material should be considered provisional.

Phycopeltis cfr. *arundinacea* (Montagne) De Toni (Figs 3-5)

Specimens formed by radiating, laterally appressed dichotomous filaments, producing orange or copper-coloured disks with glossy appearance, up to 6 mm in diameter (Fig. 3). Margin of the thallus regular and entire. Cells 5-13 × 13-55 µm in size (mainly 8-10 × 18-30), 2-7 times as long as wide (mainly 3-4) (Fig. 4). Gametangia intercalary, absent from the margin and the peripheral parts of the thallus, randomly scattered over the central parts, occasionally arranged in small groups, oval or globular at maturity,



Figs 1-6. **1.** *Phycopeltis* cfr. *amboinensis*. Habit. **2.** *Phycopeltis* cfr. *amboinensis*. Detail of ramuli with erect sterile filaments. **3.** *Phycopeltis* cfr. *arundinacea*. Habit. **4.** *Phycopeltis* cfr. *arundinacea*. Detail of surface. **5.** *Phycopeltis* cfr. *arundinacea*. Detail of a sporangiophore. **6.** *Phycopeltis irregularis*. Habit.



Figs 7-12. **7, 8.** *Phycopeltis* cfr. *prostrata*. Details of branching. **9, 10.** *Phycopeltis* cfr. *treubii*. Detail of some ramuli. **11.** *Phycopeltis* cfr. *vaga*. Habit. **12.** *Phycopeltis* cfr. *vaga*. Detail of a gametangium in apical position.

12-17 × 13-26 µm (mainly 13-15 × 16-20 µm). Sporangiate laterals intercalary, randomly scattered over the surface of the thallus except the most peripheral parts; sporangiophores formed by several cells were produced by proliferation of new sporangiate laterals from previous suffultory cells (Fig. 5). Zoosporangia ovoid or elliptical, 17-20 × 25-28 µm. Gametangia and zoosporangia occurred mostly on separate thalli; however, some specimens with gametangia were also found to bear sporangiophores.

At the time of the survey, this was the most common trentepohliacean alga in French Guiana. It was widespread on the Montagne de Kaw, where it occurred on many different species of trees (in particular on leaves of *Magnolia* spp.). Collections of it, however, were also made from several other localities (Crique Gabrielle, Stoupan, Mana, St. Laurent-du-Maroni). On the basis of the description provided in the monograph of Thompson & Wujek (1997), this alga corresponds very well to *Phycopeltis arundinacea* as circumscribed by these authors; Neustupa (2005) also reported similar specimens from South-East Asia as *P. arundinacea*. We suspect, however, that the delimitation of this species proposed by Thompson & Wujek (1997) is incorrect. *P. arundinacea* was described by Montagne (1846, as *Phyllactidium arundinaceum* Montagne) for material growing on reeds in Algeria. In recent years, one of us (FR) has examined the lectotype specimen of *Phyllactidium arundinaceum* and numerous collections of *Phycopeltis* obtained from several localities of Atlantic Europe (Rindi & Guiry, 2002a; Rindi *et al*., 2003; Rindi *et al*., 2004). From these studies, it was concluded that the morphology of the European specimens is in agreement with the type material, and it is therefore reasonable to refer them to *P. arundinacea*. The tropical material used by Thompson & Wujek (1997) for the circumscription of this species differs from the European *P. arundinacea* in several features. The length and length/width ratio of the cells are considerably higher in the tropical alga (Rindi & Guiry, 2002a). In European collections, production of a sporangiophore does not take place and, after examination of several hundreds of thalli, no specimens larger than 1.5 mm have been observed (whereas in the material from French Guiana well-developed thalli are commonly 3-5 mm in diameter). In consideration of these differences, we believe that our *Phycopeltis* from French Guiana and the tropical material described by Thompson & Wujek (1997) as *P. arundinacea* may represent a different species. Molecular data are desirable to reassess unambiguously the taxonomic relationships between these entities and other morphologically similar species of *Phycopeltis*.

Phycopeltis irregularis **(Schmidle) Wille** **(Fig. 6)**

Algae forming small thalli with irregular outline on the surface of leaves, mixed with fungal hyphae and other terrestrial algae. Thallus forming a plate with irregular margin, with no clear organization (Fig. 6); cells polygonal or irregularly shaped, 5-12 × 8-15 µm in size. No reproductive structures observed.

Specimens referable to this species were found on leaves collected from unidentified trees in the forest along the road between Regina and St. Georges on 23 June 2006, and in the forest of the Montagne de Kaw on 22 June 2006. Although the specimens were small and devoid of reproductive structures, their habit was in agreement with the morphology of this species, originally described from Samoa (Schmidle, 1897) and subsequently reported for Japan and New Zealand (Sarma, 1986). Thompson & Wujek (1997) reported it as distributed in the New World tropics, without mentioning any specific locations.

***Phycopeltis* cfr. *prostrata* (De Wildeman) Schmidle** **(Figs 7-8)**

This alga formed irregular growths on leaves and plastic surfaces, where it was mixed with fungi and other terrestrial algae producing a thin, compact film. Thallus with subdichotomous habit, formed by several radiating filaments with very irregular and dense branching (Figs 7, 8). Cells cylindrical or swollen, 2-5 times as long as wide, 3-8 µm wide. No reproductive structures observed.

P. cfr. *prostrata* occurred on leaves collected from an unidentified tree in the forest along the road between Regina and St. Georges on 23 June 2006, and on the plastic surface of a post in the forest of Mont Rorota, Montagne de Mahury, on 25 June 2006. The alga was densely mixed with fungal hyphae and presumably represented a lichenized form. *Phycopeltis prostrata*, originally described as *Trentepohlia prostrata* by De Wildeman (1896) from leaves of trees in the botanical garden of Bogor, (Java, Indonesia), has been reported for several regions of South-East Asia and Oceania (De Wildeman, 1896, 1900; Sarma, 1986). This species is notoriously a very polymorphic entity, the habit of which may vary from irregularly branched, separate filaments to regular, compact disks. The vegetative morphology of our material is in good agreement with the characterization of *P. prostrata* provided by De Wildeman (1900) and Printz (1939). However, since neither erect filaments (which are typically present in compact forms of this species) nor reproductive structures were present, the attribution of our specimens to this species should be considered tentative.

***Phycopeltis* cfr. *treubii* Karsten** **(Figs 9-10)**

Thallus ramulated, up to 2 mm in diameter, with ramuli forming a closed disk in the central part and remaining more or less separated in the peripheral parts. Ramuli with lobed margin, formed by 2-4 central filaments (Figs 9, 10). Cells 6-10 × 14-27 µm in size (mainly 7.5-9 × 17-22 µm). Gametangia and zoosporangia usually on separate thalli; some specimens bearing both reproductive structures, however, were also observed. Gametangia produced along the margin of the ramuli, in submarginal position, or intercalary, ovoid to subglobular, 7.5-20 × 16-25 µm. Sporangiate laterals intercalary or marginal along the edge of the ramuli; sporangiophores formed by several cells developed by proliferation of new sporangiate laterals from previous suffultory cells. Zoosporangia 12-15 × 15-19 µm.

This alga was collected from tree leaves at several locations on different dates (Montagne de Kaw, Mana, forests along the road between Regina and St. Georges). The morphology of our specimens is in general agreement with *Phycopeltis treubii*, a widespread tropical species described by Karsten (1891) from Buitenzorg (Bogor), Java, Indonesia. Thompson & Wujek (1997), however, remarked that in this species no plants bearing only sporangiate laterals are known. Since plants with only zoosporangia were a common occurrence in our collections, further investigations are desirable in order to confirm the identity of our material.

***Phycopeltis* cfr. *vaga* Thompson *et* Wujek** **(Figs 11-12)**

Ramulated species of *Phycopeltis*, formed by relatively narrow ramuli (not wider than 60 µm, with 1-2 central filaments), openly branched and dichotomizing (Fig. 11). Margins of the ramuli crenate to irregularly lobed. Cells

5-9 × 10-22 µm in size, mainly 5.5-7.5 × 12-17 µm. Gametangia subglobular or ovoid, 14-18 × 18-25 µm in size, produced terminally at the apex of the ramuli (Fig. 12). When the apical cell of a central filament became a gametangium, the subapical cell started growth and became the new apical cell, giving the ramulus a subdichotomous habit and continuing growth in the same way until production of a new gametangium. No sporangiate laterals were observed.

This alga was found on leaves of unidentified trees in the forest along the road between Regina and St. Georges, on 23 June 2006. *Phycopeltis vaga*, described by Thompson & Wujek (1997) from leaves of *Microphalis* sp. in Maricao, Puerto Rico, is the species to which our alga is morphologically most similar. However, considering that in our collection no sporangiate laterals could be observed and the range of cell size is different from that reported for *P. vaga* by Thompson & Wujek (1997), the examination of further collections is desirable to confirm the identification.

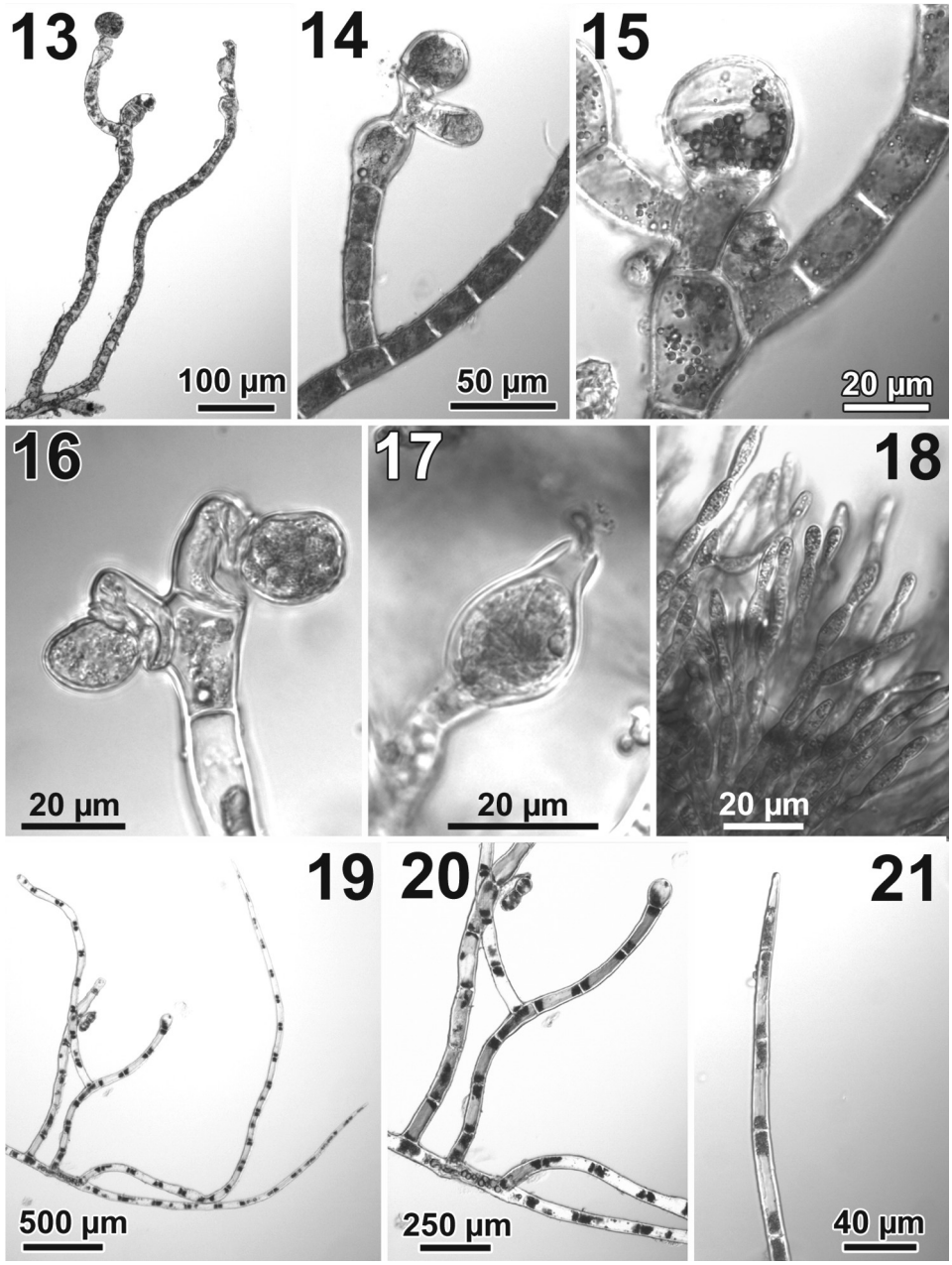
***Printzina bosseae* (De Wildeman) Thompson *et* Wujek (Figs 13-15)**

Thallus consisting of irregularly branched erect axes, arising from a limited system of prostrate filaments (Fig. 13). Cells cylindrical, 2-4 times as long as wide, 10-16 µm wide (mainly 12-14 µm). Apical cells blunt or slightly pointed, without pectic caps. Cell walls variably thick, with a slight orange colour in some parts of the thallus; plasmodesmata between adjacent cells often evident. New branches were produced either from the central part or from a corner of the cell. Branching pattern very irregular, with new branches frequently arising from the suffultory cells. Septa were often produced between the bodies and the necks of the suffultory cells and new branches were issued from both the neck and the body, either before or after discharge of the zoosporangium (Figs 14, 15). Sporangiate laterals abundant, occurring at the top of the erect axes. Zoosporangium globular, 20-30 µm in diameter; ostiole opposite to the attachment of the zoosporangium on the suffultory cell. The suffultory cell was large, with the neck produced excentrically; at maturity the neck was usually separated by a septum from the body of the cell.

This species produced bright orange tufts on the bark of an oil palm (*Elaeis guineensis* N.J. Jacquin) in the Jardin Botanique (Botanical Garden) of Cayenne, on 21 June 2006. The cell width in the type material is narrower than in our collection (9-12 µm; De Wildeman, 1891). Furthermore, in our material the colour of the cell wall is not markedly brownish as reported by De Wildeman (1891). Despite these differences, the production of new branches from the suffultory cells indicates that our material is attributable to this species. Printz (1939) and Cribb (1970) provided a better morphological characterization of *P. bosseae* and its intraspecific taxa, reporting a range of cell width in which our specimens fall (9-19 µm: Printz, 1939). The collection from Cayenne represents the first documented American record of this species, which was so far known from tropical Asia (De Wildeman, 1891, 1900; Jose & Chowdary, 1980; Salleh & Milow, 1997) and several regions of Oceania (Wille, 1915; Cribb 1958b; Sarma, 1986; Rindi *et al*., 2005).

***Printzina effusa* (Krempelhüber) Thompson *et* Wujek (Fig. 16)**

Thallus formed by an extensive system of prostrate axes from which erect axes, unbranched or poorly branched, up to 500 µm tall, arose. Prostrate axes



Figs 13-21. **13.** *Printzina bosseae*. Habit. **14.** *Printzina bosseae*. A sporangiate lateral with a new branch arising from the neck of the suffultory cell. **15.** *Printzina bosseae*. Detail of a sporangiate lateral from which new branches were issued. **16.** *Printzina effusa*. Detail of sporangiate laterals arising in couple at the top of an erect axis. **17.** *Printzina lagenifera*. Detail of a presumptive gametangium. **18.** *Printzina* cfr. *lagenifera*. Habit. **19.** *Printzina* sp. Habit. **20.** *Printzina* sp. Detail of branching. **21.** *Printzina* sp. Detail of apical part of an erect axis.

densely entangled, with cells varying in shape from elliptical to cylindrical. Erect axes arising at 90º angle from the prostrate axes, clearly tapering in the apical parts. Cells of the erect axes cylindrical, 6-11 µm wide in the basal parts (mainly 7-9 µm), 3-5 µm in the upper parts, up to 10 times as long as wide (mainly 7-8); apical cells sharply pointed. Sporangiate laterals abundant, occurring singly or in couple (Fig. 16) at the top of the erect axes. Suffultory cells with small body and sharply retorted neck; zoosporangium elliptical, 10-15 × 15-22 µm in size. Ostiole produced in basal position, adjacent to the attachment with the suffultory cell. Presumptive gametangia were rare. They were globular, up to 35 µm in diameter, provided with a short neck at maturity.

This species was collected from a wooden pole that was part of a bridge on a small stream, in the forest of Mont Rorota, Montagne de Mahury, on 25 June 2006. It formed a yellowish-brown coating, in which *Trentepohlia rigidula* (J. Müller) Hariot and other terrestrial algae were mixed.

Printzina lagenifera **(Hildebrand) Thompson *et* Wujek** **(Fig. 17)**

Alga forming pink-orange coatings, consisting of irregular growths without distinction between prostrate and erect parts. Thallus formed by numerous filaments, densely entangled and irregularly branched. Cells globular, elliptical, barrel-shaped or almost cylindrical, up to 10 times as long as wide, 5-8 µm wide. Presumptive gametangia flask-shaped, up to 20 µm in diameter, with the ostiole occurring at the top of a well-developed neck (Fig. 17). The presumptive gametangia occurred in apical position at the top of the axes or short lateral branches, less frequently in intercalary position.

A large population of this species, readily identified for the habit of the presumptive gametangia, occurred on a wooden wall at the Floramazone Lodge, on 30 June 2006. It is likely, however, that unreproductive specimens with identical vegetative morphology collected at other sites on the Montagne de Kaw belonged also to this species. Reported from Cayenne by Hariot (1889a).

Printzina **cfr.** ***lagenifera*** **(Hildebrand) Thompson *et* Wujek** **(Fig. 18)**

Two collections made from different sites showed a vegetative morphology close to *Printzina lagenifera*, but their identity at the species level could not be confirmed.

Material forming extensive orange coatings was collected from wooden poles in a public outdoor market in Cacao, on 23 June 2006. The thallus consisted of compact masses, with no differentiation between erect and prostrate parts. Branching was abundant and irregular (Fig. 18); when pressed under a coverslip, the alga fragmented easily into many short fragments. Cells were elliptical or barrel-shaped, 3-6 times as long as wide and 4-7 µm wide. No reproductive structures were observed.

The other collection was made on 27 June 2006 in Sinnamary, where an alga with similar habit formed a yellow-orange coating on metal sheeting. The thallus consisted of an irregular mass with pseudoparenchymatous structure, from which short erect axes, about 100 µm tall, were produced. The cells of the basal part were globular, subglobular or elliptical, 5-8 µm wide. The cells of the erect axes were elliptical, barrel-shaped or cylindrical, 1-4 times as long as wide, 3-6 µm wide. The apical cells were slightly pointed and devoid of caps.

Presumptive gametangia were globular, 10-15 µm in diameter, and were produced in apical, lateral or intercalary position. A neck was often present, but its development was very variable. Whereas in some gametangia the neck was well developed and comparable to the typical *P. lagenifera*, in others it was completely missing.

***Printzina* sp.** **(Figs 19-21)**

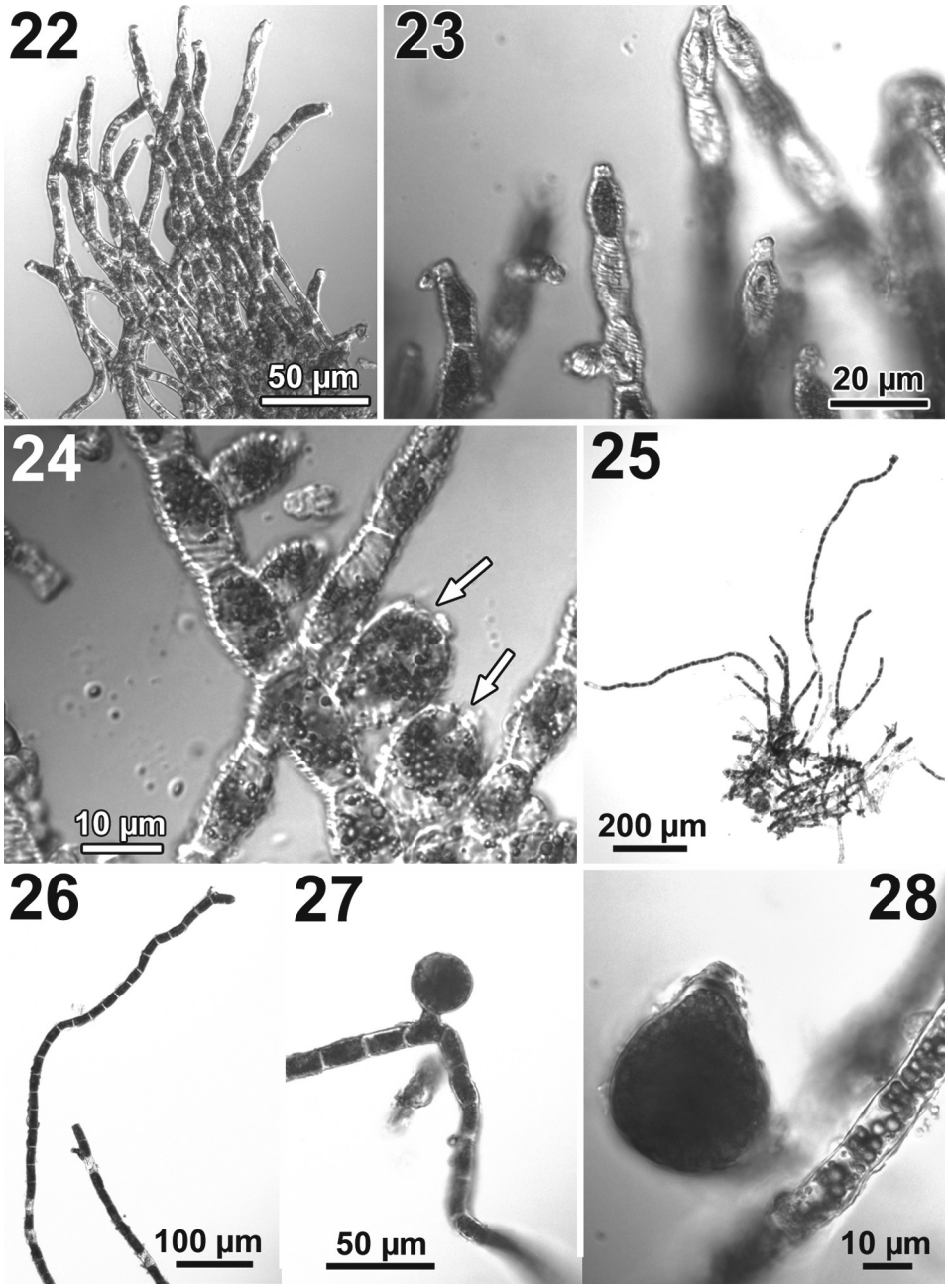
Thallus consisting of poorly or not branched erect axes, up to 2 mm tall, arising from an extensive system of prostrate filaments (Figs 19, 20). Erect axes sharply pointed, clearly tapering in the apical parts (Fig. 21). Cells cylindrical, occasionally swollen in the prostrate parts, 4-10 times as long as wide. Cells of the erect axes 15-28 µm wide in the basal parts (mainly 17-20 µm), decreasing to 6-8 µm in the apical parts. New branches arose at 90º angle from the central part of the cells. No reproductive structures were observed.

This alga was collected from the bark of an unidentified tree on the Montagne de Kaw, near the Floramazone Lodge, on 19 June 2006. The extensive development of its prostrate parts suggests that *Printzina*, as defined by Thompson & Wujek (1992), is the genus to which it should be attributed. However, no species of *Printzina* and *Trentepohlia* currently known agree with its morphology. Several tropical taxa of these genera are characterized by tapering, pointed erect axes (*Printzina effusa*, *P. diffusa* (De Wildeman) Thompson *et* Wujek, *Trentepohlia dialepta* (Nylander) Hariot, *T. ellipsiocarpa* Schmidle, *T. ellipsiocarpa* var. *africana* Schmidle and *T. minima* Schmidle). Our specimens, however, have a more robust habit and considerably wider cells than any of these taxa. We suspect that our material may represent an undescribed species; at present, however, the absence of reproductive structures and the unavailability of larger collections prevent a more precise taxonomic assessment.

***Trentepohlia abietina* (Flotow) Hansgirg** **(Fig. 22)**

Thallus forming golden-orange mats on tree bark, consisting of erect axes up to 400 µm tall, little or not branched, arising from a limited prostrate system (Fig. 22). Cells of the prostrate system globular or elliptical, 10-12 µm in diameter. Cells of the erect axes cylindrical or barrel-shaped, 2-6 times as long as wide (mainly 3-4), 5-9 µm wide. Apical cells usually larger, often bearing an apical cap. Septa between adjacent cells not noticeably thicker than lateral walls. Presumptive gametangia globular, borne laterally on the erect axes, 10-15 µm in diameter.

This species was found on the bark of a fallen tree on Mont Bourda on 25 June 2006 and on the bark of an unidentified tree on the beach of Yalimapo on 27 June 2006. A collection made from the bark of a palm tree on the beach of Kourou, in which the cells were comparatively more swollen and the cell width more variable (6.5-12.5 µm, mainly 7.5-10 µm), appears also attributable to this species. The morphology of *T. abietina* from French Guiana is in general agreement with populations of this species from other tropical and temperate regions (De Wildeman, 1900; Sarma, 1986; Rindi & Guiry, 2002b; Rindi *et al.*, 2005, 2006).



Figs. 22-28. **22.** *Trentepohlia abietina*. Habit. **23.** *Trentepohlia abietina* var. *tenue*. Detail of apical parts, showing spiral corrugation of the cell walls. **24.** *Trentepohlia abietina* var. *tenue*. Detail of erect axes with two presumptive gametangia (arrows). **25.** *Trentepohlia* cfr. *annulata*. Habit. **26.** *Trentepohlia* cfr. *annulata*. Detail of erect axes. **27.** *Trentepohlia* cfr. *annulata*. A presumptive gametangium. **28.** *Trentepohlia* cfr. *annulata*. Detail of a presumptive zoosporangium.

***Trentepohlia abietina* var. *tenue* (Zeller) Cribb** **(Figs 23-24)**

Erect axes 200-250 µm tall, little or not branched, arising from limited prostrate parts. Cells barrel-shaped or inflated, rarely cylindrical, 2-3 times as long as wide, 6-9 µm wide (Fig. 23). Apical cells larger, provided with a well developed apical cap. Cell walls heavily corrugated, ornamented by thin spiral strands (Figs 23, 24). Presumptive gametangia globular, 10-15 µm in diameter, borne laterally on the erect axes (Fig. 24).

This alga was found on bark at the base of a pinot palm (*Euterpe oleracea* Martius) in the Jardin Botanique of Cayenne on 21 June 2006 and on the bark of a palm tree on the beach of Mount Bourda, on 25 June 2006. The material that we refer to this variety is in general agreement with the characterization provided by Cribb (1970). The presence of spiral corrugations on the cell walls is the main feature by which it differs from the typical *T. abietina* (Cribb, 1970). Although the taxonomic validity of this character is somewhat dubious, pending further investigations and availability of molecular data we follow Cribb (1970) in maintaining these two taxa separated.

***Trentepohlia* cfr. *annulata* Brand** **(Figs 25-28)**

Thallus formed by erect axes, little or not branched, arising from a limited system of prostrate axes (Figs 25, 26). Cells cylindrical, 2-3 times as long as wide, 9-14 µm wide. Cross walls between adjacent cells thicker than the lateral walls, with plasmodesmata often readily observed. New branches arising in variable position, mostly from the center of the cells, less frequently close to the extremities. Pectic caps occurring on some apical cells, but not constantly present. Two types of reproductive structures were observed. Presumptive gametangia were globular, 25-35 µm in diameter, borne at the top of the erect axes or short branches (Fig. 27). Presumptive zoosporangia, similar to those described for *Trentepohlia annulata*, occurred at the top of erect axes or branches and were not supported by a differentiated suffultory cells. They were elliptical or flask-shaped, placed transversally to the direction of the supporting erect axis or branch. Their diameter was 20-33 µm; the ostiole occurred at the distal extremity, at the top of a short neck (Fig. 28).

This alga produced dark red patches on the surface of a metal post at the Fourgassié waterfalls, Montagne de Kaw, on 22 June 2006. The habit of the presumptive zoosporangia makes it well distinct from any other species of the genus. The oblique arrangement of these structures at the top of the erect axes and the absence of a suffultory cell recall the zoosporangia of *Trentepohlia annulata*. From the original illustrations of Brand (1902), however, in *T. annulata* the connection between zoosporangium and erect axis seems to occur in the central part of the sporangium, whereas in the material from French Guiana the erect axis is connected to one of the extremities of the zoosporangium. It must also be remarked that in our specimens the precise nature of these structures could not be assessed; no release of swarmers took place, so the number of flagella could not be observed. Brand (1902) reported for *T. annulata* a wider range of cell width (9.5-19 µm) and the presence of a thickened cell wall (up to 2 µm), flaky at the insertion of branches and at the cross walls. In consideration of these differences and the fact that *T. annulata* is known with certainty only from central Europe (Printz, 1939; Ettl & Gärtner, 1995), the identification of the material from the Fourgassié waterfalls must be considered merely tentative.

***Trentepohlia arborum* (C. Agardh) Hariot** **(Figs 29-30)**

Thallus forming green-orange tufts, consisting of erect axes up to 4 mm tall, poorly branched, arising from a limited system of prostrate axes. Cells cylindrical, 12-22 µm wide (mainly 14-18 µm), 2-6 times as long as wide (mainly 2.5-4). Apical cells variable in shape, blunt to more or less pointed, devoid of pectic caps. Branching sparse and irregular; new branches arising at 90° angle from the center of cells. Presumptive gametangia globular or subglobular, lateral on the erect axes or on short lateral branches, borne singly or in clusters, 25-40 µm in diameter (Fig. 29); in some specimens, their wall was irregularly roughened by thin scales. Sporangiate laterals occurred at the top of the erect axes. The enlarged apical cell of the erect axis supported 2-8 sporangiate laterals, consisting of a more or less enlarged suffultory cell from which an elliptical or kidney-shaped zoosporangium, 16-22 × 25-40 µm, was produced (Fig. 30). The ostiole of the zoosporangium was adjacent to the attachment.

At the time at which the survey was conducted, *Trentepohlia arborum* was the most common trentepohliacean species on the Montagne de Kaw. This species was found on several different substrata, both natural and artificial. It was particularly common on leaves, where it formed small tufts on the margins; it was also collected from tree bark, woodwork and plastic mosquito nets. This species also appeared to be the algal partner in forms of the lichen *Coenogonium*, which are among the most common and widespread members of the subaerial vegetation of the Montagne de Kaw. A collection of *Trentepohlia wainioi* Hariot, which is currently regarded as a synonym of *T. arborum* (Printz, 1939; Cribb, 1970), was reported from Cayenne by Hariot (1889b).

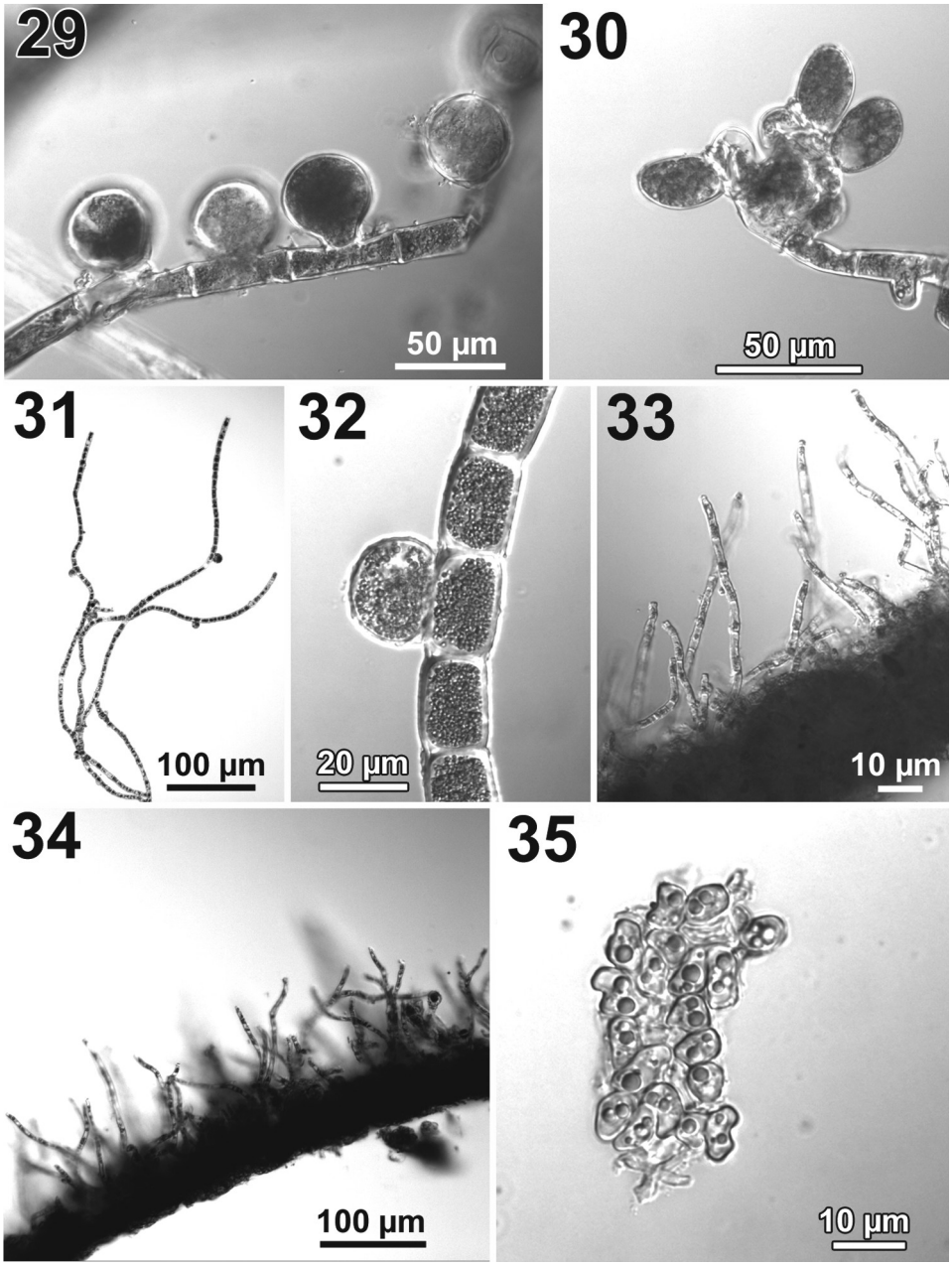
***Trentepohlia aurea* (Linnaeus) Martius** **(Figs 31-32)**

Thallus consisting of dense green-orange cushions. Erect axes irregularly branched, up to 1.5 mm tall, arising from a limited prostrate sytem (Fig. 31). Cells cylindrical, 1-3 times as long as wide (mainly 1.5-2), 8-19 µm wide (mainly 11-15 µm). Apical cells blunt, devoid of pectic caps. New branches borne in the central part of the cells. Presumptive gametangia were abundant in the collections examined. They occurred laterally on the erect axes (Fig. 32) or, less frequently, in apical position, and in some specimens were often produced in clusters of 2-4. They were globular or slightly ovoid, 25-35 µm in diameter. At maturity, the ostiole often occurred at the top of a short neck. Sporangiate laterals were rarely observed; they occurred in apical position on the erect axes or lateral branches and consisted of a slightly enlarged suffultory cell supporting an elliptical or ovoid zoosporangium.

This species was collected from painted concrete surfaces in St. Georges, on 23 June 2006. At some sites, it formed large populations mixed with mosses and cyanobacteria. The habit of the material collected is in good agreement with the concept of this species as generally circumscribed (Printz, 1939; Ettl & Gärtner, 1995) and the morphology of European populations (John, 2002; Rindi & Guiry, 2002b).

***Trentepohlia chapmanii* Rindi *et* López-Bautista** **(Figs 33-37)**

Thallus consisting of a thick and compact prostrate part, from which numerous unbranched erect axes, up to 200 µm tall, arose (Figs 33, 34). The



Figs 29-35. **29.** *Trentepohlia arborum*. Detail of some presumptive gametangia. **30.** *Trentepohlia arborum*. Sporangiate laterals occurring in a cluster at the top of an erect axis. **31.** *Trentepohlia aurea*. Habit. **32.** *Trentepohlia aurea*. Detail of a presumptive gametangium. **33.** *Trentepohlia chapmanii*. Detail of some erect axes **34.** *Trentepohlia chapmanii*. Habit of thallus in transversal section. **35.** *Trentepohlia chapmanii*. Detail of a fragment of cells of the basal layer.

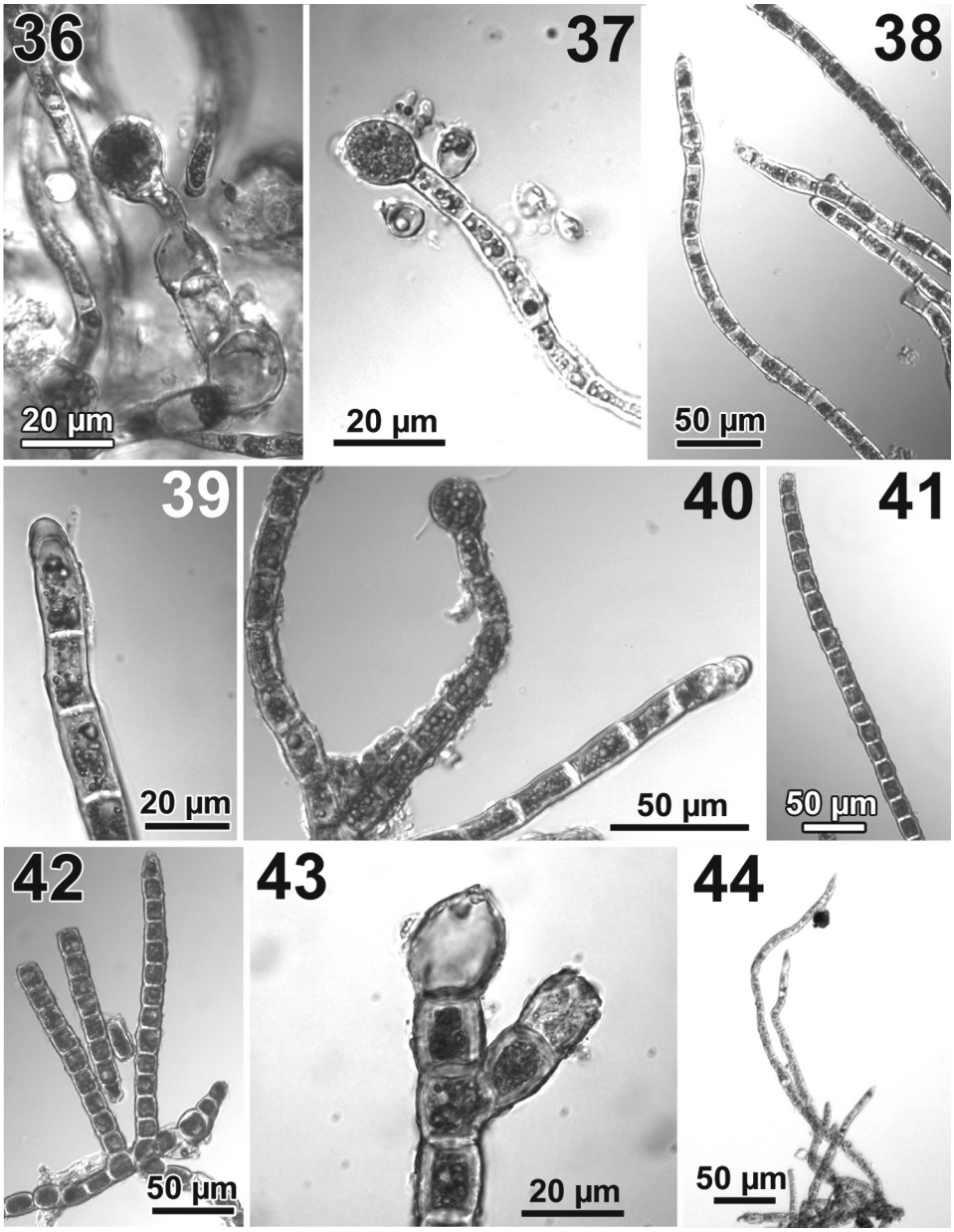
prostrate part was formed by many filaments densely entangled and irregularly branched. In the older parts of the thallus, it had a very irregular organization and produced a pseudoparenchymatous mass up to 50 µm thick (Fig. 34); its basal layer, as observed in underneath view, consisted of cells with irregular shape, usually polygonal, 3-10 µm wide (Fig. 35). No distinct individual filaments were recognizable and the overall morphology of the basal layer was reminiscent of some species of *Phycopeltis* with irregular organization, in particular *Phycopeltis kosteriana* Cribb and *Phycopeltis irregularis* (Schmidle) Wille. The cells of the prostrate part were elliptical, globular or barrel-shaped, 7-10 µm wide. The erect axes arose from the superficial portion of the prostrate part and produced a dense cover in surface view. Their cells were cylindrical, 3.5-6 µm wide and 3-8 times as long as wide. Apical cells were longer, slightly pointed, provided with a small pectic cap. Tiny spiral corrugations, observable with strong magnification, occurred on the cell walls of the erect axes. Sporangiate laterals occurred at the top of short erect axes, usually 2-3 cells long, and consisted of a flask-shaped suffultory cell, 10-16 µm wide, supporting a globular zoosporangium, 10-15 µm in diameter (Fig. 36). The neck of the suffultory cell was straight or slightly curved; the position of the ostiole in the zoosporangium could not be observed. Presumptive gametangia were globular or ovoid, 10-12 µm in diameter, and occurred in apical or lateral position on the erect axes (Fig. 37).

This species produced thin orange crusts on bamboo reeds facing sea, 10-15 m from shoreline, at Fort Diamant, area of Rémire-Montjoly, on 25 June 2006. The presence of numerous thin, cylindrical erect axes strikingly differentiated from the thick, pseudoparenchymatous prostrate part makes this species very distinctive and separates it from all other members of the order. See Rindi & López-Bautista (2007) for a detailed discussion.

Trentepohlia cucullata De Wildeman (Figs 38-40)

Thallus consisting of erect branches poorly or not branched, 1-1.5 mm tall, arising from a limited system of prostrate axes (Fig. 38). Cells cylindrical, 2-3 times as long as wide, 8-14 µm wide (mainly 10-12 µm). Apical cells blunt, often provided with a brownish cap (Fig. 39). New branches produced mainly from the central part of the cells, less frequently from the corners. Gametangia globular, produced laterally or apically on the erect axes, 25-40 µm in diameter (Fig. 40).

This species was collected from the woodwork of a pier on a small river at Crique Gabrielle on 22 June 2006, and from bark of an unidentified tree in St. Georges on 23 June 2006. A collection made from the plastic net of a chicken cage at the Floramazone Lodge on 22 June 2006 is also probably referable to this entity; in this collection, however, caps were present only on some cells and were not brown, and the size of the gametangia was smaller (20-25 µm in diameter). Our specimens are in agreement with *Trentepohlia cucullata*, as described by De Wildeman (1896) for material collected from tree bark on Java, although their cell walls do not show the yellowish colour mentioned in the original description. The presence of a brown apical cap, considered the diagnostic character of this species (De Wildeman, 1896, 1900; Printz, 1939) is evident in our collections. This is the first record for the Americas of this species, previously known for Indonesia (De Wildeman, 1896, 1900), Hawaii (Wille, 1915, as var. *sandvicensis* Wille), Papua New Guinea (Cribb, 1958b) and India (Jose & Chowdary, 1980, as var. *sandvicensis*).



Figs 36-44. **36.** *Trentepohlia chapmanii*. Detail of a sporangiate lateral. **37.** *Trentepohlia chapmanii*. Detail of a presumptive gametangium. **38.** *Trentepohlia cucullata*. Habit. **39.** *Trentepohlia cucullata*. Detail of apex of an erect axis, showing the brown cap. **40.** *Trentepohlia cucullata*. Detail of erect axes with a presumptive gametangium. **41.** *Trentepohlia diffracta* var. *colorata*. Habit of an erect axis. **42.** *Trentepohlia diffracta* var. *colorata*. Habit. **43.** *Trentepohlia diffracta* var. *colorata*. Detail of a presumptive gametangium. **44.** *Trentepohlia dusenii*. Habit of erect axes.

***Trentepohlia diffracta* var. *colorata* Cribb** **(Figs 41-43)**

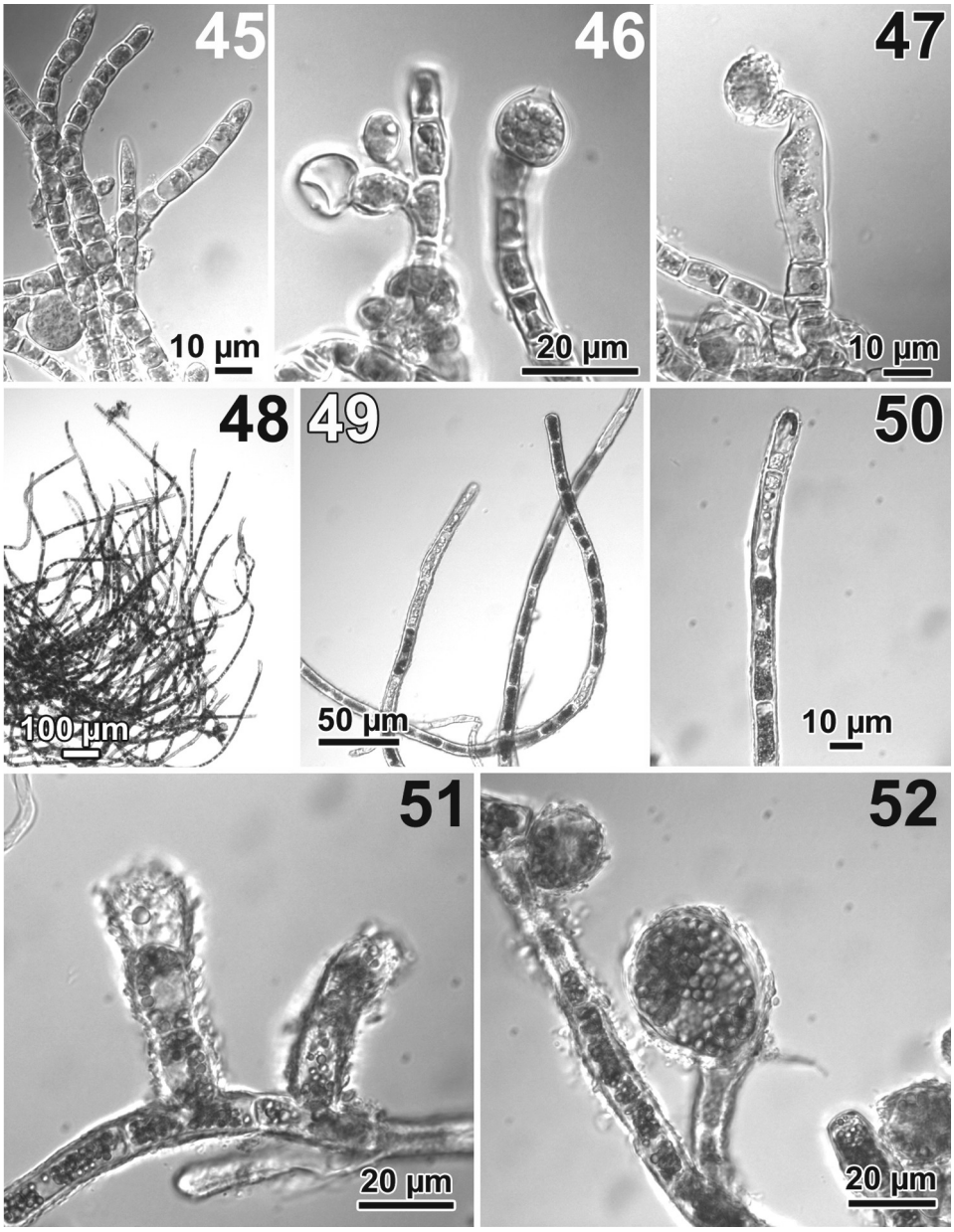
Thallus consisting of erect axes up to 700 µm tall, unbranched or poorly branched, arising from a limited system of prostrate filaments (Figs 41, 42). Erect axes easily fragmentable, with cells cylindrical or barrel-shaped, 11-15 µm wide (mainly 13-14 µm), 1-1.5 times as long as wide. Apical cells short, blunt and devoid of pectic caps. Cell wall thick (2.5-3 µm), with brown-orange colour in the older parts of the thallus. Plasmodesmata between adjacent cells often evident. The insertion of lateral branches occurred on the top corner of axial cells; young branches arising from the central part of the cell, however, were also observable. Presumptive gametangia rare, produced apically on the erect axes, globular, 18 µm in diameter (Fig. 43). The ostiole was located at the top of the gametangium.

This alga formed a dense orange coating on the bark of an unidentified tree in primary rainforest on the Montagne de Kaw, near the Floramazone Lodge; collections were made on 21 and 30 June 2006. The discovery of this taxon in French Guiana represents the first record after the original description by Cribb (1968), who collected it from the same type of habitat on Mount Hobwee, Queensland, Australia. The morphological correspondence of our material with Cribb's (1968) original collection is excellent; see Rindi & López-Bautista (2007) for further details.

***Trentepohlia dusenii* Hariot** **(Figs 44-47)**

Thallus consisting of a thick, spongy prostrate part formed by a system of densely branched and imbricate prostrate axes, from which erect axes poorly or not branched, up to 350 µm tall, arose (Fig. 44). Cells of the prostrate part varying in shape from cylindrical to globular or elliptical, 6-9 µm wide. Cells of the erect axes mostly cylindrical, occasionally barrel-shaped, 1-4 times as long as wide (mainly 1.5) (Fig. 45). Variation in the width of erect axes was noted. The thinner axes, corresponding to the gametophyte generation, were 4.5-7.5 µm wide (mainly 5.5-6); the thicker axes, considered to correspond to the sporophyte generation, were 7-8.5 µm wide (mainly 7.5-8 µm). Apical cells variable in shape from slightly pointed and bullet-shaped to blunt; pectic caps absent. Chloroplasts evident, consisting of one or a few lobed parietal plates. Presumptive gametangia produced on the erect axes in apical, lateral or intercalary position, globular or ovoid, 10-15 µm in diameter (Fig. 46). In some gametangia, the ostiole occurred at the top of a short beak. Sporangiate laterals infrequent, produced singly at the top of the erect axes (Fig. 47). Suffultory cell long, only slightly enlarged, with a neck bent at approximately 90 degrees angle. Zoosporangium elliptical, 10-13 × 14-16 µm in size. Escape pore adjacent to the connection between zoosporangium and suffultory cell.

This species was collected from metal and plastic parts of a post located in a shaded site near a stream, in the forest of Mont Rorota, Montagne de Mahury, on 25 June 2006. It formed a dense grass-green mat, easily peeled from the substratum, covering a large portion of one of the metal poles holding the post. *T. dusenii* is one of the least known and least recorded species of *Trentepohlia*. Apart for the original description from Bonge, Cameroon (Hariot in Wittrock & Nordstedt, 1893) it has been reported from Springbrook, Queensland, Australia (Cribb, 1963) and Calcutta, India (Jose & Chowdary, 1980, citing the unpublished Ph.D. thesis of Chowdary). Our collection from French Guiana represents the first record for the Americas. Our material is in agreement with the



Figs 45-52. **45.** *Trentepohlia dusenii*. Detail of erect axes. **46.** *Trentepohlia dusenii*. Some presumptive gametangia. **47.** *Trentepohlia dusenii*. Detail of a sporangiate lateral. **48.** *Trentepohlia* cfr. *flintii*. Habit. **49.** *Trentepohlia* cfr. *flintii*. Habit of some erect axes. **50.** *Trentepohlia* cfr. *flintii*. Detail of the apical part of an erect axis. **51.** *Trentepohlia* cfr. *flintii*. Detail of branching, showing corrugation of the cell wall. **52.** *Trentepohlia* cfr. *flintii*. Detail of a presumptive gametangium.

original description and its identification has been confirmed by examination of an original syntype specimen (PC0110846). For further details, see Rindi & López-Bautista (2007).

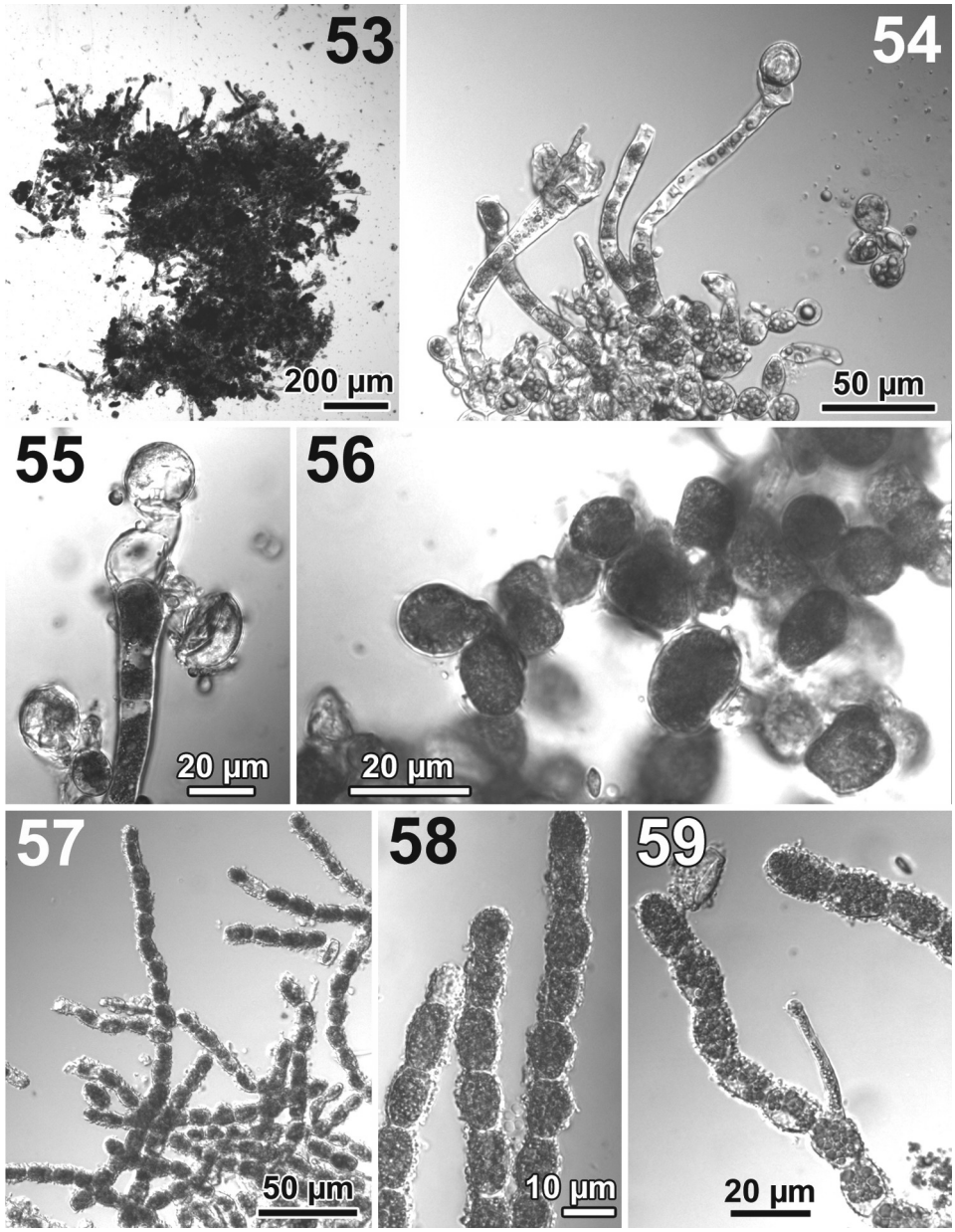
Trentepohlia cfr. *flintii* Sarma (Figs 48-52)

Thallus formed by erect axes poorly or not branched, up to 900 µm tall, arising from a limited prostrate system (Figs 48, 49). Cells cylindrical, 4-6 times as long as wide, 7.5-12.5 µm wide (mainly 8-10 µm). Apical cells variable in shape. Many erect axes had the same diameter throughout their length and their apical cells were blunt, dome-shaped (Fig. 50). Other axes have pointed tips; in these, the diameter decreased from the basal parts to the apical parts up to 4-5 µm. The cell wall was densely corrugated by numerous small scales (Fig. 51). New branches arose at 90° angle from the central part of the cells. Presumptive gametangia were produced laterally or apically on the erect axes (Fig. 52). They were globular, 20-30 µm in diameter, and their wall was densely covered by thin scales.

This alga produced orange tufts on the bark of a fallen tree on Mount Bourda, on 25 June 2006. The dense corrugation of the cell wall is the most prominent feature of its morphology. Corrugation of variable habit and intensity has been reported for several species and taxa, such as *Trentepohlia abietina* var. *tenue* (Zeller) Cribb and var. *corrugata* (Leighton) Cribb (Cribb, 1970), *T. flava* (W.J. Hooker *et* Arnott) Cribb (Cribb, 1970), *T. flintii* Sarma (Sarma, 1986), *T. negeri* Brand (Brand, 1902; Printz, 1939), *T. peruana* (Kützing) Printz and *T. rigidula* (Müller) Hariot (Printz, 1939; Cribb, 1970). None, however, agrees with the morphology of the material from Mount Bourda. *T. flintii*, based by Sarma (1986) on foliicolous specimens collected in the Piha area, Auckland, New Zealand, appears morphologically closest to it. However, range of cell size, length/width ratio of cells and shape of the presumptive gametangia are different (Sarma, 1986). We believe that the alga from Mount Bourda may possibly represent an undescribed species; further collections, however, are necessary to provide a better morphological characterization.

Trentepohlia infestans Rindi *et* López-Bautista (Figs 53-55)

Thallus consisting of a crustose, prostrate part, from which erect axes, unbranched or little-branched, arise (Figs 53, 54). Prostrate part formed by many individual filaments, densely entangled to produce a compact mass. Cells of the prostrate parts globular, elliptical or barrel-shaped, 10-13 µm wide. Erect axes arising in large numbers from the surface of the prostrate part, short (up to 200 µm tall, formed by 3-5 cells), unbranched or branched at the base. Cells of the erect axes cylindrical, 7-12.5 µm wide (mostly 8-10 µm), 2-5 times as long as broad. Sporangiate laterals produced at the top of the erect axes, formed by a globular zoosporangium, 15-22 µm in diameter, borne on a more or less enlarged suffultory cell, 15-20 µm wide (Fig. 55). In new sporangiate laterals, the neck of the suffultory cell was comparatively thin, variably bent and arose excentrically from the body of the suffultory cell. Regeneration of a sporangiate lateral on the same erect axis occurred frequently. In some case, this happened without shedding of the zoosporangium. The suffultory cell dried and became bleached without releasing the zoosporangium, and the apical cell of the erect axis produced a new sporangiate lateral, which displaced laterally the original.



Figs 53-59. **53.** *Trentepohlia infestans*. Habit. **54.** *Trentepohlia infestans*. Detail of some erect axes and superficial part of prostrate thallus. **55.** Detail of a sporangiate lateral. **56.** *Trentepohlia* cfr. *iolithus*. Detail of cells. **57.** *Trentepohlia* cfr. *peruana*. Habit. **58.** *Trentepohlia* cfr. *peruana*. Detail of erect axes. **59.** *Trentepohlia* cfr. *peruana*. Erect axes with a unicellular, pigmented hair.

This species was collected from painted concrete walls in the industrial area of Collery Marengo, near Cayenne. It produced dark red streaks with the appearance of more or less vertical stripes, sometimes extending to produce large populations with the habit of a uniform layer of red paint. Although samples could be collected only from a relatively limited number of sites, it is likely that similar red growths observed on other walls in the same area were also produced by this species. The presence of a crustose prostrate part formed by globular cells, short erect axes formed by cylindrical cells and regeneration of sporangiate laterals on the same erect axes are the morphological characters that differentiate this alga from other similar species. For a detailed discussion, see Rindi & López-Bautista (2007).

***Trentepohlia* cfr. *iolithus* (Linnaeus) Wallroth** **(Fig. 56)**

Thallus forming thick compact crusts, light red to pink in colour, produced by numerous filaments irregularly branched and densely entangled, without clear distinction between erect and prostrate parts (Fig. 56). Filaments easily fragmented when pressed. Cells globular, elliptical or barrel-shaped, 9-17 µm wide (mainly 12-14 µm). No reproductive structures observed.

This alga formed extensive growths on painted metal surfaces of a bridge in Sinnamary, on 27 June 2006. The absence of reproductive structures makes it impossible to identify with certainty. Compact, crust-like forms are known for several species of *Trentepohlia*, such as *T. iolithus* (Linnaeus) Wallroth, *T. odorata* (Wiggers) Wittrock and *T. umbrina* (Kützing) Bornet (Hariot, 1889a; De Wildeman, 1900; Printz, 1939; Cribb, 1963; Rindi & Guiry, 2002b); for comparison with *T. infestans*, see the relevant paragraph here and the discussion in Rindi & López-Bautista (2007). In these species, the habit of crustose forms is similar and unreproductive material may be impossible to identify with certainty. The alga from Sinnamary is morphologically very similar to thin forms of *T. iolithus* found on concrete surfaces in humid regions of Atlantic Europe (Rindi & Guiry, 2002b, 2003; Rindi *et al*., 2003). Pending the availability of further collections, however, its identification is better considered tentative.

***Trentepohlia* cfr. *peruana* (Kützing) Printz** **(Figs 57-59)**

Alga consisting of short erect axes, 150-200 µm tall, mostly unbranched, arising from a limited system of prostrate parts (Fig. 57). Cells of the erect axes elliptical or barrel-shaped, 1-2.5 times as long as wide, 6.5-9 µm wide (mainly 7.5-8 µm) (Fig. 58). Cells of the prostrate parts globular, 9-11 µm in diameter. Throughout the thallus, the cell wall was densely corrugated by thin superficial scales (Figs 58, 59). Thin unicellular hairs, either coloured or colourless, were produced on cells of the erect axes (Fig. 59). When pressed, the alga was easily fragmented into many short fragments, mostly 10-12 cells long. No reproductive structures were observed.

This alga formed a compact orange crust on the surface of a wooden pole of a pier, on a small river at Crique Gabrielle on 22 June 2006. With some doubt, we refer the material collected to *Trentepohlia peruana* as circumscribed by Cribb (1970). Species of *Trentepohlia* producing thin unicellular hairs have been traditionally separated from the typical *Trentepohlia* and Hariot (1890b) proposed for these algae the separate genus *Nylandera*. Six species belonging to this group have been described: *T. peruana*, *T. bogoriensis* De Wildeman, *T. lagerheimii* De

Wildeman (= *Printzina lagerheimii* (De Wildeman) Thompson *et* Wujek), *T. prolifera* De Wildeman, *T. tentaculata* (Hariot) De Wildeman and *T. willei* (Tiffany) Printz. The distinction between species is based primarily on branching pattern, size of cells and size of unicellular hairs (Printz, 1939). However, it has long been recognized that this group includes polymorphic organisms, showing a large range of variation for several morphological characters (Cribb, 1970). After examination of type specimens and large collections from Queensland, Cribb (1970) reduced *T. bogoriensis*, *T. prolifera* and *T. tentaculata* to synonyms of *T. peruana*. Unlike these species, the material from Crique Gabrielle had a thallus formed mainly by erect axes, and some unicellular hairs were pigmented. In consideration of the wide morphological range attributed by Cribb (1970) to *T. peruana*, to refer provisionally our material to this species seems to us the best solution. Further collections and molecular data, however, are necessary to elucidate both the position of this alga and the taxonomic relationships within the hair-bearing species of *Trentepohlia*.

***Trentepohlia rigidula* (J. Müller) Hariot** **(Fig. 60)**

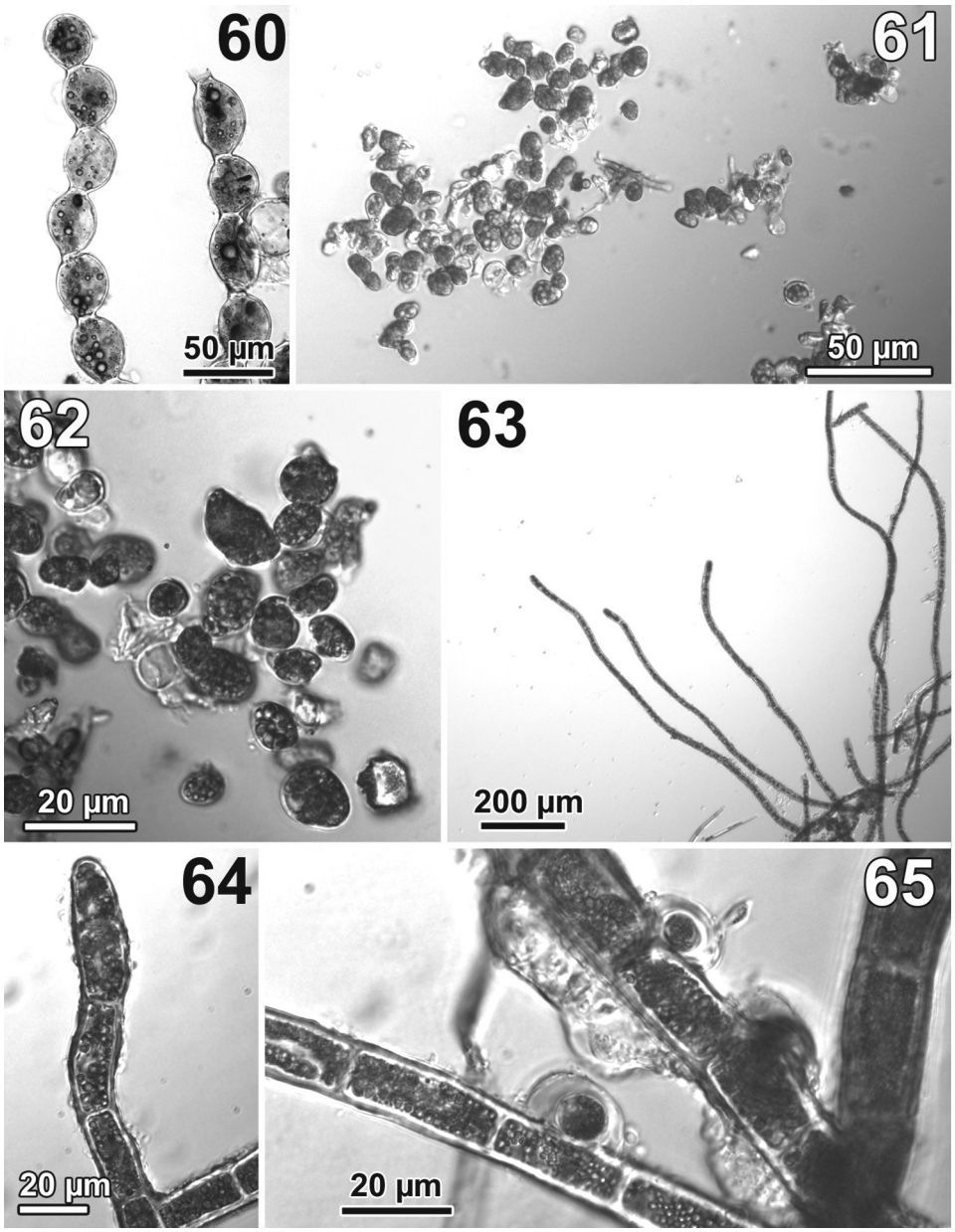
Alga formed by filaments with irregular branching, without distinction between erect and prostrate parts. Cells globular, 11-17 µm in diameter, with smooth cell walls (Fig. 60). No reproductive structures observed.

Some filaments of this species were found mixed with *Printzina effusa* on a wooden bridge over a stream on Mont Rorota, Montagne de Mahury, on 25 June 2006. The morphology of the material collected corresponds to the species most frequently reported as *Trentepohlia monilia* De Wildeman (= *Physolinum monile* (De Wildeman) Printz). We follow the opinion of Cribb (1970), who regarded this entity as a synonym of *Trentepohlia rigidula*.

***Trentepohlia* cfr. *umbrina* (Kützing) Bornet** **(Figs 61-62)**

Alga forming compact red crusts, with hard texture when dry and very soft when wet. The thallus consisted of irregular masses formed by numerous filaments, densely entangled and irregularly branched; no distinction between erect and prostrate parts was observable. Filaments easily fragmented when pressed under coverslips (Fig. 61). Cells globular, elliptical or barrel-shaped, 6-14 µm wide (mainly 8-11) (Fig. 62). No reproductive structures observed.

This alga produced dark red streaks on concrete painted walls. Collections of it were made from buildings near the beach of Mount Bourda on 25 June 2006, in Sinnamary on 27 June 2006, and from the concrete wall of a power cabin in the gardens of CIRAD in Kourou on 27 June 2006. Due to the absence of reproductive structures, the taxonomic identity of this alga is uncertain. We suspect that it might represent the gametophytic generation of *Trentepohlia infestans*, with which it shares an identical habitat and a very similar morphology. However, the range of cell size is smaller than in *T. infestans* and no erect axes are observable; the texture is also different, as this alga is much more easily fragmented than *T. infestans*. On the basis of the information currently available, we provisionally refer this alga to *Trentepohlia umbrina* (Kützing) Bornet, a widespread species reported for many temperate and tropical regions (Printz, 1939; Sarma, 1986; Ettl & Gärtner, 1995; Thompson & Wujek, 1997, as *Phycopeltis umbrina* (Kützing) Thompson & Wujek). *T. umbrina* was erected by Kützing (1843) for corticolous material from southern Germany, (as *Chroolepus*



Figs 60-65. **60.** *Trentepohlia rigidula*. Detail of some filaments. **61.** *Trentepohlia* cfr. *umbrina*. Habit of fragmented thallus. **62.** *Trentepohlia* cfr. *umbrina*. Detail of some cells. **63.** *Trentepohlia* sp. Habit of erect axes. **64.** *Trentepohlia* sp. Detail of apex of an erect axis. **65.** *Trentepohlia* sp. Detail of branching, showing new branches arising as papilla-like protrusions.

umbrinum); forms attributable to it have also been reported from artificial substrata (John, 1988; Rindi & Guiry, 2002b; Rindi *et al.*, 2003). The tendency to get easily fragmented into short fragments is typical of *T. umbrina* and has been largely used as a character for the identification of this species (Printz, 1939, 1964; Ettl & Gärtner, 1995). However, the cell width in *T. umbrina* is usually larger than in the specimens from French Guiana (8-27 µm; 12-18 in Kützing's original collections of *Chroolepus umbrinum*: Rindi, personal observations) and no reproductive structures could be observed in our material. Further collections will therefore be necessary to clarify the identity of the alga from French Guiana.

***Trentepohlia* sp.** **(Figs 63-65)**

Thallus consisting of erect axes, poorly branched or unbranched, up to 1.5 mm tall, arising from limited prostrate parts. (Fig. 63) Cells cylindrical, 2-3 times as long as wide, 10-16 µm wide (mainly 12-14 µm). Cell walls thick (2-2.5 µm), with an orange-brownish colour in the in the older parts of the thallus. Apical cells blunt, devoid of apical caps (Fig. 64). New branches arose producing a characteristic papilla-like protrusion (Fig. 65). No reproductive structures were observed.

This alga was collected from bark of an unidentified tree near the Floramazone Lodge on 30 June 2006; the absence of reproductive structures or other useful features prevent identification at the species level. For cell size and the thick cell wall with orange-brownish colour, our material agrees with *Printzina luteofusca* (De Wildeman) Thompson *et* Wujek (described as *Trentepohlia luteofusca* by De Wildeman (1891) from Fort de Kock, Sumatra, Indonesia). Our material, however, does not bear the whorls of detachable cells reported for *P. luteofusca* and the apical cells do not show the inflated shape considered typical of this species (Printz, 1939; Cribb, 1970). Further collections will be necessary to clarify its taxonomic identity.

DISCUSSION

This survey has revealed the presence of 28 taxa of Trentepohliales in French Guiana. Two of these (*Trentepohlia chapmanii* and *T. infestans*) were described separately as new species (Rindi & López-Bautista, 2007). For five taxa (*Phycopeltis irregularis*, *Printzina bosseae*, *Trentepohlia cucullata, T. diffracta* var. *colorata*, *T. dusenii*) the present study provides the first records for the Americas. Such records are not unexpected, since these taxa occur in other tropical areas and some of them have a wide geographical range. Their discovery, however, highlights how limited is the state of knowledge of the Trentepohliales for most tropical regions. Interestingly, despite of careful search, it was not possible to rediscover *Printzina leprieurii* (Hariot) Thompson *et* Wujek, described as *Trentepohlia leprieurii* by Hariot (1890a: 53) for foliicolous material from Cayenne. Several taxa collected in this survey could not be identified at the species level and further investigations will be necessary to clarify their taxonomic identity; in any case, their morphology appears distinctive and it is unlikely that they will turn out to be morphological variants of species already identified. Therefore, as currently known, the trentepohliacean flora of French Guiana

consists of not less than 29 taxa. A comparison with the few tropical regions for which reliable data are available shows that this must be considered a very high figure. At present, 27 taxa currently accepted are known for India (Brühl & Biswas, 1923; Saxena, 1961; Jeeji-Bai, 1962; Randhawa & Venkataraman, 1962; Jose & Chowdary, 1980; Panikkar & Sindhu, 1993; Krishnamurthy, 2000), 30 for the area of Bogor, Indonesia (De Wildeman, 1900) and 31 for Queensland, Australia (Day *et al*., 1995; Phillips, 2002). It should be considered, however, that India and Queensland have a much larger territorial extent than French Guiana and that for this investigation it has not been possible to collect in more internal zones. We expect that surveys in the area of Saül and other internal parts of the French Guianean rainforest would probably reveal the presence of additional taxa. On this basis, it can be legitimately concluded that French Guiana is a biodiversity hotspot for the Trentepohliales. There can be hardly any doubt that the humid climate produced by the Intertropical Zone of Convergence and the variety of habitats of this region play a key role in this regard. The widespread distribution of Trentepohliales in regions with rainy and humid climate is a well-known phenomenon (John, 1988; Rindi & Guiry, 2002b), and wind and rain are considered to play a fundamental role in the dispersal of these algae. The collections for the present study were made in June; this period corresponds to the final part of the rainy season (Barret, 2004) and it can be expected to be particularly favorable for the development of the Trentepohliales. The fact that sampling was carried out at several locations, both on the Montagne de Kaw and in the coastal strip, and from many different habitats, certainly contributed to the high number of taxa recorded. Our results show a differentiation between the trentepohliacean flora of the rainforest environment and that of the exposed habitats of the coastal strip (Table 1). The Montagne de Kaw is the part of French

Table 1. Ecological differentiation of the trentepohliacean taxa collected in relation to the type of environment.

Taxa associated with rainforest habitats	*Taxa associated with exposed habitats (coastal strip)*	*Generalist taxa collected in both types of habitats*
Phycopeltis cfr. *amboinensis*	*Cephaleuros virescens*	*Phycopeltis* cfr. *arundinacea*
Phycopeltis irregularis	*Printzina bosseae*	
Phycopeltis cfr. *prostrata*	*Printzina* cfr. *lagenifera*	
Phycopeltis cfr. *treubii*	*Trentepohlia abietina*	
Phycopeltis cfr. *vaga*	*Trentepohlia abietina* var. *tenue*	
Printzina effuse	*Trentepohlia aurea*	
Printzina lagenifera	*Trentepohlia chapmanii*	
Printzina sp.	*Trentepohlia cucullata*	
Trentepohlia cfr. *annulata*	*Trentepohlia* cfr. *flintii*	
Trentepohlia arborum	*Trentepohlia infestans*	
Trentepohlia diffracta var. *colorata*	*Trentepohlia* cfr. *iolithus*	
Trentepohlia dusenii	*Trentepohlia* cfr. *umbrina*	
Trentepohlia cfr. *peruana*		
Trentepohlia rigidula		
Trentepohlia sp.		

Guiana with the highest annual rainfall; the coastal strip, in which the vegetation consists mainly of savannas and swamps, is characterized by lower rainfall and higher insolation (Barret, 2004). Species occurring in rainforest environments are adapted to shaded conditions and high humidity, and they mainly occur on natural substrata, such as tree bark and leaves. Conversely, species occurring in the coastal strip are more tolerant to strong irradiation and dry conditions, and are frequently found on artificial substrata. No similar information is available for any other tropical area, which makes it impossible to compare our observations with reports for other regions. However, the general impression that species of *Phycopeltis* have a preference for humid and shaded habitats and that some species of *Trentepohlia* (*T. abietina* and *T. aurea*) and *Cephaleuros* tend to occur in more exposed habitats is in agreement with previous observations of the authors for other geographical areas (south-eastern U.S.A. and Panama; López-Bautista & Rindi, unpublished observations).

Finally, the high diversity of Trentepohliales found on artificial surfaces in French Guiana is noteworthy: 9 trentepohliacean taxa were collected from artificial substrata. The diversity of the substrata on which these algae occurred is also remarkable, as they included painted and unpainted concrete, unpainted metal, plastic sheeting, metal posts and plastic nets. Species of *Trentepohlia* have been frequently reported from artificial surfaces, especially in the tropics (Islam, 1972; Wee & Lee, 1980; Ong *et al*., 1992). Their diversity, however, has been rarely characterized. In taxonomic investigations of microalgae on artificial substrata, Trentepohliales are often identified only at the genus or family level (Gaylarde & Gaylarde, 2000; Tomaselli *et al*., 2000; Crispim *et al*., 2004; Gaylarde *et al*., 2006). Our results, in particular the discovery of *Trentepohlia infestans*, show that great attention should be paid to these substrata and their importance over the natural habitats should not be underestimated. It is not possible to establish from our observations whether the Trentepohliales in French Guiana cause mechanical biodegradation of the surfaces colonized. But it is obvious that *Trentepohlia infestans* and *T.* cfr. *umbrina* can cause aesthetic disfigurements as striking as *T. odorata* in Singapore (Wee & Lee, 1980; Lee & Wee, 1982) and *T. iolithus* in western Ireland and northern France (Rindi & Guiry 2002b, 2003; Rindi *et al*., 2003).

As a more general conclusion, this study confirms that the tropical regions represent a major repository of unexplored microalgal diversity. Other species of Trentepohliales have been described in recent years from rainforests of central America and south-eastern Asia (Thompson & Wujek, 1997; Neustupa, 2003, 2005) and there is little doubt that detailed surveys conducted in other regions would bring to light many more undescribed taxa. A similarly high diversity to that revealed for the Trentepohliales can be expected to be common to many other groups of terrestrial microalgae of French Guiana and the whole Amazonian region. Detailed surveys of the microalgal flora of these regions are greatly desirable and can be expected to lead to many exciting discoveries.

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