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A survey of the Rhodophyta and associated macroalgae from coastal streams in French Guiana

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Abstract — Eighteen primarily lowland stream segments were sampled along the coast of French Guiana in South America. Streams varied from small rivulets to larger streams (< 2-20 m width) with substrata ranging from sand and gravel to large boulders. Waters were warm (24-25ºC), acidic to neutral pH (4.6-6.9) and low ion content (10-60 $\mu S \cdot cm^{-1}$). Mean species number per stream segment was 4.2 and ranged from 1-10. From the 75 samples collected, 26 infrageneric taxa were identified as follows: 9 Cyanobacteria, 4 Chlorophyta, 3 Heterokontophyta and 10 Rhodophyta. The rhodophytes were not only the most species rich, but also the most dominant in percent cover. The genus *Batrachospermum* was represented by eight taxa. *Batrachospermum* section *Contorta* was the most species rich with *B. ambiguum*, *B. gracillimum*, *B. guyanense*, *B. intortum* and *B. nodiflorum*, with each collected from one to two locations. In contrast, only two species from section *Aristata*, *B. cayennense* and *B. macrosporum*, were identified, but gametophytes were collected in eight and six locations, respectively. From section *Turfosa, B. turfosum*, a taxon typical of brown water streams, was present in three of the streams surveyed. *Compsopogon coeruleus* was collected from two locations. A rarely reported taxon, *Ptilothamnion richardsii*, was discovered as an epiphyte on aquatic macrophytes in one stream and on *B. turfosum* in another.

***Batrachospermum* / Chlorophyta / coastal streams / *Cyanophyta* / French Guiana / Heterokontophyta / Rhodophyta**

Résumé — Une vue d'ensemble des Rhodophytes et des macrolgues associées dans les ruisseaux côtiers de la Guyane française. Dix-huit segments de cours d'eau ont été étudiés le long de la côte de la Guyane française en Amérique du Sud. Ces cours d'eau vont de petits ruisseaux à de plus grandes rivières (< 2-20 m) avec des substrats de sable, de gravier ou de gros rochers. Les eaux étaient chaudes (24-25 ºC), à pH acide à neutre (4,6-6,9) et à conductivité ionique basse (10-60 $\mu S \cdot cm^{-1}$). Le nombre moyen d'espèces par segment était de 4,2 et variait de 1 à 10 espèces par segment. Des 75 échantillons récoltés, 26 taxons infragénériques ont été identifiés comme suit : 9 Cyanobacteria, 4 Chlorophyta, 3 Heterokontophyta et 10 Rhodophyta. Les rhodophytes étaient non seulement les plus riches en nombre d'espèces, mais également en pourcentage de recouvrement. Le genre *Batrachospermum* était représenté par huit taxons. La section *Contorta* de *Batrachospermum* comptait le plus grand nombre d'espèces, *B. ambiguum, B. gracillimum, B. guyanense,*

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B. intortum et *B. nodiflorum*, chacune de ces espèces ayant été trouvée à un ou deux endroits. Seulement deux espèces de la section *Aristata, B. cayennense* et *B. macrosporum*, ont été identifiées, mais des gamétophytes ont été trouvés en huit et six endroits, respectivement. De la section *Turfosa, B. turfosum*, un taxon typique des ruisseaux à eau brune, était présent dans trois des ruisseaux examinés. *Compsopogon coeruleus* a été récolté à deux endroits. Un taxon rarement signalé, *Ptilothamnion richardsii*, a été découvert en épiphyte sur les macrophytes aquatiques dans un ruisseau et sur *B. turfosum* dans une autre localité.

***Batrachospermum* / Chlorophyta / Cyanophyta / Guyane française / Heterokontophyta / Rhodophyta / ruisseaux côtiers**

INTRODUCTION

French Guiana (Guyane), a department of France, is located in northern South America near the equator (Fig. 1). It comprises part of the Guiana Shield area, a distinct floristic province that also includes Guyana, Suriname, and parts of Venezuela and Brazil (Brummit, 2001). At present, the 'Biological Diversity of the Guianas' (BDG) and 'Fungal and Plant Diversity of Central French Guiana' projects, along with other research groups, are cataloging the diversity of the region.

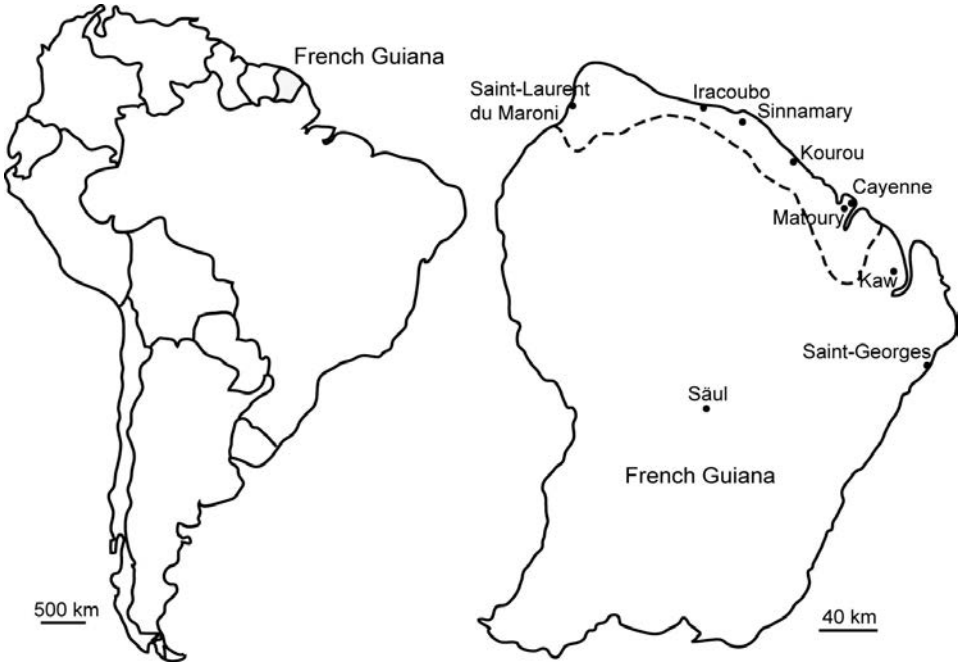


Fig. 1. Location of French Guiana, shaded, in South America and a higher magnification of French Guiana with the dashed line demarcating the area from which the coastal streams were sampled.

Much of the freshwater algal flora is yet to be documented, but the area may have a rich algal flora as evidenced by a study of samples from three lentic habitats (Bourrelly & Couté, 1983), which yielded 206 taxa (predominately desmids) and 16 new taxa.

Montagne (1850) published an account of 76 taxa from collections made in the region by Leprieur in the early 1800s. There were numerous records of brackish and freshwater Rhodophyta, among these were species belonging to the genera *Bostrychia*, *Balliopsis* (as *Ballia*) and *Compsopogon*. Nine new species of *Batrachospermum* were also described, but with little detail on the vegetative and reproductive features that are presently used for infrageneric classification. Kumano (1990) re-examined the specimens and provided illustrations of carpogonia and carposporophytes for better taxonomic placement. Two species, *B. guyanense* and *B. nodiflorum*, are only known from the type collection and have not been re-collected in that locality or elsewhere (Thérézien, 1985). One other study in French Guiana of freshwater reds concentrated on the revision of the genus *Balliopsis* (as *Ballia*) with new specimens collected (Couté & Sarthou, 1990).

It would appear that French Guiana is rich in freshwater red algal taxa and that rare species may be collected. In addition, this area has been poorly collected in modern times with only two publications including freshwater rhodophytes (Thérézien, 1985; Couté & Sarthou, 1990). Therefore, the present survey was initiated to collect stream macroalgae and to photo-document freshwater red algal taxa in particular.

MATERIALS AND METHODS

Eighteen stream segments were sampled during August 12-28, 2002 along the coast of French Guiana from Cayenne to Saint-Laurent du Maroni (Fig. 1). At each site, a minimum of 20 m stream length was surveyed for macroalgae (algae with a discrete structure visible) and algal cover was estimated for each taxon as described previously (Sheath *et al*., 1986). Representative samples of each taxon encountered were immediately fixed in 2.5% calcium carbonate-buffered glutaraldehyde for later identification. Latitude, longitude and elevation were obtained using a Trimble Scoutmaster portable GPS unit for most locations (Tab. 1). Within the sampling area, the maximum width and depth were determined, and water temperature measured. Water was noted as colorless or brown-colored. Water pH was measured using a pHTester 2™ and specific conductance with TDSTestr 3™. Mean current velocity was calculated from three measurements using an Ohio professional stream flow meter. The percentage of canopy cover by overhanging vegetation and the percentage of substratum types were estimated.

Discrete morphological entities from the field notes were separated using an Olympus SZH-ILLD stereoscope. Macroalgal specimens were identified to species level, when possible, using an Olympus BX40 compound light microscope. Rhodophyta species were identified using modern descriptions and keys from the literature (Necchi, 1990; Sheath *et al*., 1992, 1994a, b; Vis *et al*., 1992; Entwisle & Foard, 1999; Kumano, 2002). Algal keys, such as Prescott (1962), Geitler (1932) and John *et al*. (2002) were used for the other taxa with the taxonomy updated as necessary. Vouchers of Rhodophyta samples, for which there was adequate material, have been deposited in Herbier de Guyane (CAY). Pearson Product Moment or

Table 1. Physical and chemical characteristics of 18 stream segments in coastal French Guiana.

Stream Number[a]	*Location latitude, longitude*	*Elevation (m)*	*Max. Width (m)*	*Max. Depth (cm)*	*Mean Current Velocity ($cm \cdot sec^{-1}$)*	*Water Temp. (°C)*	*pH*	*Specific Conductance ($\mu S \cdot cm^{-1}$)*	*Water Color*[b]	*% Substratum type*	*% Canopy Cover*	*Macroalgae*	
												Species Number	*Cover Scale*[c]
1	–	–	8	67	38	24	6.9	30	0	50 gravel, 50 cobble	75	4	2
2	–	–	1.9	18	46	25	6.5	50	0	70 rock, 5 cobble, 20 sand	80	1	1
3	4°34.068'N, 52°23.945'W	40	15.3	>100	67	24	6.5	20	–	25 bedrock, 25 rock, 10 cobble, 40 sand	25	4	2
4	4°32.068'N, 52°22.399'W	27	6	>100	42	24	5.6	10	0	< 1 rock, 95 cobble, 5 sand	90	1	1
5	4°43.280'N, 52°24.024'W	34	1.6	55	78	25	4.6	20	1	80 bedrock, 5 rock, 15 cobble	90	4	4
6	4°43.433'N, 52°24.092'W	27	1.5	21	19	25	4.6	20	1	100 bedrock	90	5	3
7	5°17.616'N, 53°57.960'W	43	15	100	44	25	5.9	20	1	90 bedrock, 1 cobble, 9 sand	10	7	5
8	5°32.862'N, 53°28.179'W	5	20	>100	38	24	5.7	20	1	100 bedrock	5	8	3
9	5°28.565'N, 53°34.062'W	27	1.8	20	34	24	4.9	20	1	70 sand, 30 muck	0	3	5
10	5°28.565'N, 53°34.062'W	27	4	55	44	24	5.7	20	1	10 rock, 90 sand	1	4	2
11	5°27.843'N, 53°54.392'W	21	4.4	17	32	24	5.5	20	0	5 cobble, 95 sand	0	2	3
12	5°25.797'N, 53°44.394'W	–	6.2	>100	10	24	5.8	20	0	–	–	5	4
13	5°01.798'N, 54°05.303'W	79	25	>100	25	24	6.4	20	0	98 bedrock, 2 sand	50	10	3
14	5°07.411'N, 52°43.990'W	21	4.6	>100	1	25	6.1	20	0	1 rock, 99 sand	10	2	4
15	5°09.549'N, 52°53.651'W	27	6.9	38	13	25	5.5	30	1	50 rock, 25 cobble, 25 sand	0	5	2
16	5°03.989'N, 52°59.931'W	49	5	>100	28	24	5.7	20	0	2 rock, 2 cobble, 90 gravel, 5 sand, 1 wood	80	3	2
17	5°29.356'N, 53°18.253'W	34	13.7	80	17	25	4.8	60	0	15 rock, 1 cobble, 83 sand, 1 wood	5	4	2
18	–	–	3.9	43	–	24	5.3	20	1	10 rock, 40 sand, 50 leaves	90	2	1

[a] For details see Appendix.
[b] 0: colorless, 1: brown colored.
[c] 1: <1%, 2: 1-10%, 3: 11-25%, 4: 26-50%, 5: 51-75%, 6: 76-100% (Sheath *et al.,* 1986).

APPENDIX : LOCATION OF FRENCH GUIANA SAMPLING SITES

1 Chutes de Fourgassié Carbet on road D6 in Kaw Mountains east of Cayenne.
2 On trail in Grand Matoury Mountain Reserve in Matoury suburb of Cayenne.
3 Crique Boulanger Carbet on road N2 east of Cayenne.
4 Crique Blanche Carbet on road N2 east of Cayenne.
5 Small rivulet waterfall on road N2 east of Cayenne.
6 Small rivulet waterfall on road N2 east of Cayenne.
7 Crique Tatou Carbet on route de Paul Isnard, near Saint-Laurent du Maroni.
8 L'Organabo Rivière on road N1 at public access, west of Iracoubo.
9 Small tributary of stream 10.
10 Un-named stream on road N1 between Kourou and Sinnamary.
11 Un-named stream on road N1 near St. Laurent du Maroni.
12 Stany Rivière on road N1 near St. Laurent du Maroni.
13 Chutes Voltaire at Camp Voltaire off the route de Paul Isnard.
14 Crique Soumourou Carbet on road N1, near Kourou.
15 Crique Malmanoury Carbet on road N1, near Kourou.
16 River at Carbet on La Route de Berrage Petit Saut between Kourou and Sinnamary.
17 Crique Morpio Carbet on road N1 between Iracoubo and Organabo.
18 Small stream on Le Bagne des Annamites trail to Rivière Tonnegrade, off of road D6.

Spearman ranked correlations were performed for all stream variables, species richness and algal percent cover given in Table 1 to determine significant trends using the statistical software NCSS (Hintze 2000).

RESULTS

The streams sampled were in the lowlands (within 80 m of sea level), had warm water temperatures, acidic to neutral pH and low specific conductance (Tab. 1). Streams varied in size, with widths ranging from 1.9 to 20 m and depths from 17 to >100 cm. These two parameters were positively correlated ($p < 0.01$). Smaller streams tended to be acidic and had tannic brown-colored waters, whereas the larger streams were more neutral and had colorless waters as shown by the positive correlation ($p < 0.05$) between width and pH and the negative correlation ($p < 0.05$) of pH and water color. The streams had various substrata and the percent composition varied greatly (Tab. 1). Streams ranged from open with no canopy cover to heavily shaded with a dense overgrowth of vegetation, but the percent canopy cover was not correlated to stream size. Both the macroalgal species numbers and cover varied greatly (1-10, <1-75%, respectively). Larger streams tended to have more species with species number being correlated to stream width ($p < 0.05$). However, macroalgal cover of the stream bottom did not show this trend and greater species numbers did not produce a higher cover value ($p > 0.05$). The mean number of macroalgal species per stream segment was 4.2.

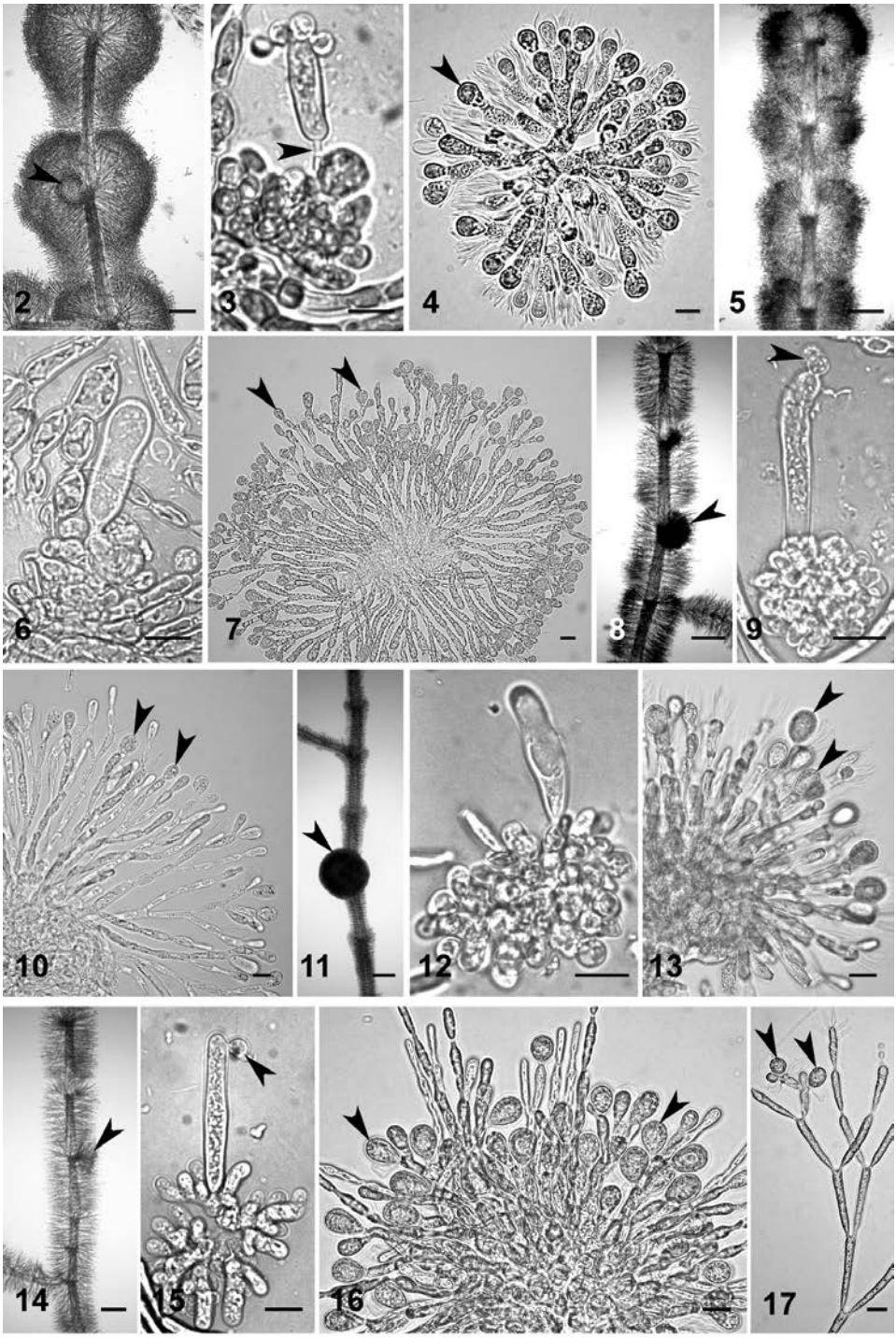
A total of 75 samples were collected from the 18 streams. Twenty-six infrageneric taxa were identified from the following taxonomic groups: 9 Cyano-

Tab. 2. Macroalgal species collected in streams of coastal French Guiana, South America.

Taxon	*Stream Location*[a]
Cyanobacteria	
Geitlerinema splendidum (Grev. ex Gomont) Anagn.	8, 11, 12
Leptolyngbya sp.[b]	10
Microcoleus vaginatus Vaucher ex Gomont	1
Phormidium corium C. Agardh ex Gomont	5
P. retzii C. Agardh ex Gomont	1
Pseudanabaena cf. *galeata* Böch.	6
Scytonema coactile Montagne	7
S. crassum Näg. in Kütz.*	13
Stigonema informe (Kütz.) Bornet *et* Flahault	7, 8, 13
Chlorophyta	
Mougeotia sp.	13
Oedogonium sp.	3, 7, 12, 13
Schizochlamys gelatinosa A. Braun	15
Spirogyra sp.	6, 7, 8, 9, 10, 13, 14, 15, 16, 17
Heterokontophyta	
Eunotia femoriformis (Patrick) Hustedt	9
Eunotia rabenhorstiana var. *elongata* (Patrick) Metzeltin & Lange-Bertalot	3, 5, 6, 7
Tribonema ulotriculosum (Kütz.) Hazen*	8, 15
Rhodophyta	
Batrachospermum ambiguum Montagne	*1, 13*
B. ambiguum chantransia stage[c]	2
B. cayennense Montagne	4, 5, 6, 7, 9, 12, 13, 15, 17
B. gracillimum W. West et G.S. West *emend.* Necchi	10
B. guyanense (Montagne) Kumano	8
B. intortum Jao	17, 18
B. macrosporum Montagne	8, 11, 14, 15, 16, 18
B. macrosporum chantransia stage[c]	3, 5, 6, 10, 15, 17
B. macrosporum cf. chantransia stage[d]	8, 13
B. nodiflorum Montagne	8, 12, 13
B. turfosum Bory *emend.* Sheath, Vis *et* Cole	7, 12, 16
Compsopogon coeruleus (Balb.) Montagne	1, 3
Ptilothamnion richardsii Skuja	13

* New record for South America.
[a] Stream location number as given in Tab. 1.
[b] The morphology of this specimen resembles *Leptolyngbya frigida* but the habitat, which is increasingly being used as a diagnostic character, is not consistent for the species.
[c] Unpublished DNA sequence data homology with *Batrachospermum* gametophytes confirms that the specimens from these streams are chantransia stage of these taxa.
[d] The morphology of specimens from these streams is similar to that of confirmed *B. macrosporum* chantransia, but there is the possibility that these could be chantransia of another batrachospermalean species.

Figs 2-17. Characteristics of *Batrachospermum* Section *Contorta* species collected from coastal streams in French Guiana. Figs 2-4. *Batrachospermum ambiguum*. Fig. 2. Main axis with obovoid whorl, dark cortication and large internal carposporophyte (arrowhead). Fig. 3. Fertilized carpogonium with distinct stalk (arrowhead). Fig. 4. Mature carposporophyte with carposporangium (arrowhead). Figs 5-7. *Batrachospermum gracillimum*. Fig. 5. Main axis with compressed obovoid whorls. Fig. 6. Inflated club-shaped carpogonium. Fig. 7. Mature carposporophyte with carposporangia (arrowheads). Figs 8-10. *Batrachospermum guyanense*. Fig. 8. Main axis with barrel-shaped whorls and large carposporophyte (arrowhead). Fig. 9. Carpogonium with spermatia (arrowhead) attached to long cylindrical trichogyne. Fig. 10. Carposporophyte with terminal carposporangia (arrowheads). Figs 11-13. *Batrachospermum nodiflorum*. Fig. 11. Main axis with reduced whorls and large protuberant carposporophyte (arrowhead). Fig. 12. Carpogonium with inflated club-shaped trichogyne. Fig. 13. Compact carposporophyte with terminal carposporangia (arrowheads). Figs 14-17. *Batrachospermum intortum*. Fig. 14. Main axis with indistinct barrel-shaped whorls containing a diffuse carposporophyte (arrowhead). Fig. 15. Carpogonium with a spermatium (arrowhead) attached to an elongate trichogyne. Fig. 16. Carposporophyte with numerous carposporangia (arrowheads). Fig. 17. Vegetative fascicle with monosporangia (arrowheads). Scale bars: 100µm in Figs 2, 5, 8, 11, 14 and 10µm in all other figures.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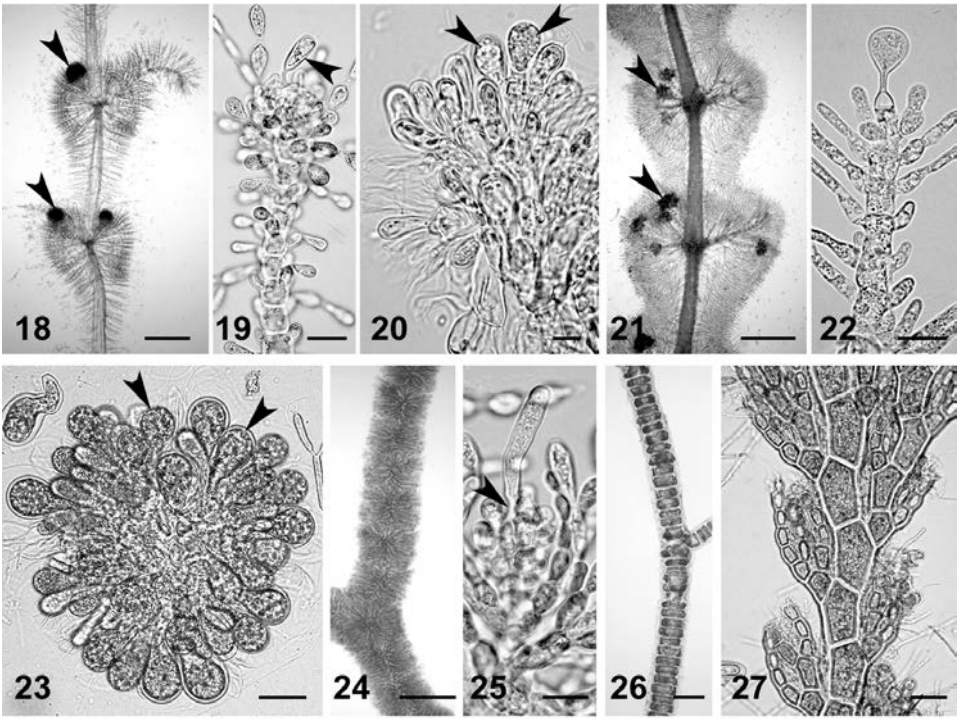
bacteria, 4 Chlorophyta, 3 Heterokontophyta and 10 Rhodophyta (Tab. 2). Most of the Cyanobacteria were collected in only one location and many of the taxa typically formed mats of interwoven filaments. Both the chlorophytes, *Oedogonium* and *Spirogyra*, occurred at numerous locations. The specimens from each taxon were morphologically similar, but could not be identified due to lack of reproductive features. Two diatom taxa were included as macroalgae because they formed large colonies that were visible with the naked eye. Only one tribophyte, *Tribonema ulotriculosum*, was collected in 2 streams. The ten rhodophyte taxa were from three genera, with the genus *Batrachospermum* represented by eight species and one species each from *Compsopogon* and *Ptilothamnion* (Tab. 2).

Batrachospermum section *Contorta*, with all members having curled carpogonial branches, was the most species-rich section with *B. ambiguum, B. gracillimum, B. guyanense, B. intortum* and *B. nodiflorum.* However, each species was collected from only one or two locations (Tab. 2). *Batrachospermum ambiguum* gametophytes were collected from two locations and have brown cortication of the main axis with obovoid whorls, which completely contain the carposporophytes (Fig. 2). The carpogonium of this species is cylindrical with a distinct stalk and the carposporophytes are compact (Figs 3, 4). *Batrachospermum gracillimum*, collected at one locality, has compressed obovoid whorls, inflated club-shaped carpogonia and loosely compact carposporophytes (Figs 5-7). *Batrachospermum guyanense* was collected growing among *B. nodiflorum* and *B. cayennense* in stream 8 (Tab. 2). This species has barrel-shaped whorls with large carposporophytes and a carpogonium with a long cylindrical trichogyne (Figs 8, 9). Like *B. gracillimum*, the carposporophyte is loosely aggregated with numerous carpospores at the tips of gonimoblast filaments (Fig. 10). In addition to stream 8, *B. nodiflorum* was recorded from two other streams (Tab. 2). This species has reduced whorls superficially resembling taxa from section *Setacea* (Fig. 11). The carpogonium has an inflated club-shaped trichogyne and the carposporophyte is composed of short compact gonimoblast filaments (Figs 12, 13). In both streams that *B. intortum* occurred, it covered <1% of the substratum. This species has a main axis with indistinct, barrel-shaped whorls containing diffuse carposporophytes (Fig. 14). The carpogonium has a sessile, elongate trichogyne (Fig. 15). The carposporophyte is dense with gonimoblast filaments and monosporangia are abundant at the tips of vegetative fascicles (Figs 16, 17).

In contrast to *Batrachospermum* section *Contorta*, only two species from section *Aristata, B. cayennense* and *B. macrosporum,* were identified, but gametophytes were collected in eight and six locations, respectively. The main axis of *B. cayennense* has obovoid whorls with prominently stalked carposporophytes (Fig. 18). In this species the carpogonial branch is elongate and composed of numerous cells, and the carpogonium has a clavate trichogyne (Fig. 19). The compact carposporophyte has terminal carposporangia (Fig. 20). *Batrachospermum macrosporum* has a similar whorl morphology to *B. cayennense*, with obovoid whorls with numerous prominently stalked carposporophytes (Fig. 21). The carpogonium has an orbicular trichogyne on a many-celled carpogonial branch (Fig. 22). The carposporangia are large (~35 μm in diameter) in comparison to those of *B. cayennense* (~10 μm in diameter) and are borne at the tips of densely packed gonimoblast filaments (Fig. 23).

Batrachospermum turfosum from the section *Turfosa* was present in three of the streams surveyed. This species typically has indistinct and confluent whorls and a carpogonium that is stalked with an elongate trichogyne (Figs 24, 25). *Compsopogon coeruleus* was collected from two locations. In both locations the outer covering was brown-colored, but the overall thallus morphology was typical



Figs 18-27. Characteristics of freshwater red algae collected from coastal streams in French Guiana. Figs 18-20. *Batrachospermum cayennense*. Fig. 18. Main axis with obovoidal whorls containing prominently stalked carposporophytes (arrowheads). Fig. 19. Carpogonium with clavate trichogyne (arrowhead) on an elongate, short-celled carpogonial branch. Fig. 20. Compact carposporophyte with terminal carposporangium (arrowhead). Figs 21-23. *Batrachospermum macrosporum*. Fig. 21. Obovoidal whorls containing prominently stalked carposporophytes (arrowheads). Fig. 22. Carpogonium with orbicular trichogyne (arrowhead) on an elongate carpogonial branch. Fig. 23. Compact carposporophyte with numerous carposporangia (arrowheads). Figs 24, 25. *Batrachospermum turfosum*. Fig. 24. Main axis with compact indistinct barrel-shaped whorls. Fig. 25. Carpogonium stalked (arrowhead) with elongate trichogyne. Fig. 26. Corticated filamentous thallus of *Compsopogon coeruleus*. Fig. 27. *Ptilothamnion richardsii* with zigzag axis by means of sympodial growth and pinnate lateral branching. Scale bars: 300μm in Figs 18, 21, 24, 26; 10μm in Figs 19, 20, 22, 25; 30μm in Fig. 23 and 20μm in Fig. 27.

for the species (Fig. 26). A rarely reported taxon, *Ptilothamnion richardsii*, was discovered as an epiphyte on aquatic macrophytes in two streams. The cells of the main axis of this taxon have a zigzag appearance due to sympodial growth and there are numerous pinnate lateral branches composed of cells that are slightly smaller than those of the main axis (Fig. 27).

In nine of the streams, bluish tufts attributable to the chantransia stage of *Batrachospermum* were collected. In stream 2, the chantransia stage of *B. ambiguum* was collected (unpublished molecular data), but macroscopic gametophytes were absent. *Batrachospermum macrosporum* chantransia was confirmed by molecular data (unpublished) to be present in six stream and most likely in two other streams as well. However, only in streams 8 and 15 were both chantransia

and gametophytes collected (Tab. 2). Therefore, *B. macrosporum* was the most cosmopolitan species with one of these life history stages being present in 12 of the 18 streams.

At numerous locations three to five taxa of freshwater reds were growing together (Tab. 2). For example, *Batrachospermum ambiguum, B. cayennense, B. macrosporum* chantransia, *B. nodiflorum* and *Ptilothamnion richardsii* were collected in an ~ 40 m length of stream 13. The rhodophytes were not only the most species rich, but also the most dominant in percent cover comprising more that 40% of the total algal cover in 15 of the 18 streams.

DISCUSSION

Thirty infrageneric macroalgal taxa identified from only eighteen stream segments sampled appears to be a high number of taxa for the number of streams in comparison to other studies in South America. Forty species from 52 stream segments were collected in the eastern Atlantic rainforest of Brazil, 48 taxa from 50 streams in northwest São Paulo State, Brazil and 32 taxa from 33 stream segments in Bolivia (Branco & Necchi, 1996a; Necchi *et al*., 1997; McClintic *et al*. 2003). This finding may indicate that this region is floristically richer, but the high number could also be a function of stream segment sample size. The number of species per stream segment was 4.2, which is high compared with other studies of streams in Bolivia (2.4: McClintic *et al*., 2003), southeastern Brazil (3.1, 2.6: Necchi *et al*. 1995; Branco & Necchi, 1996b); tropical North America (3.1: Sheath *et al*., 1992), North America in general (3.1: Sheath *et al*., 1992) and Hawaii (3.4, 3.9: Vis *et al*., 1994; Filkin *et al*., 2003). Therefore, not only does coastal French Guiana appear to have high species richness as a region, but this richness is reflected in the individual streams.

The Rhodophyta was the most species rich taxonomic group in this survey, which is similar to the findings of a survey in the eastern Atlantic rainforest, Brazil (Branco & Necchi, 1996a). However, this result appears to be unusual with surveys from other parts of South America noting the dominance of other taxonomic groups, Chlorophyta and Cyanobacteria, respectively (Necchi *et al*., 1997; McClintic *et al*., 2003) and other tropical areas (i.e. tropical North America: Sheath *et al*., 1992; Hawaiian Islands: Vis *et al*., 1994; Filkin *et al*., 2003). Branco & Necchi (1996a) suggested that light availability might have limited the Chlorophyta because they were not present in the shaded parts of the streams, but this probably was not a factor in the present study since half of the streams had <50% canopy cover. Likewise, they found that Rhodophyta were present in both the shaded and unshaded sites and suggested that both light quantity and quality may play a role in the dominance of the rhodophytes. In a study of 52 stream segments from the eastern Atlantic rainforest of Brazil, nine rhodophyte taxa were collected similar to the present study of 18 stream segments (Branco & Necchi, 1996a). It would appear that the present study is unusual with so many Rhodophyta taxa collected from so few streams and such a small geographic area. Four of the nine entities, *Batrachospermum ambiguum, B. macrosporum* gametophytes, *B. macrosporum* chantransia (as *Audouinella macrospora*) and *Compsopogon coeruleus* (as *C. leptoclados*), were common to both studies (Tab. 2, Branco & Necchi, 1996a). Of the Rhodophyta, *Batrachospermum* section *Contorta* was the most species rich, similar to other studies that have shown this section to be widespread in the tropics (Necchi, 1990; Sheath *et al*., 1992).

Although numerous species of *Batrachospermum*, *Compsopogon coeruleus* and *Ptilothamnion richardsii* were collected in this survey, other tropical freshwater red algal genera such as *Balliopsis* [newly erected genus by Saunders & Necchi (2002) for all freshwater *Ballia* species], *Bostrychia* and *Caloglossa* were not found. These three genera have been reported from tropical locations worldwide, including the tropical North and South America (Sheath *et al*., 1993 and references therein; Necchi & Zucchi, 1995). The streams in the present survey were relatively close (based on the scant location data) to those from which Montagne (1850) described species of these genera. Likewise, the streams for the present survey were collected during the same month (August) as material of *Balliopsis* (as *Ballia*) was obtained a short distance (~100 km) from many of the sampling sites (Couté & Sarthou, 1990). Therefore, it is uncertain why these taxa were not collected in the present study.

Many of the non-rhodophyte taxa identified to species have been previously reported from South America. Of the seven cyanobacterial species positively identified, six have been previously reported (e.g. Franceschini, 1990; Sant'anna & Azevedo, 1995; Silva & Sant'anna, 1996; McClintic *et al*., 2003). *Scytonema crassum* appears to be a new record for South America. The chlorophyte *Schizochlamys gelatinosa* has been collected in southeastern Brazil (Necchi *et al.*, 1997). It would appear that the tribophyte *Tribonema ulotriculosum* has not been previously reported. Both *Eunotia* species have been previously photo-documented from tropical areas of South America (Metzeltin & Lange-Bertalot, 1998).

Of the eight *Batrachospermum* species collected, five (*B. ambiguum, B. guyanense, B. nodiflorum, B. cayennense* and *B. macrosporum*) were first described from French Guiana by Montagne (1850). *Batrachospermum ambiguum*, *B. cayennense* and *B. macrosporum* appear to be cosmopolitan in tropical and subtropical areas. *Batrachospermum ambiguum* has been recorded from South America (Branco & Necchi, 1996a: southeastern Brazil), North America (Sheath *et al*., 1992: Belize, Costa Rica, Puerto Rico) and Australia (Entwisle & Foard, 1997). *Batrachospermum cayennense* has been collected in numerous streams in various parts of Brazil, South America (Necchi, 1990 & references therein), Malaysia, Asia (Kumano & Ratnasabapathy, 1982) and Australia (Entwisle & Foard, 1997), but no collections have been made in North America. *Batrachospermum macrosporum* has also been previously recorded from South America (Necchi, 1990: Brazil). It also occurs in North America, having been extensively collected in the coastal plains region of the US and in Belize (Sheath *et al.,* 1994a). Both *B. guyanense* and *B. nodiflorum* appear to be rare and possibly endemic taxa since each has only been reported from its type locality in French Guiana. From the descriptions of the type localities, "near Cayenne" and "near Tigres Mountains, Cayenne," it is difficult to ascertain the exact streams sampled by Leprieur. Our collections of these taxa (one of *B. guyanense* and two of *B. nodiflorum*) were from streams near Saint-Laurent du Maroni, which is a considerable distance from Cayenne (260 km) (Fig. 1). Therefore, we believe our collections were not from the type localities and represent new localities.

The remaining three *Batrachospermum* species, *B. gracillimum, B. intortum* and *B. turfosum* have not been previously reported from French Guiana. *Batrachospermum gracillimum* was first described from Angola in Africa and has since been reported from numerous streams in Brazil (Necchi, 1990). *Batrachospermum intortum* appears to be cosmopolitan, with the type locality in China (Jao, 1941), and having been collected in North America from New Mexico and the Caribbean islands of Cuba and Jamaica (Sheath *et al*., 1992). *Batrachospermum turfosum* appears to be the most widespread among the *Batra-*

chospermum species collected. This taxon (as *B. keratophytum*) is reported in North America from the tundra in the north to the coastal plains in the south (Sheath *et al*., 1994b), numerous locations throughout Europe, in Australia, in Brazil and Japan (Necchi, 1990 and references therein).

The two other rhodophyte taxa, *Compsopogon coeruleus* and *Ptilothamion richardsii* were collected in one or two streams in this survey. *Compsopogon coeruleus* is a cosmopolitan species reported from numerous locations in tropical and subtropical regions worldwide (e. g. D'Lacoste & Ganesan, 1987; Vis *et al*., 1992; Entwisle & Price, 1993; Necchi, *et al*. 1999; Rintoul *et al*., 1999; Kumano, 2002). In contrast to *C. coeruleus*, *Ptilothamnion richardsii* has only been reported from a handful of locales as follows: one from British Guiana and three from Queensland, Australia (Entwisle & Foard, 1999 and references therein). Like the other reports of this taxon, our specimens had no sexual reproduction structures, only monosporangia.

Macroscopic plants or specimens of the chantransia stage of *Batrachospermum macrosporum* were quite abundant, whereas that of *B. ambiguum* was present in only one stream. Interestingly, six of the eight streams with *B. macrosporum* chantransia and the one with *B. ambiguum* did not contain gametophytes of these taxa. There does not appear to be any difference in stream parameters measured for those streams in which there were gametophytes and those with chantransia stage for *B. macrosporum*. The chantransia stage of *B. ambiguum* was collected in a stream, which was smaller than the two with gametophytes but otherwise was comparable. Whether the chantransia stage produces gametophytes may depend on factors not measured in this study (e.g. irradiance, nutrient levels, type of grazers present, etc.).

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