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Benthic macroalgae of an unpolluted tropical river (Río Savegre, Costa Rica)

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Abstract: A survey of the benthic macroalgae and physical data was monthly performed in Río Savegre from its headwaters to its lowplain course. The macroalgae were observed with a viewing box at 20 cm intervals following a fixed rope across the stream and microscopical observations were made at laboratory. The species composition of benthic macroalgae found in Río Savegre is characteristic for unpolluted, clear, carbonate poor streams. From the source to the mouth a change from species adapted to cold, fast flowing streams to species adjusted to higher temperatures, lower current velocity and periodic desiccation was observed. There was a replacement of the multilayered, well structured macroalgal community in the upper part of the river by surface films formed by microalgae in the lower part. In addition a high-light community consisting of *Spirogyra* sp., *Nostoc verrucosum* and *Tetraspora* sp. could be distinguished from the dim-light species *Prasiola mexicana* and *Hildenbrandia* sp.

Key words: Tropical river, benthic macroalgae composition, phytobenthos, unpolluted, Río Savegre.

Benthic algae are the major primary producers in rivers and streams, offer protection against the current as well as food to aquatic insect larvae (Minshall *et al.* 1985). The benthic algae form a multilayered, well organised community (Blum 1957) on any type of substrate, be it rocks, soft sediments or macrophytes. This community frequently consists of microscopic as well as macroscopic discernible species and vegetation types, belonging to different taxonomic groups (Rott 1991). Diatoms are the most species-rich group among the microalgae. Among the macroalgae cyanophytes dominate in fast-flowing, unpolluted environments, while chlorophytes sensu stricto are more common in polluted, slow flowing rivers (Kann 1978).

Prior to applying monitoring methods to macroalgae in tropical rivers, information on variability of species composition, morphology and distribution in natural tropical ecosystems is necessary. The aim of this study was to obtain qualitative information on macroalgae species composition from both the upper and lower parts of Río Savegre river system.

MATERIALS AND METHODS

Study area: Río Savegre is located in the Pacific region of Costa Rica (Fig.1), in a zone of seasonal tropical climate, with a rainy and a dry season. The rain mostly falls from May to November. The dry season ranges from De-

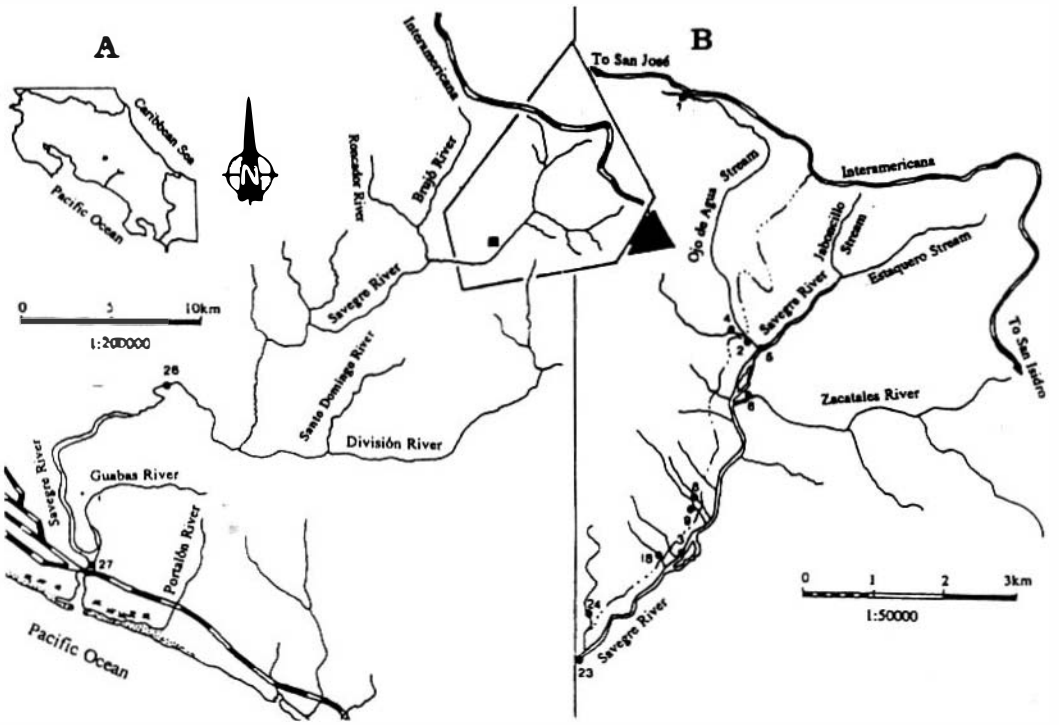

Fig. 1. Río Savegre basin and sampling sites. (A) Overview of the whole catchment and position of sites SA-26 and SA-27 in the lower part. (B) Detail of upper part of the catchment with location of sites SA-1, SA-2, SA-3, SA-4, SA-5, SA-6, SA-8, SA-9, SA-18, SA-23, SA-24.

cember to April. The river originates in the Cordillera de Talamanca at 3200 m of altitude, draining mainly marine sediments and igneous rock. Due to the negligible human presence in the basin, pollution is insignificant. Therefore low values of nutrients, especially nitrate, were found (Silva 1994). The rather high levels of phosphate and silicate can be explained by the weathering of the igneous bedrock, underlaying the upper marine sediments characteristic for the geology of this area (Weyl 1957). This river and its tributaries are very clear and slightly alkaline. In the uppermost part, Rio Savegre is a cool mountain stream, surrounded by dense forest and some pasture land. In the lowest section it is a warm river, mainly surrounded by crop and cattle farms. The chemical and physical features of the river are summarized in Table 1.

Sampling sites: Samples were collected monthly in the period from January 1991 to April 1992 from the main river and several tributaries in the upper part (altitude 2890 - 2300 m a.s.l.) and in the lower part (altitude 200-10 m a.s.l.) of Río Savegre (Fig.1).

The sampling sites were distributed along an altitudinal gradient between the Ojo de Agua headwaters and the mouth of Río Savegre. Two reaches at SA-1, SA-2, SA-3, SA-5, SA-6, SA-26 (Fig. 1), were selected to observe algal colonies. The observation of algal colonies was accomplished using a viewing box of a metal frame with a glass bottom of 20 x 20 cm square following a line transect method (Blum 1957). Each transect was 20 cm wide, and the algae were observed at 20 cm intervals following a fixed rope across the stream. Microscopical observations were made to identify the genus and species of the macroalgae found in each transect. The taxa were identified using Geitler (1932), Bourrelly (1972,

TABLE 1

Physical, hydrological and morphological features of the river sections sampled in the Rio Savegre basin

Site	Altitude (m.a.s.l.)	Air temp.(°C)	Water temp.(°C)	Channel width (m)	Discharge ($m^3 s^{-1}$)	Ann.Precip. (mm)	Susp. sed. ($mg l^{-1}$)	Turbidity (U.N.T.)	Conduct ($\mu S. cm^{-1}$)
Upper part Main River									
SA-5	2600	13.0-27.0 (10)	11.0-14.0 (10)	9.0-10.0	N.D.	N.D.	2-28 (10)	1-7	80-140
SA-3	2400	15.0-26.0 (16)	11.0-15.0 (16)	9.0-10.0	0.2-1.4	N.D.	0-101 (15)	1-13 (10)	82-135 (12)
SA-23	2300	16.0-25.0 (8)	11.0-16.0 (8)	10.0-12.0	N.D.	N.D.	0-83 (7)	1-10 (7)	98-131 (8)
Tributaries									
SA-1	2890	9.0-15.0 (15)	8.0-10.0 (15)	0.5-1.0	N.D.	2060	2-11 (13)	0.8-1.5 (13)	95-150 (9)
SA-2	2700	13.0-20.0 (16)	10.0-13.0 (16)	5.0-5.5	0.1-0.7	N.D.	0-47 (15)	1-8 (9)	64-120 (12)
SA-4	2700	11.0-24.0 (8)	10.0-14.0 (8)	1.0-1.5	N.D.	N.D.	1-58 (6)	1-5 (4)	58-112 (6)
SA-6	2500	12.0-24.0 (12)	9.0-12.0 (12)	9.0-10.0	0.1-1.4	N.D.	0-70 (10)	1-8 (9)	70-140 (10)
SA-8	2400	15.0-22.0 (11)	13.0-15.0 (11)	0.5-1.0	N.D.	N.D.	0-374 (13)	1-2 (7)	96-130 (10)
SA-9	2400	15.0-22.0 (11)	13.0-14.0 (11)	0.5-1.0	N.D.	N.D.	4-60 (10)	0-18 (10)	100-132 (10)
SA-18	2400	12.0-23.0 (12)	12.0-14.0 (12)	0.5-1.0	N.D.	N.D.	1-287 (10)	1-7 (8)	86-220 (11)
SA-24	2300	12.0-23.0 (5)	14.0-16.0 (5)	0.5-1.0	N.D.	N.D.	3-94 (5)	0-1.5 (3)	95-116 (3)
Lower part Main River									
SA-26	200	28.0-35.0 (5)	24.0-29.0 (5)	20-25	7-70	4470	9-92 (5)	2-25 (5)	84-143 (5)
SA-27	10	26.0-31.0 (5)	26.0-30.0 (5)	30-50	N.D.	N.D.	9-34 (4)	2-13 (4)	108-170 (5)

Numbers indicate absolute values or ranges, numbers in brackets indicate numbers of measurements.
N.D.= Not Determined, site abbreviations see text.

1985) and Kann (1978).

RESULTS

Stream algal communities: I shall refer to those species or vegetation types which could be identified visually at he field: (1) The cyanophyte *Nostoc verrucosum* characterised by brown-black, mucilaginous dense mats, up to 10 mm thick, consisting of ellipsoidic syncoenobia, associated with the green alga *Tetraspora* sp., a soft mucilaginous green mat; (2) *Spirogyra* sp. forming masses of long, intensively green filamentous strands of up to 10 cm length; (3) the chlorophyte *Prasiola mexicana* with its green, lettuce-like "leaves" forming close mats on the stones; (4) dark-films of algae including the green alga *Gongrosira* sp, and the bluegreen algae *Pleurocapsa* sp., *Phormidium autumnale*, and *Homoeothrix* sp.: this association is recorded as one form and called "encrusting dark algae"; and (5) *Hildenbrandia* sp., forming conspicuous, closely attached red covers. Table 2 shows the species composition of macroalgae for the upper and lower parts of the river.

The composition of algal communities changed with altitude. In the upper part of the river *Nostoc verrucosum* and *Tetraspora* sp. were common (up to 50%) in rapidly flowing water. Both species were often found to be covering the tops and upwardfacing surfaces of large stones and boulders in sunny places. *Tetraspora* was often overgrowing *Nostoc*,

TABLE 2

Species composition of frequent macroalgae and macrophytes for different sections of Río Savegre

River section	Río Savegre Upper part	Río Savegre Lower part
Pollution	None	None
Cyanophyceae		
Chamaesiphon polymorfus Geitler	X	
Chamaesiphon pseudapolymorfus F.E. Fritsch		X
Dichothrix orsiniana var. *africana* Frémy		X
Homoeothrix sp.	X	X
Hydrococcus sp.	X	X
Nostac verrucosum Vaucher	X	
Phormidium autumnate (Ag.) Ex Gom.	X	
Pleurocapsa sp.	X	X
Pseudanabaena sp.		X
Rivularia sp.		X
Siphononema sp.		X
Chlorophyceae		
Gongrosira sp.	X	X
Prasiola mexicana	X	
Spirogyra sp.		
Tetraspora sp.	X	
Rhodophyceae		
Hildenbrandia sp.	X	

especially young and small *Nostoc* colonies. *Tetraspora* sp. also was found in quiet waters near the banks, forming big floating mats.

Long filamentous threads of *Spirogyra* sp. were common (62%) at SA-3. This alga grew on the bottom of the riverbed and the filaments were spread downstream. *Prasiola mexicana*, was common at SA-2, SA-5 and at other reaches of the main stream and the tributaries, where shaded situations prevailed (approx. 80% shading by riparian vegetation). This species occurred near the base and on the sides of stable substrata under slow flowing conditions (0.1 $m^3 s^{-1}$).

Big stones bore patches of encrusting dark algae, which were widespread in places with strong current. In many cases these patches form a thin film, roughly circular with many rounded lobes covering large parts of completely submerged rock surfaces. This growth form was observed mainly in SA-1, SA-3, SA-5 and SA-6, rarely at SA-2. *Hildenbrandia* sp. was easy to recognise from its red colour and occurred attached to the sides of the rocks facing the current. This species was also observed on the sides of pebbles, likewise on the sides of a waterfall, a habitat which is reached only by spray. This was the case at SA-2 and SA-6.

At the sampling point located in the lower part of the Rio Savegre (SA-26), surface films of the green alga *Gongrosira* sp. and the blue-green algae *Chamaesiphon pseudopolymorphus, Dichothrix orsiniana* var. *africana, Homoeothrix* sp., *Hydrococcus* sp., *Pleurocapsa* sp., *Pseudanabaena* sp., *Rivularia* sp. and *Siphononema* sp. were recorded on stones and boulders in the shallow areas of the banks or on pool bottoms, but not in the central part of the river.

DISCUSSION

The macroalgae found in Río Savegre are typical benthic algae living on rocky substrata in running waters: most of them form covers or mats closely attached to the substratum and thus little exposed to the current. *Spirogyra*, a filamentous form, was found in water depths higher than 20 cm and slow-flowing to stagnant areas. *Prasiola* was the only one to colonize the very shallow areas (5-10 cm depth), which may fall dry during periods of low water level.

There were differences in species composition between the upper and the lower part of Rio Savegre, with replacement of the multilayered, well structured macroalgal community in the upper part by benthic films formed by microalgae in the lower part, which can also be observed in temperate river systems (Rott and Pfister 1988). A shift in species composition from the source to the mouth of a river system has been described by several authors (Wehr 1981, Ward 1986, Sabater and Sabater 1992). The difference in species composition in Río Savegre can be correlated with increased temperatures and discharge with increasing distance from the source although differences in turbidity and conductivity along Rio Savegre were not pronounced (Table 1). Many representatives of the genera found in the upper section of Río Savegre are known to prefer temperatures below 15°C for vegetative growth (Blum 1957, Minckley 1963, Prescott 1975). Representatives of the genera found in the lower part of Río Savegre were also found in temperate lowland streams during summer, when temperatures exceded 20°C (Kann 1978).

Among the few taxa identifiable to species

level in this study, none as reported is restricted to the tropics, but all of them have been reported for other tropical countries as well (Komárek 1989, Geitler 1932, 1935, 1936). Though it is difficult to give information on geographic distribution and ecological preferences of taxa above the genus level, the following autecological information on the species and genera from the literature is compared to our findings:

Chamaesiphon polymorphus and *Chamaesiphon pseudopolymorphus:* The family Chamaesiphonaceae is widely distributed in temperate areas, but only a few species have been reported from the tropics (Komárek 1989).

Chamaesiphon polymorphus is reported by Geitler and Ruttner (1936) from calcareous cold streams from the Sunda Islands, Indonesia. Both species were found in the upper and lower part of the Rio Savegre respectively. The former was commonly found in low nutrient, cold waters; while the later species was observed in low nutrient high temperature water.

Dichothrix orsiniana, found in the lower part of Río Savegre sharing the same substrate with *Pleurocapsa* sp., *Pseudanabaena* sp, *Rivularia* sp, *Siphononema* sp. is assumed to be a cosmopolitan species. The variety *africana* was first found by Frémy on humid rocks in Africa (Geitler 1932).

Nostoc verrucosum, is cosmopolite, too. It has been reported by Geitler (Geitler and Ruttner 1935/36) from tropical streams in the Sunda Islands. It is common in fast flowing mountain streams (Geitler 1932). In the upper part of Rio Savegre it was one of the first recolonizers after the end of the maximum discharge period. The specimens found showed many heterocytes, an indication of high N_2 fixing rates, which may be a competitive advantage in an oligotrophic system as Río Savegre. A reason for its preference of sunny reaches could be the high light requirements for N_2 fixation (Fogg 1974).

Oscillatoria species have been observed to be dominant at the bottom of periodical pools in Cuba (Komárek 1989). *Oscillatoria* and *Plectonema* species have been found abundantly in moderately polluted waters in Indonesia (Wargasasmita 1990), and also in nutrient enriched temperate streams and rivers (Kann 1978, Pipp and Rott 1993). Representatives of the genus *Pleurocapsa* were also found in warm rivers in Sumatra (Geitler and Ruttner 1935/36).

Phormidium autumnale, a species more frequently reported from temperate areas (Kann 1978, Round 1981) than from the tropics, was observed in the upper part of the Río Savegre together with *Homoeothrix* sp., *Hydrococcus* sp., *Pleurocapsa* sp. and the green alga *Gongrosira* sp. It was found as well, but in lower quantities in a warm, polluted river in Costa Rica (Río Tárcoles), (Silva 1994).

Prasiola mexicana was the most desiccation tolerant species from Río Savegre, growing on hygropetric sites (Smith 1950, Chapman and Chapman 1981) as well as in cold mountain streams (Smith 1950, Bourrelly 1972), especially in shaded areas. In Río Savegre it occurred at the water line of stones, which were not totally covered with water, and it was present almost throughout the year (except in the driest months).

Spirogyra sp. is the only abundant species in lentic areas and in soft sediment areas of the upper part of Savegre. The habitat preferences observed here, coincide with observations made in other regions, where it is reported to be one of the commonest green algae in stagnant waters and in lentic reaches of running waters (Blum 1957, Minckley 1963, Chapman and Chapman 1981). As other zygnematalean algae, *Spirogyra* species require high light intensities, especially for reproduction (Kadlubowska 1984). This genus is also known from the tropics, from Ceylon and the Sunda Islands (Fritsch 1907, Skuja 1938), where it lives in the same habitat as mentioned before.

Tetraspora sp. is a cosmopolite genus found in cold running waters (Bourrelly 1972). Early stages are attached to the substrate and later it becomes free-floating (Chapman and Chapman 1981), as observed in this study. The most remarkable feature about the species found in Río Savegre is its association with *Nostoc verrucosum* which to our knowledge has not been described in the literature. In an oligotrophic environment the advantage for the green alga could be the supply of additional nitrogen from the excretions of the nitrogen-fixing blue green partner. Young *Nostoc* colonies, which are totally covered by the *Tetraspora* filaments might be

protected against current, light or predators.

The present study detected a difference of macroalgae species in the upper and lower parts of an unpolluted, tropical river. It offers information about species composition of macroalgae, which changes from the cold water upper part to the relatively warm water the lowerst section of the river. Species composition in Río Savegre was rather similar to macroalgal communities known from temperate streams of similar stream order and geology.

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RESUMEN

Durante un período de un año se estudió la composición de macroalgas en el Rio Savegre, Costa Rica a lo largo de un gradiente longitudinal desde el nacimiento del río (3200 m.s.n.m.) hasta su desembocadura (10 m.s.n.m). La composición de especies de macroalgas en el Rio Savegre corresponden a una comunidad característica de agua no contaminada y ríos pobres de carbonato; así como especies adaptadas a bajas temperaturas en la parte superior del rio y especies adaptadas a altas temperaturas en la sección inferior del rio.

Las especies comunes en la parte superior del rio corresponden a *Nostoc verrucosum*, *Tetraspora* sp., *Spirogyra* sp. y *Prasiola mexicana*. En la parte baja del Río Savegre dominan *Gongrosira* sp., *Chamaesiphon pseudopolymorhus*, *Dichothrix orsiniana* var. africana, *Homoeothrix* sp., *Pleurocapsa* sp., *Pseudanabaena* sp., *Rivularia* sp. y *Siphononema* sp.

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