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ROBERT ARFI, MARC BOUVY[1] and PIERRE LUQUET[2]

Centre de Recherches Océanologiques, ORSTOM BP V18, Abidjan, Côte d'Ivoire
[1]Centre ORSTOM, 911 av. Agropolis, 34032 Montpellier, France
[2]Institut National de Recherche Agronomique, Station d'Hydrobiologie, BP 3, 64310 Saint Pée sur Nivelle, France

Effects of a Seasonal Salinity Change on Periphyton Biomass in a Shallow Tropical Lagoon

key words: acadja, bamboo, periphyton, Ebrié Lagoon, Côte d'Ivoire, tropical area.

Abstract

In the Ebrié Lagoon (Côte d'Ivoire), growth of periphyton on bamboo stuck in the sediment is at the basis of the acadja, a low-cost system developed in order to enhance aquaculture of omnivorous fish like the tilapia *Sarotherodon melanotheron*. A survey based on hydrological, bacterial and algal data (including phytoplankton and periphyton) was conducted from November 1992 to June 1993 in an experimental structure. Climatic and hydrological seasonality was marked during the study. Succeeding to a rainy season, the oligohaline situation starting in November was characterized by low bacterial and chlorophyll biomass attached to the bamboo (respectively 1 and 18 mg m^{-2}). The mesohaline situation observed from January featured a sharp increase in periphyton biomass, with a maximum in April (16 and 177 mg m^{-2} for bacterial and algal biomass, respectively). The flood of the Agnéby river, induced in June by the local rains, originated again oligohaline conditions. The biomass decrease observed in May and June resulted from a shift towards low salinity (from 9.8 to 1.8 psu), a decrease in light availability (combined effects of a decreasing solar radiation during the rainy season and an increase of water turbidity due to the flood) and a lower phytoplankton biomass (therefore limiting the secondary epiphytism potentialities). In this shallow tropical environment characterized by high nutrient concentrations (due to local hydrology and organic nature of the substrate), the combination of seasonal variations of climatic (light availability), hydrological (salinity) and biological (abundance or lack of epiphytic algae) seems to control the periphyton biomass growing on bamboo. Therefore, marked seasonality in the production of resource available for the target fish would limit the interest of the acadja as an aquaculture system in brackish ecosystems.

1. Introduction

Artifical habitats are widely used in shallow water bodies in order to enhance aquatic productivity, and in particular the fish biomass. Such structures are supposed to meet feeding, behavioural and protection requirements for various fish species. In Western Africa lagoons, brush or palms artificially installed in shallow water create a particular biotope called «acadja» which is widely used as a fishery tool (WELCOMME, 1972; WELCOMME and KAPETSKY, 1981, HEM *et al.*, 1990; SOLARIN and UDOLISA, 1993). In Côte d'Ivoire, this structure was proposed as a low-cost aquaculture system in the Ebrié lagoon as well as in inland ponds and adapted by using bamboo vertically stuck in the sediment (HEM and AVIT, 1994). The high fish production observed in these structures (AVIT *et al.*, 1995) is attributed to the organic material accumulated in the periphytic communities growing on the supports. This material (bacteria, fixed and periphytic algae, fungi, protozoa, micro- and macrometazoa), usually referred to as periphyton, is recognised as a major trophic component in such shallow aquatic areas (WETZEL, 1983; HAINES *et al.*, 1987). This fixed resource is easily available for various consumers, like planktonic or benthic invertebrates (LAMBERTI and MOORE, 1984) and fishes (POWER *et al.,* 1985). Most of the West Africa lagoons have high primary production but produce relatively low fish biomass (KAPETSKY, 1984). Therefore, the potential increase of the resource made available to the top consumers through the periphyton was considered as a way to improve productivity. Low variation of light and temperature is supposed to cause low seasonal variability and to provide high periphytic yield throughout the year in favourable conditions (high temperature, waters with high nutrient concentrations). Research on feeding on periphyton by local tilapia *Sarotherodon melanotheron* (LEGENDRE *et al.,* 1989) was the basis of an aquaculture study developed at the Layo experimental station (Ebrié Lagoon, Côte d'Ivoire). Previous works conducted at Layo have described the specific composition and the productivity of periphytic microflora (GUIRAL *et al.,* 1993; KONAN-BROU, 1994; KONAN-BROU and GUIRAL, 1994; ARFI and BOUVY, 1996) and meiobenthos (GUIRAL *et al.,* 1996) growing on bamboo installed in an experimental acadja.

The use of this habitat-system as an aquaculture tool and its wide generalisation to comparable ecosystems in other countries implies to assess the resource that the system would be able to produce. Periphyton can develop large biomass when environmental conditions are favourable for the settlement and the growth of various organisms. Variations in the periphytic biomass may be caused by several factors including substratum composition, light, temperature, nutrient supply and grazing (BOTHWELL, 1988; HANSSON, 1992). In the tropical zone, daylength is relatively constant throughout the year and the temperature variation is very attenuated (LEWIS, 1987). Therefore, in tropical brackish waters, salinity is often considered as an overriding factor. In particular, the threshold between oligohaline and mesohaline conditions (5–7 psu) which represents the lower limit for estuarine species and the upper limit for freshwater species is linked to major physiological changes for estuarine organisms (REMANE and SCHLIEPER, 1971). Other variation in abiotic factors, like cloudiness, precipitation and water turbidity could induce other regulating effects. In most of the brackish environments along the West Africa coast (like the numerous lagoons connected permanently or seasonally to the Atlantic Ocean), the seasonal alternation between wet and dry seasons induces marked changes in water salinity. These changes are at the basis of strong ecological consequences, and their effects have been studied in the pelagic system of the Ebrié lagoon (GUIRAL, 1992).

But seasonality of the periphyton in the acadja system so far has not been analyzed, and little is known on the external factors controlling the periphytic biomass (KONAN-BROU, 1993) or on the relative importance of bacteria and algae. However, the sustainability of such an aquaculture system is linked to the biomass it can produce and/or support. A marked seasonality in the resource production would limit the interest of the acadja in aquaculture in tropical lagoons. Therefore, the aim of the present study conducted on a monthly basis for 8 months was to determine the main factors (light, temperature, salinity, turbidity, nutrients) influencing the bacterial and algal periphytic biomass in an experimental structure using data collected simultaneously on bamboo and in the surrounding lagoon water.

2. Material and Methods

The experimental station of Layo is situated in the Western part of Ebrié lagoon, close to the Agnéby River mouth (for more details, see KONAN-BROU and GUIRAL, 1994). Water temperature varies from around 25 °C (July and November, at the end of the two rainy seasons) to around 34 °C during the two dry seasons, with limited daily variations (2 to 4 °C). Low salinity (1–2 psu) is usually observed during rain and flood periods. The Vridi Canal (the only connection to the Atlantic Ocean, located 40 km East of Layo) allows the entrance of marine water, which, together with high evaporation, results in salinity as high as 10–12 psu during the dry season. In the study area, the water level is not fluctuating during the seasons, because Layo is located in a particular site of the Ebrié lagoon, where the tidal effect is deeply attenuated. Throughout the year, the tide variation is comprised between 5 and 10 cm in the Layo area, whereas this variation is close to 100 cm at the entrance of the Vridi Canal, and close to 40–50 cm at the western end of the lagoon. Throughout the year, and particularly during the flood of the Agnéby River, Layo is a very turbid environment with relatively high nutrient concentrations (range for ammonia: 2 to 50 $\mu mol\ l^{-1}$; nitrate: 1 to 30 $\mu mol\ l^{-1}$; reactive phosphorus: 0.5 to 10 $\mu mol\ l^{-1}$). From November 1992 to June 1993, an experimental acadja situated 300 m off the northern shore of the lagoon (average depth 1 m) was sampled monthly. The acadja consisted of bamboo sticks (average length and diameter: 150 and 6 cm respectively) vertically stuck into the bottom and regularly spaced (4 to 5 sticks per m^2) in a site (50 m × 25 m) surrounded by a net. All sticks in the acadja had been placed in February 1991.

Data corresponding to the Agnéby flow (average daily measurements cumulated monthly) were obtained from the Côte d'Ivoire Water Authority. The monthly solar irradiation (thermopile Kipp-Zonen and Lintronic integrator) and rainfall amount were collected by the ORSTOM Hydrological Laboratory, located 20 km East of Layo. Light values recorded in kJ were transformed in Photosynthetically Active Radiation (PAR) using the relation $1\ kJ\ m^{-2}\ s^{-1} = 4.6\ mmol\ m^{-2}\ s^{-1}$ and expressed per month. PAR available just under the airwater interface was estimated to 38% of the global irradiance (MOREL, 1978; COTE and PLATT, 1983).

Water samples in the acadja were collected 10 cm under the surface on several occasions (2 to 8 samples per month, comprising the days of periphyton sampling). Conductivity was measured using a Tacussel conductimeter. This parameter is more accurate than salinity for oligohaline water, but in order to allow easy comparison with values classically observed in brackish water and estuaries, conductivity was expressed as salinity using the relation proposed by APHA (1985). Turbidity (expressed in NTU, Nephelometric Turbidity Unit) was measured using a HE 9 turbidimeter. Light attenuation coefficients were calculated from turbidity values using a relation calculated for data we have obtained in the Layo area ($k = 0.054^* \text{ Turb} + 1.509$ $n = 19$, $r = 0.86^{**}$). From this relation and from the monthly PAR, the amount of PAR reaching the depth of the middle of the upper level (15 cm), of the intermediate level (45 cm) and of the bottom level (80 cm) was estimated. Dissolved nutrient concentrations (ammonia and orthophosphates) were measured using a Technicon Auto Analyzer II according to the procedure described by STRICKLAND and PARSONS (1972). Seston weigths were estimated after filtration on Whatman GF/F membranes and drying at 105 °C for 48 h. Chlorophyll retained on GF/F filters was measured on a Turner Designs fluorometer after methanol extraction. Pelagic bacteria were enumerated and their volume calculated from direct observations using an epifluorescence microscopy procedure (PORTER and FEIG, 1980), photographic slides and a digitising device. Cell volumes were converted to biomass using a conversion factor of 0.20 $pgC\ \mu m^{-3}$ (SIMON and AZAM, 1989). From previous studies conducted in the Layo site on wind induced resuspension (BOUVY *et al.*, 1994; ARFI and BOUVY, 1995), periodic resuspension of seston on diel basis allows to assume an homogeneous distribution of bacteria and phytoplankton in the water column. Therefore, values were expressed in $mg\ m^{-2}$, after integration over the 1 m deep water column.

Each month, 15 bamboo stakes chosen at random were removed from the site and their entire immersed surface was scraped with a scalpel. The material corresponding to the upper level (0–35 cm), the intermediate level (35–70 cm) and the bottom level (70–105 cm) was conserved separately. The periphyton collected from these 3 levels was immediately subsampled after thorough mixing. Mineral and organic weights were estimated after combustion of the dried material (550 °C, 4 hours). Particulate Organic Carbon (POC) concentrations were obtained from carbonate-free (HCl fume) subsamples on a LECO CHN analyser. Fixed algae pigment concentrations were estimated as above, and algal biomass were expressed as chlorophyll because no C : N ratio was estimated for the study. Biomass of epiphytic bacteria was estimated from material scraped off a known surface diluted in 0.22 µm filtered lagoon water. Samples were sonicated (30 W during 30 s) in order to disperse the attached cells. Bacterial densities and biomass were estimated as described above.

According to the hydrological conditions, the study was divided in two periods, one oligohaline (November to January and June, with salinity <5 psu) and one mesohaline (February to May, with salinity >5 psu). Climatic, hydrological and biological data were grouped according to these two situations, and the means were compared using t-tests. For a few data sets, the normality test failed, and the comparison was performed using a Mann-Whitney non-parametric test. Comparisons between levels (upper, intermediate and lower) were conducted for all parameters using a one-way (non-parametric Kruskall-Wallis ANOVA).

3. Results

3.1. Environmental Factors and Hydrology

At the beginning of the survey, high PAR were observed, with a monthly value of 903 mol · m^{-2} in November (Fig. 1a). December was characterised by lower values corresponding to dust during the Harmattan period (794 mol · m^{-2}). After this event, the mean irradiance increased regularly until the end of the dry season (in April: 963 mol · m^{-2}). More cloudy weather was observed in May, and radiation values decreased sharply to a monthly value of 618 mol · m^{-2} in June. Water turbidity fluctuated between 10 and 12 NTU in November and December, then the values decreased in January and February (6–7 NTU). A marked rise was observed during the rainy season and the highest turbidity (22 NTU) was noted during the flood of the Agnéby River. Reflecting global radiation, cloudiness and water turbidity, the light attenuation coefficients remained fairly constant from November to April, whereas the available PAR underwater decreased slightly in May, and markedly in June (Fig. 1a). For each sampling level, PAR in June represented respectively 65%, 54% and 44% of the average PAR recorded during the dry season.

Following a «short» rainy season (September–October), the dry season began in November and ended in June, when high rainfalls were noted (515 mm). The Agnéby flow (Fig. 1b) is directly linked to the rainfall, with low discharges observed during the dry sequence and floods occurring during the rainy periods (flow > 15 m^3 s^{-1}). During the survey, salinity was >6.5 psu from February to April (sequence characterised by mesohaline conditions), while

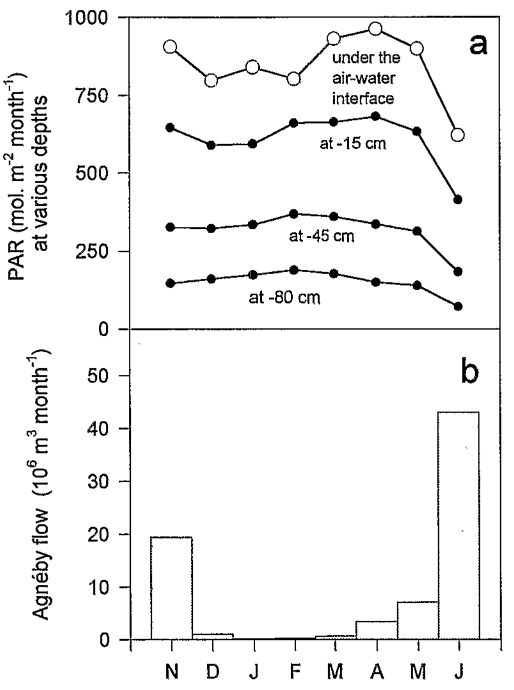

Figure 1. Monthly Photosynthetically Active Radiation values measured at Layo (Western Ebrié Lagoon, Côte d'Ivoire) under the air-water interface and calculated at 15, 45 and 80 cm under the surface (a) and monthly Agnéby flow from November 1992 to June 1993 (b).

the sequences following a rainy season (November and December) or those characterized by high precipitation and flow values (June) featured salinity <5 psu. January showed a progressive shift from an oligohaline to a mesohaline situation, while the regular rainfall observed from May induced a sudden shift from a mesohaline to an oligohaline situation (Fig. 2a).

Water temperature and pH were recorded at the same location for another study (ADINGRA, pers. comm.). Temperature values fluctuated within a limited range during the dry season (average range 30–32 °C), excepted in January (values close to 27 °C during the Harmattan event). The rainy season was characterized by a marked temperature decrease (around 33 °C in May, 30 °C in June) related to the increasing cloudiness and the Agnéby flow, inducing a sudden input of freshwater in the area. Values of pH fluctuated between 6.7 and 7.3, without marked trend. Orthophosphate and ammonia were characterized by the

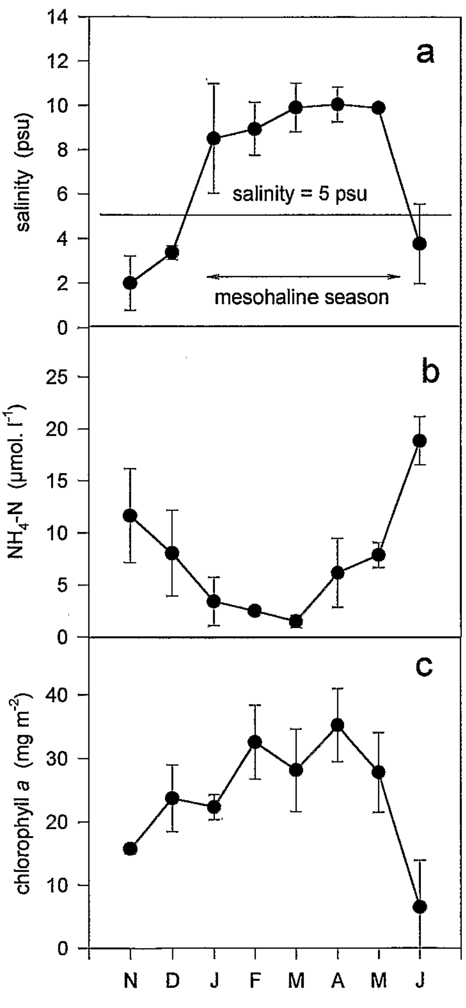

Figure 2. Monthly average values and standard deviation (error bars) for salinity (a), NH_4–N concentrations (b) and chlorophyll biomass in water (c) at Layo from November 1992 to June 1993.

Table 1. Seasonal averages and standard-deviation (within parenthesis) of environmental, seston and periphyton parameters for an experimental acadja system in the Ebrié Lagoon at Layo. Results are given for the oligohaline and mesohaline periods with the result of the t-test comparing the two periods (NS: non significant; $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$).

	oligohaline period (Nov–Dec–Jan–Jun)	n	mesohaline period (Feb–Mar–Apr–May)	n	differ-erence
environmental factors					
PAR (mol m^{-2} $month^{-1}$)	777 (120)	4	894 (45)	4	NS
salinity (psu)	3.16 (1.13)	14	9.69 (1.12)	23	***
turbidity (NTU)	16.2 (5.9)	8	10.8 (3.4)	19	*
PO_4–P (µmol l^{-1})	1.49 (0.66)	8	0.75 (0.18)	19	***
NH_4–N (µmol l^{-1})	11.99 (5.46)	8	5.65 (4.45)	19	***
plankton chlorophyll (mg m^{-2})	17.3 (8.5)	8	30.1 (7.1)	19	***
periphytic constituents					
dry weight (g m^{-2})	13.3 (4.7)	4	38.2 (12.5)	4	**
organic material (g m^{-2})	9.9 (2.9)	4	24.5 (7.7)	4	**
mineral material (g m^{-2})	3.4 (1.7)	4	13.7 (5.1)	4	**
chlorophyll (mg m^{-2})	30.3 (7.9)	4	105.3 (51.0)	4	*
bacteria (mg C m^{-2})	3.16 (1.13)	4	10.19 (4.32)	4	**
POC (g m^{-2})	4.51 (1.56)	4	11.27 (2.83)	4	**

same seasonal pattern with high concentrations during the oligohaline periods, and low values during the mesohaline sequence (see Fig. 2b for the ammonia pattern). The chlorophyll biomass increased from the beginning of the study to a maximum observed in April (35.2 mg m^{-2}). Then a sharp decrease was observed, with a very low value (6.4 mg m^{-2}) in June (Fig. 2c). No clear variation of biomass was noted for the pelagic bacterial communities (range between 49 and 88 mg C m^{-2}).

Seasonal variation in the main environmental factors is obvious, and with the data grouped by season (according to the threshold salinity of 5 psu), significant differences were observed between the oligohaline and the mesohaline seasons (Table 1). The oligohaline situation was characterized by higher turbidity and higher nutrient concentrations than the mesohaline situation, whilst phytoplanktonic chlorophyll concentration was lower during the oligohaline season.

3.2. Periphyton Biomass

The vertical stratification of the periphytic material was evident over the whole study (Table 2). The upper level was always the richest, while the bottom level was always the poorest. But the differences between the 3 layers were mainly significant for the algal material which was light-dependent. Also, a marked seasonal variation was observed, with low values noted during the oligohaline situation and high values occurring during the mesohaline situation (Fig. 3). The highest dry weights of periphytic material were observed in April at the 3 sampling levels (respectively 4.7, 4.0 and 3.7 mg cm^{-2}). POC amounts culminated also in April (respectively 1.8, 1.7 and 1.2 mg cm^{-2}). Average organic weights for the upper level were higher than those observed at the two other levels. The highest bacterial biomasses were always observed in the upper and intermediate levels (respective average over the study: 0.79 and 0.63 µg C cm^{-2}, Table 1), while the bottom level of the bamboo was

Table 2. Average and standard deviation (within parenthesis) for the studied parameters calculated for the upper (0–35 cm), intermediate (35–70 cm) and bottom (70–100 cm) levels. Results of the non-parametric ANOVA between levels are given by significance degrees (NS: non significant; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$).

whole study (n = 8)	upper level	intermediate level	bottom level	p
periphytic weight (mg cm^{-2})	2.55 (1.50)	2.12 (1.22)	1.69 (1.18)	NS
organic weight (mg cm^{-2})	1.80 (0.97)	1.45 (0.77)	1.03 (0.60)	*
mineral weight (mg cm^{-2})	0.75 (0.58)	0.67 (0.47)	0.66 (0.61)	NS
bacteria (μg C cm^{-2})	0.79 (0.77)	0.63 (0.71)	0.25 (0.29)	NS
pigments (μg cm^{-2})	12.11 (7.51)	6.72 (7.53)	2.03 (2.30)	**
POC (mg cm^{-2})	1.13 (0.40)	0.80 (0.47)	0.50 (0.43)	NS
oligohaline situation (n = 4)	**upper level**	**intermediate level**	**bottom level**	**p**
periphytic weight (mg cm^{-2})	1.44 (0.92)	1.05 (0.33)	0.98 (0.58)	NS
organic weight (mg cm^{-2})	1.11 (0.71)	0.79 (0.21)	0.72 (0.40)	NS
mineral weight (mg cm^{-2})	0.33 (0.21)	0.26 (0.12)	0.26 (0.21)	NS
bacteria (μg C cm^{-2})	0.14 (0.05)	0.09 (0.02)	0.03 (0.03)	***
pigments (μg cm^{-2})	7.50 (1.71)	2.05 (1.09)	0.41 (0.43)	***
POC (mg cm^{-2})	0.84 (0.19)	0.44 (0.19)	0.17 (0.19)	**
mesohaline situation (n = 4)	**upper level**	**intermediate level**	**bottom level**	**p**
periphytic weight (mg cm^{-2})	3.67 (1.04)	3.21 (0.51)	2.39 (1.27)	NS
organic weight (mg cm^{-2})	2.49 (0.64)	2.12 (0.41)	1.32 (0.66)	NS
mineral weight (mg cm^{-2})	1.17 (0.47)	1.09 (0.18)	1.06 (0.62)	NS
bacteria (μg C cm^{-2})	1.44 (0.51)	1.16 (0.65)	0.46 (0.27)	NS
pigments (μg cm^{-2})	16.72 (8.49)	11.39 (8.53)	3.64 (2.28)	**
POC (mg cm^{-2})	1.43 (0.33)	1.16 (0.36)	0.82 (0.35)	NS

characterized by low values (mean biomass: 0.25 μg C cm^{-2}). During the whole study, the highest chlorophyll values were always observed in the upper level (Table 2), while the bottom level featured low biomasses, with minimum values observed at the beginning of the study.

Integrated over the whole bamboo surface, the total dry weight of attached material in the acadja was characterized by a marked cycle (Fig. 4a), from a low value observed in November (2.2 g m^{-2}) to a maximum noted in April (39.8 g m^{-2}). After this peak, the weight decreased rapidly (15.1 g m^{-2} in June). Periphytic POC concentrations varied from a low value of 2.4 g m^{-2} (November) to a maximum of 15.6 g m^{-2} again observed in April. The percentage of organic matter decreased from 82% in November to a minimum of 59% in April, and then increased until the end of the study (74% in June). Attached bacterial biomass showed a marked pattern, with low values observed from November (0.51 mg C m^{-2}) to January and high values noted from March to May (maximum in April: 16.1 mg C m^{-2}, Fig. 4b). This attached biomass represented at the least 1/100 (November) and at the most 1/4 (April) of the pelagic bacterial biomass integrated over the 1 m deep water column. Bacterial cellular volumes were similar at the three levels from November to January, with a cell average volume of 0.107 μm^3 (range: 0.071 to 0.130 μm^3). The bacterial biovolumes increased at the three levels between February and May, with high values close to 0.190 μm^3. The same trend was observed for periphytic chlorophyll, with a marked increase from November and a maximum in April (177 mg m^{-2}, Fig. 4c).

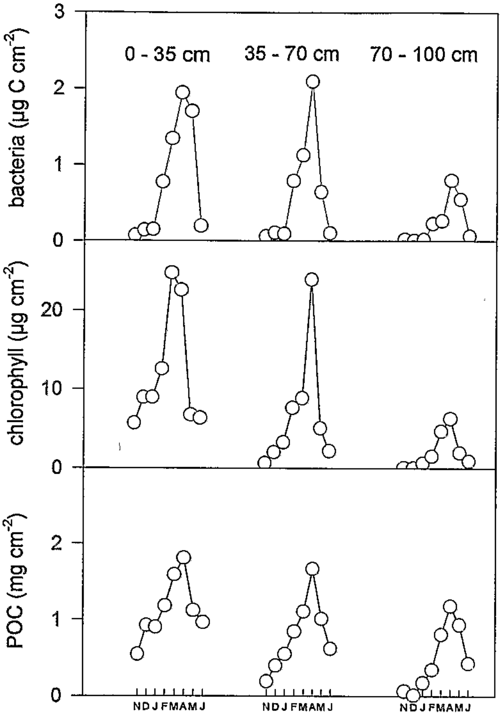

Figure 3. Monthly variation of bacterial biomass, algal biomass and POC on bamboo at three depths.

Temporal variation in all these parameters was closely correlated, and correlation coefficients were highly significant (Table 3). A stepwise regression was performed with the periphytic dry weight as dependent variable and the environmental factors as independent variables. The model retained by the analysis was a combination of Agnéby flow, PAR and phytoplankton chlorophyll, in degressive order. With these 3 parameters, the model extracted 95% of the information ($r^2 = 0.953$).

4. Discussion and Conclusions

All periphytic biomass parameters appeared closely correlated. The seasonal variation in periphytic biomass was mainly explained by Agnéby flow, PAR and phytoplanktonic chlorophyll, with freshwater flow as principal factor. The event induces a sudden decrease in salinity, but is also directly linked to rainfall (and therefore cloudiness and turbidity increase) and to PAR limitation. Whilst solar irradiance have increased regularly during the mesohaline period (corresponding to the dry season), the sky was heavily overcast in May and June. Therefore, the global irradiation was considerably reduced, with average values 30 to 40% lower than those observed in the Ebrié lagoon area during a dry season (DURAND and GUIRAL, 1994). The regular increase of the average water turbidity from January (5 NTU) to April (15 NTU) was partly linked to the development of the phytoplanktonic biomass, the chlorophyll concentration increasing from 22.3 mg m^{-2} to 35.2 mg m^{-2} during

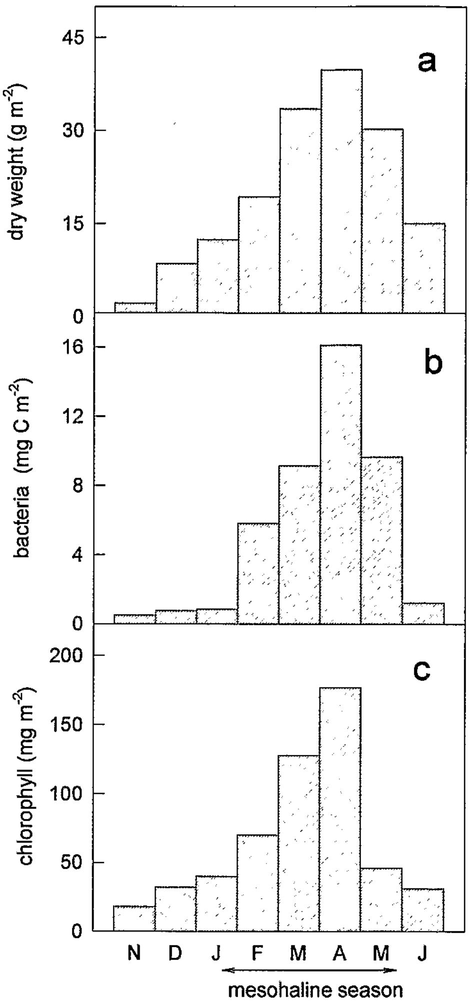

Figure 4. Monthly average values for periphytic material on bamboo: total dry weight (a), bacterial biomass (b) and algal chlorophyll (c) from November, 1992 to June, 1993.

this sequence. The turbidity values observed in May (15.3 NTU) and June (22.4 NTU) are directly related to the Agnéby River flood, corresponding respectively to a four fold (May) and a twenty fold increase (June) in the average flow of the preceding days (average flow during the dry season, January–April: 0.4 $m^3 s^{-1}$, during the rainy season, May–July: 11.5 $m^3 s^{-1}$). The combination of decreasing solar radiation (seasonal cloudiness effect) and of increasing water turbidity (seasonal flow effect) induced a drastic decrease of the light available for the attached algae.

The drastic volume change observed in the attached bacteria parallel with changes in planktonic algae (Table 3) suggests a close coupling between these two communities, as postulated for periphyton by WETZEL (1993), extrapolating from pelagic limnology (BIRD and KALFF, 1984). Whereas bacteria represented always a very low biomass,

Table 3. Correlation matrix for the periphyton constituents giving coefficient (r) in the lower left and significance levels in the upper right corner (NS: non significant; *p < 0.05; **p < 0.01; ***p < 0.001).

	periphytic weight	POC	organic weight	mineral weight	bacteria	pigments
periphytic weight	1	***	***	***	***	**
POC	0.99	1	***	***	***	*
organic weight	0.99	0.99	1	***	***	**
mineral weight	0.99	0.97	0.97	1	***	*
bacteria	0.97	0.96	0.98	0.95	1	*
pigments	0.92	0.90	0.92	0.90	0.89	1

compared to the other biological components of the periphyton, photosynthetic exudates issued from periphytes (both algal and animal) were directly available as dissolved nutrients for bacterial cells, making the characteristics of fixed bacterial communities dependent on the presence and the activity of periphyton. Since algal pigments explain a significant proportion of periphytic biomass variation, the natural algal immigration of algae able to shift between a planktonic to an attached status may also participate to the variations of the periphytic biomass. In favourable hydrological conditions, the algal biomass increased regularly. But once the available PAR in the water column decreased markedly, light requirements of periphyton were no longer met. Thus, algal growth and survival would not be favoured, inducing detrimental effects, detachment or death of organisms (in particular, of adnate periphytes living at the base of the mat, as reported by MEULEMANS and ROOS, 1984).

Other environmental parameters seemed of less significant importance in this tropical and eutrophic system:

– the drop in temperature observed in June, coming after a long period of relatively constant and high values probably have had a limited ecological effect, since these variations were not severe enough to induce large detrimental effect on the periphytic communities. But we can assume that temperature can participate to the global change from the dry season conditions to the rainy season conditions, whereas these parameters can explain the seasonal variations of biomass in temperate locations (BOTHWELL, 1988).

– annual salinity changes in the Layo area are limited in range, but values fluctuate around the physiological turning point of 5–7 psu (GUIRAL, 1992). The biological material sampled on November and December reflected oligohaline conditions. From January and during the dry season, marine water entering the lagoon have induced a progressive increase of salinity in the Ebrié ecosystem, and the marked increase of the attached biomass coincided with the installation of this mesohaline situation (salinity comprised between 8 and 12 psu). Oligohaline organisms might have been replaced by euryhaline organisms colonising the substrate, as soon as the turning point was passed. These species were probably present in the estuarine part of the lagoon, and proliferated in this central part of the lagoon as soon as the new haline conditions appeared. Then, the heavy rains occurring from mid-May and the consecutive floods have drastically changed the environmental conditions. Once the turning point passed again toward low salinity, these euryhaline organisms encountered unfavourable conditions. The sharp decrease in periphyton biomass can be related to this new situation.

– nutrient availability and especially P concentration in water is often considered as the major factor determining periphytic algal biomass (HANSSON, 1992). Our data showed a relation between ambient nutrient concentrations and periphytic biomass, the nutrient stock decreasing along with the biomass increase and increasing in situation of low biomass. Nevertheless, orthophosphate and ammonia were never depleted during the study (respective minimal concentrations of PO_4–P and NH_4–N: 0.5 and 0.8 µmol l^{-1}). The highest values observed in May and June, in relation to the allochtonous inputs during the rainy season (PO_4–P and NH_4–N concentrations, respectively 2.0 and 20.5 µmol l^{-1}), corresponded to the lowest algal biomass.

The stepwise regression has also integrated the phytoplanktonic biomass in the model describing the periphytic biomass variation. Besides a shift towards low salinity and an increase in light attenuation, the change in attached biomass was also related to a limitation of the secondary epiphytism (settlement of phytoplanktonic cells, mainly diatoms, on other algae). Some algal species are known for their ambivalence, becoming planktonic or epiphytic with environmental changes (HANCOCK, 1985). Secondary epiphytism can be compared to an immigration of bentho-pelagic cells to a site where more favourable conditions are encountered (STEVENSON and STOERMER, 1982; JENKERSON and HICKMAN, 1986). Studies of bamboo colonisation conducted in the same area (ARFI and BOUVY, in press) have demonstrated that first bacteria, then planktonic adnate diatoms (dominated by *Nitzschia*) were the pioneer organisms colonising the substrate. They were followed by filamentous chlorophytes *(Rhizoclonium riparium)* and cyanobacteria *(Lyngbya epiphytica)*, which, in turn, allowed loosely attached diatoms to be connected to this new substrate. This succession is usually encountered in substrate colonisation by epiphytes (MCCORMICK and STEVENSON, 1991). Most of these species are euryhaline organisms currently observed in the Layo environment (ARFI and BOUVY, 1995). Secondary epiphytism has contributed to the periphytic biomass increase (along with the growth of filamentous algae) when mesophyte species were present in the local phytoplankton. During the Agnéby floods, the phytoplanktonic biomass was 4 fold lower and the importance of secondary epiphytism process was probably reduced by this dilution effect.

In eutrophic Ebrié lagoon, seasonal variations of nutrient concentrations are limited, and the combined change in available PAR, salinity and phytoplanktonic biomass is responsible of the deep variations of periphytic biomass observed during this study. Periphyton showed a continuous biomass increase when favourable conditions were encountered: mesohaline situation, sufficient light (sunny conditions in a turbid context), high ambient phytoplanktonic biomass with presence of bentho-pelagic species. But the transition toward the rainy season characterised by an oligohaline situation, insufficient light (cloudy conditions with very turbid water), low ambient phytoplanktonic biomass with rarity of bentho-pelagic species induced a sharp decrease of the periphytic biomass. The epiphytic bacterial biomass represented a very low percentage of the attached carbon standing stock. If the periphytic algae represented at the most fivefold the phytoplanktonic biomass (April), the attached and the pelagic biomasses were roughly equal on several occasions.

Therefore, in spite of a potentially rich environment in quite endless summer conditions, the sole presence of an artificial reef would not be sufficient to allow the permanence of a large periphyton biomass in such systems characterised by a marked hydrological seasonality. If the acadja system is considered as a low-cost aquaculture structure, the choice of favourable sites to settle such facilities will have to take into account the temporal fluctuations of hydrological factors. Very few studies have treated the periphyton growing on bamboo although in the tropical zone, the role of bamboo as material used for a wide variety of purpose in aquaculture farms (fishes, oysters) in fundamental in the socioeconomical context (CAI and LI, 1990; INGLES and LAO, 1994). Further comprehensive studies integrating biotic factors (particularly fish grazing effects) will have to be developed, in order to get a better knowledge of the acadja's functioning prior to its wide geographical generalisation as a suitable and performing aquaculture technique.

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Book Review

WILLEM H. DE SMET. **Rotifera, vol. 4: The Proalidae (Monogononta)**. Guides to the Indentification of the Microinvertebrates of the Continental Waters of the World, 9–336 Figures, 15 Plates with S.E.M. photographs, 99 pp – SPB Academic Publishing bv 1995. ISSN 0928-2440. US $ 41.00.

The book is the fourth piece in a set of guides edited by H. J. DUMONT (University of Gent, Belgium) and produced by experts currently active in their fields. As all the books of the series it is a clear and comprehensive review of what is now known about one, small group of Rotifera. As the author points out the family Proalidae HARRING and MYERS, 1924 comprises predominantly free-living, epiphytic-epibenthic and psammobiontic species as well as species living epizoic on invertebrates, endoparasites of algae and ectoparasites of invertebrates. The family is poorly described, mostly due to difficult identification of these illoricate specimens after preservation.

The book starts with an introductory part being a short general description of the family Proalidae containing four genera: *Bryceela* with 2 species, *Wulfertia* with 3 species, *Proalinopsis* with 6 species and the most numerous among them – *Proales* with 43 valid species. The shortest chapter of this part of the text, i.e. "Diagnosis" introduces these features of the rotifers that make possible their identification to the family. The next two chapters are devoted to external morphology and internal organization of these very variable rotifers. A good illustration of this variability could be the range of the length of their females, from 70 µm in *Proales minima* to 1050 µm in *P. segnis*. The last chapter of this part characterizes briefly distribution and ecology of the Proalidae.

The next (largest) part begins with "Key to genera". The rest of it offers dichotomous keys to species and extremely accurate descriptions of the species in the chapters entitled "Descriptions" and considering characteristics as synonims of a species, type locality, description, distribution and ecology and sometimes additional notes. This common for all species scheme of description makes this part of the book very clear and easy to use. What makes this chapter surprising is the exhaustiveness of the information together with the extreme clarity of the writing.

The book ends with a Check-list of namens and synonyms, References (151 items) and an Index to species.

Figures, though mostly reproduced from the literature, have been improved and their quality is extremely high. All species are illustrated with drawings showing their dorsal and lateral (if possible) views, trophi (also shown dorsally and laterally) and sometimes additionally some more important details of their morphology. Invaluable addition to figures are previously unpublished and extremely well done S.E.M. photographs of trophi of 14 rotifer species. They are ordered into 14 plates showing dorsal, ventral and lateral views and details of trophi.

To sum up, this is an excellent little book, devoid of errors (at least I could not find any), well written and well edited. As part of the larger series, this volume should occupy a place on the shelves of all rotiferologists and planktonologists.

JOLANTA EJSMONT-KARABIN