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The benthic macroinvertebrate community in Caribbean Costa Rican streams and the effect of two sampling methods

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Abstract: The benthic macroinvertebrate community of streams draining the south-Caribbean coast of Costa Rica, was studied to determine community structure and composition through time (September 1995 – May 1996), the effect of vegetation cover on drainage area (forest vs. disturbed sites) and to compare two sampling methods; Surber and kitchen sieve. Five sites, predominantly with a forest cover drainage area, show abundances (mean=157.60 indivs./m^2) and taxa richness (mean=9.65 spp./m^2) significantly higher than those found in the disturbed drainage areas (means=82.08 and 4.62 respectively). All sites have high community heterogeneity indices (> 0.80) which, together with the low similarity indices (< 0.40) between sampling times indicate a macroinvertebrate community subject to frequent disturbance events that diminish species permanence in the aquatic system. The kitchen sieve sampling method with ten replicates (4 000 cm^2) is significantly more effective in sampling the community in terms of abundance (mean=165.10) than the traditional Surber sampler (mean=83.03) using three replicates (3 333 cm^2). Both are equally effective in the number of taxa collected, although each device captures different taxa. The species similarity between the Surber and the sieve method ranges between 0.1379 to 0.7619 when combining all sampling times.

Key words: Streams, community structure, tropical Caribbean, sampling method, macroinvertebrates, Costa Rica, richness.

Freshwater ecosystems can be divided into two main categories; systems with longitudinal current movements (streams and rivers), and those with circular or no movement at all (ponds, lagoons, swamps, lakes). Most commonly, these systems obtain the attention of the surrounding human population because of human dependence on water to survive and develop (Middleton 1995). Only rarely are these water ecosystems analyzed as something beyond water conduits; for example, as ecosystems containing a unique biodiversity interacting with the terrestrial and marine ecosystems (Abramovitz 1996). By contrast, the Amazon river (Lowe-McConnell 1987, 1994), the rivers in Asia and Australia (Dudgeon and Lam 1994) and the deep African lakes (Lowe-McConnell *et al.* 1992) contain such taxa richness that attracts the attention of numerous biologists and human communities, mainly due to their icthyc production. Central American systems are, comparatively, poor in fish species and the opinion within the human population about streams and rivers is that they only serve as water conduits.

The South Caribbean coastal area of Costa Rica is currently experiencing an increase in the rate of development, especially as a result of tourism. In consequence, there is a normal augmentation in the need for water, as well as the production of garbage disposed into the various surrounding water systems. In response to these problems, the local community has initiated various efforts towards the understanding of the aquatic biodiversity and functioning of their surrounding ecosystems (e.g. projects of ANAI, Asociación para la Conservación y el Desarrollo de Talamanca). This study is part of these efforts and has been designed to respond to the following objectives:

To determine the actual state of the freshwater ecosystems draining the coastal area between Puerto Viejo and Gandoca de Talamanca.

To determine the sampling efficiency of two different techniques for the benthic macroinvertebrate community.

Information about total biodiversity of an ecosystem is an impossible task for a short term project. Hence, it is evident that one group in particular must be chosen for initial focus. As an indicator of the functioning of a lotic ecosystem and its biodiversity, the benthic macroinvertebrate community has been chosen. The benthic macroinvertebrates are a practical group as indicators of system productivity, and easy to sample and replicate in space and time (Resh *et al.* 1996).

MATERIALS AND METHODS

Sampling was done (1995-1996) on September 13-15, December 12-14, February 12-14 and May 16-18. The precipitation pattern during the sampling year showed abnormal values with a very dry December and a very wet February (Fig. 1).

Study Site: The catchment of the freshwater ecosystems draining the coastal area between Cahuita and Gandoca Lagoon are characterized by an intermittently opened primary forest. These open areas are the result of initial wood extraction, cattle grazing, multispecific plantations of cacao (*Theobroma* sp.), laurel (*Cordia alliodora*), naked indian (*Bursera simarouba*), medicinal plants, manioc, banana, plantain and others, or they become an extension of the habitation area of a newly established family. None of the sites visited were totally forested, totally agricultural, or totally cattle pasture; instead they represented a mosaic of different kinds of use. The sampling

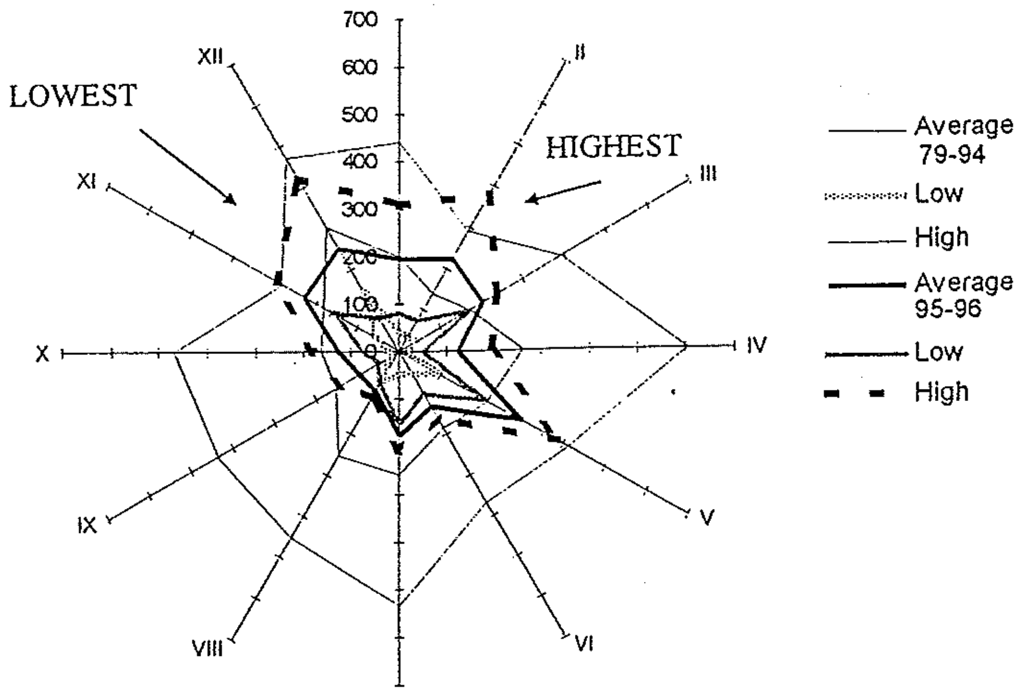

Fig. 1. Average monthy rainfall (mm) recorded between (1979-1994) and during this study 1995-1996 from the meteorological station Sixaola in Talamanca, Costa Rica. Source: Hydrology Department, Instituto Costarricense de Electricidad. Roman numbers represent each month with the scale representing the rainfall.

sites were located in the Río Carbón, Black Sands Creek, Río Cocles, Río Caño Negro, Hone Wark stream and Río Gandoca. Sites one, two, five, six and eight are those which primarily have a forested drainage area. Sites three, four, seven and nine have a disturbed (i.e. original vegetation is cut) drainage area (Table 1, Fig. 2).

Physical and chemical water analyses: In each site and visit, data were gathered water and air temperature with a hand thermometer, channel width with a 30 m measuring tape, depth with a cm calibrated stick, and water velocity with a Gurly meter at various points across the channel. In addition, dissolved oxygen was measured with an oxygen electrode, pH and conductivity with a field electrode.

For the analysis of total suspended solids (TSS) a 1 000 ml water sample was taken, together with a separate 500 ml sample for the determination of total alkalinity. Similarly, two unfiltered samples were taken in acid and destilled water washed polyethylene 60 ml bottles to measure total phosphorus and ammonia, as well as two 0.45 µm Millipore filtered samples for the measurement of nitrate and soluble phosphorus. These samples were frozen in the field and taken to the laboratory of the CIMAR (Centro de Investigaciones en Ciencias del Mar y Limnología, University of Costa Rica) to be analyzed within a period of three months. TSS and alkalinity were determined within a period of seven days.

The total suspended solids were determined after filtering a known volume through pre-dried and pre-weighed Whatman GF/C filters, dried at 80 °C for 24 hr and weighing the difference in mg/l. The alkalinity determination was done titrating with a weak H_2SO_4 acid (Wetzel and Likens 1979).

The soluble reactive phosphorus (PO_4-P) and the total P (TP) were done utilizing the molybdenum blue colorimetric method (AP-

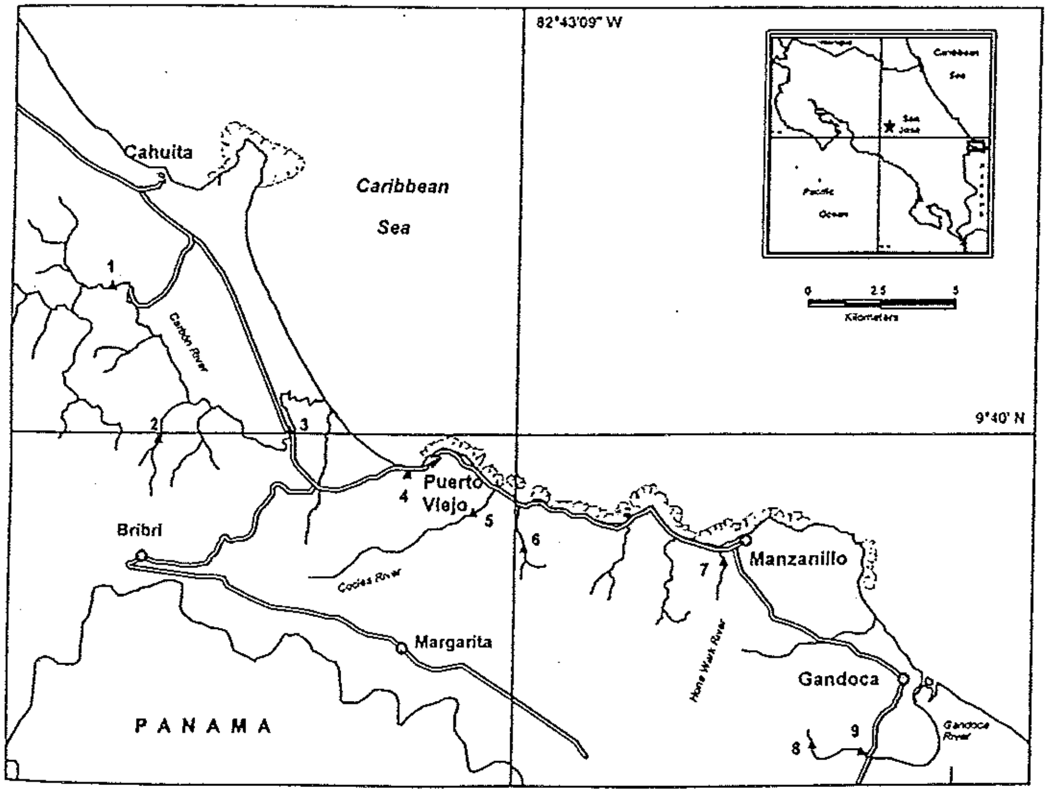

Fig. 2. Sampling sites (numbers) in the area of Puerto Viejo Manzanillo and Gandoca, Talamanca, Costa Rica.

TABLE 1

Physical and chemical characteristics of the stream reaches visited in September 1995 through May 1996. Puerto Viejo de Talamanca, Manzanillo and Gandoca, Costa Rica. G: grazes, B: banana plants, I: Inga, *E:* Erythrina, *C: Cacao, Ca:* Cassia, *DRF: dense rainforest, P:* Pentachethra macroloba, *Cr:* Crysophyllum caimito.
** TSS: total suspended solids. (-) no measurement*

			Forested					Disturbed			
	n	Site	1	2	4	5	8	3	6	7	9
Longitude (W)			82°51'28"	82°50'36"	82°45'39"	82°44'42"	82°38'08"	82°48'05"	82°44'06"	82°40'00"	82°37'33"
Latitude (N)			9°42'25"	9°40'18"	9°39'08"	9°38'21"	9°34'28"	9°39'52"	9°37'21"	9°37'39"	9°33'42"
Drainage			F	F	D	F	F	D	F	D	D
Width (m)			12.5	18	8	12	4.5	16	17	6	8
Riparian Vegetation			G,B	G,B	G,B,I,G,E	G,B,C,Ca	DRF	G,B	G,B,C,E,I	G,B,C	G,P,Cr
Temperature (°C)	1	IX/95	29	28	25	26	24	-	25	25	24
	1	XII/95	27.5	27	26	25	23	26	24	24	24
	1	II/96	18	-	19	18	20	23	17	18	18.5
	1	IV/96	17	27	19	19	25	27	17	25	25
Conductivity (uS/cm)	1	II/96	175	-	490	700	495	110	1000	800	950
	1	IV/96	230	190	150	320	90	270	450	270	120
Discharge (m3/s)	1	IX/95	-	0.062	n.d.	0.057	n.d.	0.53	n.d.	n.d.	n.d.
	1	XII/95	3.5	0.93	n.d.	n.d.	n.d.	4.58	0.1	n.d.	n.d.
	1	II/96	4.01	high	high	high	0.373	high	high	high	high
	1	IV/96	4.04	0.9	0.8	high	0.83	4.44	1.547	0.117	high
Alkalinity (mg CaCO3/mg)	1	IX/95	-	234	213	156	197	183	330	286	103
	1	XII/95	5	12	6	10	7	10	20	11	10
	1	II/96	6	2	4	2	2	-	10	3	1.1
TSS* (mg/l)	1	IX/95	1.4	4.7	0.9	0.2	6.1	-	4.5	4	3.5
	1	XII/95	4.1	7.5	3.5	3.1	8.2	14.3	6.3	2	6.4
	1	II/96	912	-	250.1	440.8	48	24.4	250.8	14.7	24.3
	1	IV/96									
Nitrate-N (ug/l)	3	IX/95	95	95	52	26	30	-	41	31	6
	3	XII/95	11	n.d.	7	4	23	4	n.d.	6	21
	3	II/96	-	-	172	281	30	70	338	302	28
	3	IV/96	10	4	4	10	14	28	31	11	17
Ammonia-N (ug/l)	3	IX/95	6	11	18	n.d.	28	-	6	15	29
	3	XII/95	7	14	7	6	9	n.d.	5	14	14
	3	II/96	56	-	n.d.	64	n.d.	15	54	9	9
	3	IV/96	5	n.d.	n.d.	17	n.d.	6	6	n.d.	n.d.
Phosphate-P (ug/l)	3	IX/95	75	65	91	65	124	-	20	85	68
	3	XII/95	55	66	64	23	64	48	55	69	55
	3	II/96	-	-	40	20	30	47	40	40	77
	3	IV/96	53	75	n.d.	14	25	50	41	57	55
Total-P (ug/l)	3	IX/95	85	81	106	75	132	-	41	103	85
	3	XII/95	80	71	5	37	94	71	55	62	71
	3	II/96	73	-	44	67	11	34	42	21	41
	3	IV/96	96	94	55	51	39	113	200	122	80

HA 1985), as well as the TP following a concentrated sulfuric acid digestion and a 25' autoclaving. The nitrate ($NO_3^{-}N$) was determined through the hydrazine reduction method (Kamphake *et al.* 1967) and the ammonia through the indophenol method (Solórzano 1969).

Macroinvertebrate community: The aquatic macroinvertebrates were sampled at each one of the sites four times through the year; in September, December, February and May. The most common method to capture the organisms living in between the substrate particles of the stream bottom is simple: a net. In the present study two slightly different methods were utilized:

1) the Surber method (1 mm^2 mesh size), which basically encloses a flat area of 1 ft^2 (1111.11 cm^2). Manually this limited area is disturbed into approx. 1 cm depth. This method was replicated at each site three times for a total area of 3333.33 cm^2) (Surber 1937).

2) "kitchen sieve" method (21 cm diameter, round, 1mm^2 mesh size). With this method a limited flat area in the bottom of the stream of 20x20 cm (400 cm^2) was manually disturbed, and replicated ten times in each site for a total area of 4000 cm^2 and a mesh size of 1 mm^2. These replicates were taken choosing a random point to start and then moving upstream in a zig-zag direction, taking a sample every 80-100 cm including the center and edges of the stream.

All samples were fixed in the field with 70 % ethanol and brought to the laboratory to separate the organisms from the sediment and organic matter. All organisms were identified to the minimum taxonomic level possible and counted to determine the abundance per unit area.

Aquatic macroinvertebrates can be categorized by their various feeding habits and differential abilities to withstand stream current and turbulence as well as different refuge needs against predators. To determine if presence and abundance of the various types of substrate present in the stream effects diversity and biomass of the macroinvertebrate groups, we sampled: leaves, sediment, and pebbles in riffles and pools. Macroinvertebrates were fixed in the field with 70 % ethanol and taken to the laboratory to be identified, counted and measured for their body biomass determination. The results of this part of the research are presented in Ramírez *et al.* (1998).

RESULTS

Physical and chemical characteristics: The physical and chemical characteristics of the sampled sites in the area between Puerto Viejo and Gandoca are summarized in Table 1. In general terms, these streams can be defined as having warm waters (23-29 °C) during the low precipitation months and cool waters du-ring the rainy months (17-27 °C). These waters are influenced by the magnitude of the rains, showing changes of several orders of magnitude in total suspended solids and ammonia-N (Table 1).

The nutrient concentrations found in the streams draining this coastal area are similar to those found in other areas of the Costa Rican

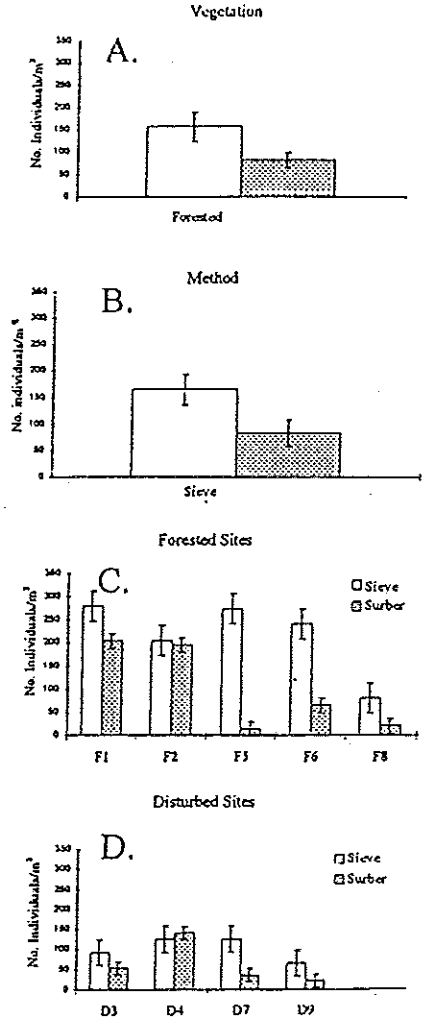

Fig. 3. Abundance of the benthic macroinvertebrate community. A. Forest (n=10) vs. Disturbed (n=8) sites. B. Overall sieve (n=9) vs. Surver (n=9) sampling. C. Distribution of organisms per forest site and method (n=4). D. Distribution of organisms per disturbed site and method. Bars: ± 1 standard error.

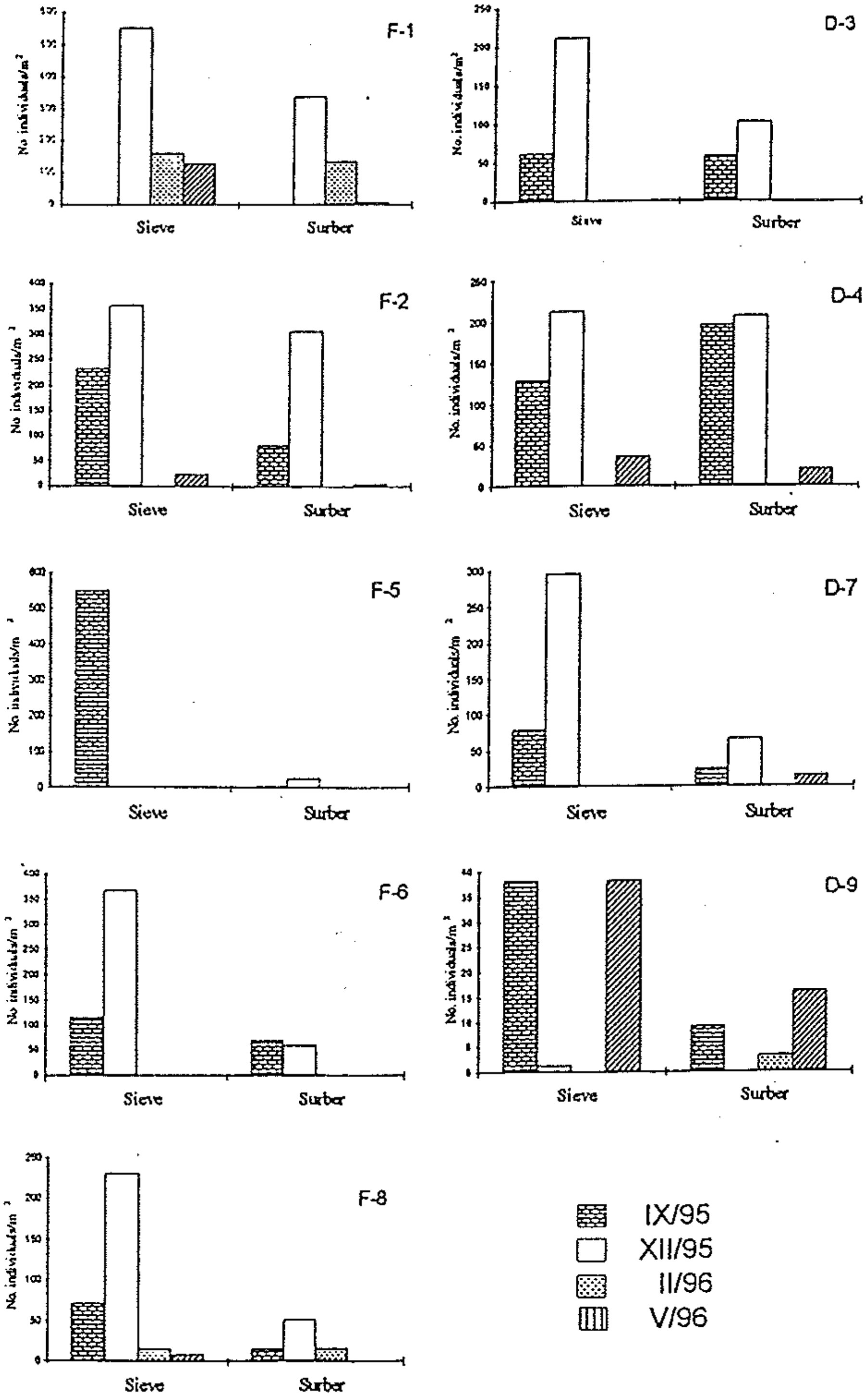

Fig. 4. Total number of individuals/m² through time. Sieve method: 4 000 cm²; Surber method: 3 333 cm². September 1995-May 1996. Note that vertical scale is not the same for all graphs.

Caribbean (Paaby and Goldman 1992, Sanford *et al.* 1994). In addition, and similar to other Costa Rican systems, these stream waters contain occasionally sufficiently high concentrations of nitrate-N, ammonia-N and phosphorus-P as to define them as eutrophic (Bishop 1973, Jordan 1985, Margaleff 1983).

Abundance: The benthic macroinvertebrate community is differentially represented between the sites grouped as forested and disturbed according to their drainage vegetation cover, with average abundance/m^2 significantly higher in the forested sites (Two-Way ANOVA F=5.49, P=0.0344, Fig. 3a). Additionally, significantly higher abundances/m^2 of macroinvertebrates were captured using the "sieve method" (Two-Way ANOVA F=5.82, P=0.0302, Fig. 3b-d).

The abundance of macroinvertebrates oscillates temporally for both methods and sites types (Fig. 4). In December the abundance was the highest. It is worth mentioning that this month was a dry month (Fig. 1). In the month of February, the absence of organisms in all sites may evidence the effect of flooding (Fig. 1). Samples from May, at all sites, except 9, show no recovery in the numbers of macroinvertebrates back to values similar to those found in December (Fig. 4).

Taxa richness (taxa): A total of 82 taxa were collected from the six sampled streams (Table 2). However, only a few species constituted the communities of the sampled sites (Fig. 5a-d, Table 2). Each site, combining both sampling methods) contains from 16-43 taxa in the forested sites and from 13-41 in the disturbed ones, with statistical evidence supporting a higher taxa richness in the forested drainage area sites (Two-Way ANOVA F=6.31, P=0.0249). Temporal effects on the taxa richness is evident, showing a larger number of taxa during the less rainy months of the year, September and December (Fig. 6).

Composition: The total number of taxa present in each sampled site (Table 2) is a partial indicator of community structure as this absolute number hides important composition changes throughout the year and between sites. The species composition similarity between the five forested sites (1,2,5,6,8) ranges

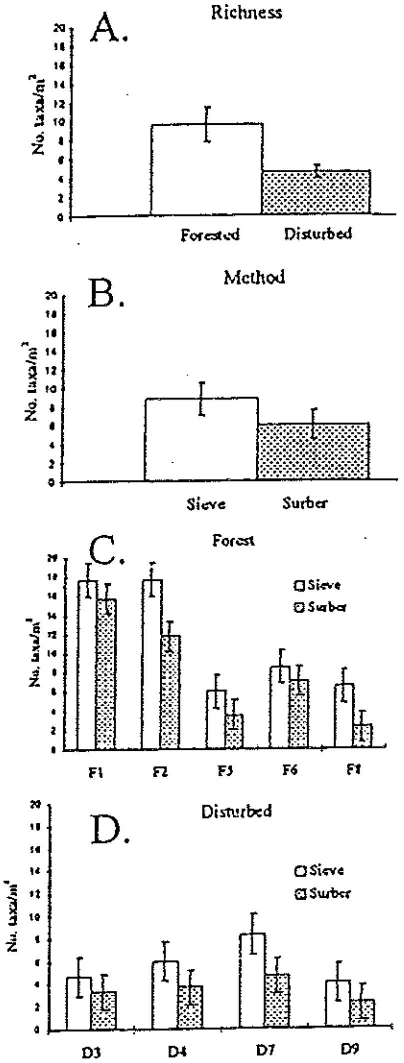

Fig. 5. Species richness of the benthic macroinvertebrate community. A. Forest (n=10) vs. Disturbed (n=8) sites. B. Overall sieve (n=9) vs. Surver (n=9) sampling. C. Distribution of organisms per forest site and method (n=4). D. Distribution of organisms per disturbed site and method. Bars: ± 1 standard error.

from 0.237 - 0.667, with 30 % of the comparisons > 0.45. The similarity index between the disturbed sites (3,4,7,9) are almost the same with values ranging between 0.286 - 0.667 but with only 16.6 % of the comparisons > 0.45. When comparing the "forested" sites and the "disturbed" sites the similarity ranges between 0.280 - 0.788, with 35 % of the comparisons >

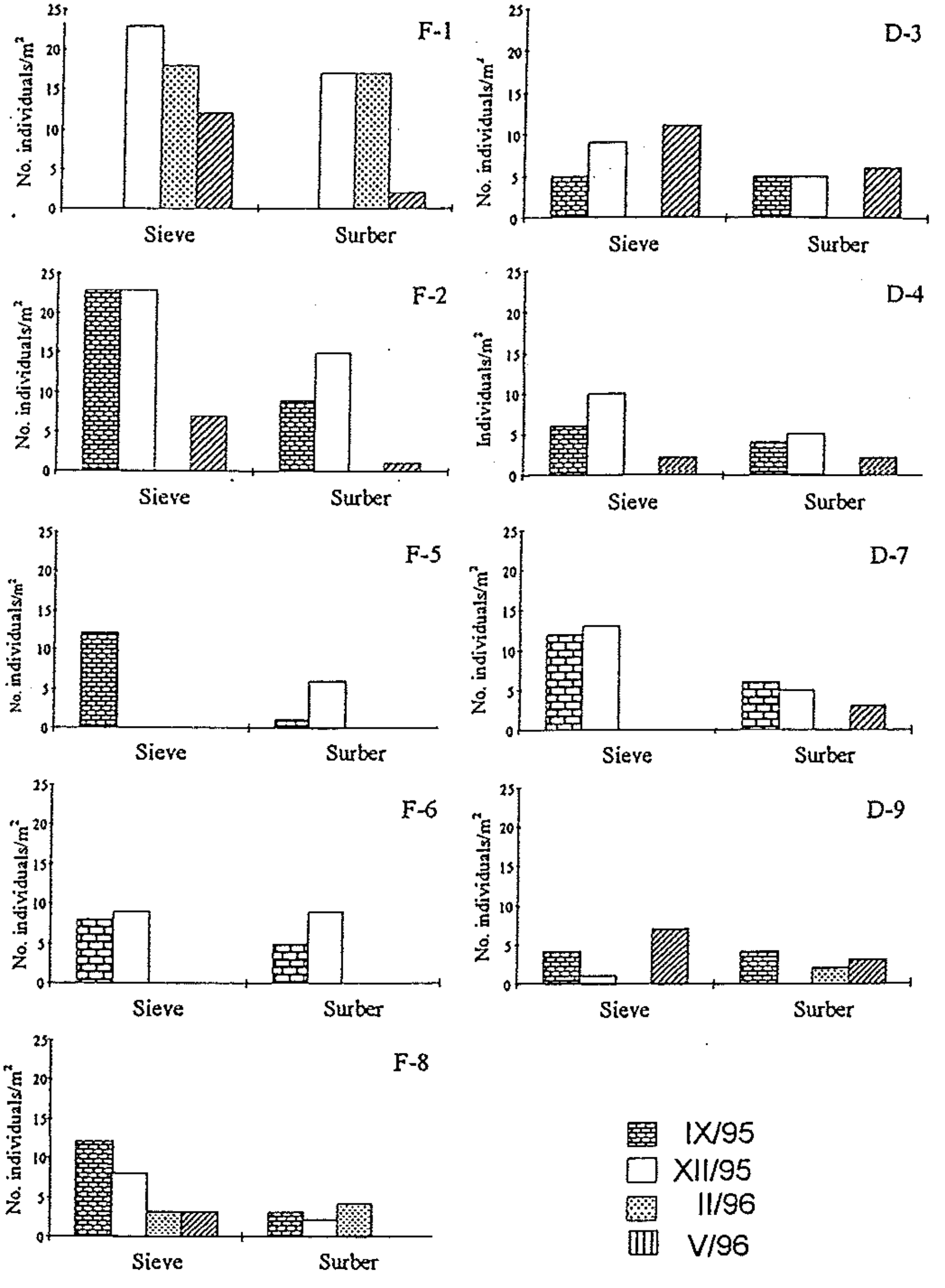

Fig. 6. Total number of morphospecies/m^2 through time. Sieve method: 4 000 cm^2; Surber method: 3 333 cm^2. September 1995-May 1996. F = Forest sites, D = disturbed sites.

0.45. There was not a clear trend showing a higher similarity between sites under the same degree of disturbance in their drainage area are absent (One-Way ANOVA F=0.09, P=0.7683, Table 3a).

Similarly, the morphospecies composition of the sampled community through time varies considerably, with similarity indexes < 0.25 in 60 % of the temporal comparisons and < 0.40 in 81 % of them (Table 3b). These values are low and indicate continuous changes in the species composition within 2-3 month intervals.

The sampling methods, Surber and "Kitchen sieve" do not differ significantly (Two-Way ANOVA F = 1.88, P = 0.1914) in the

TABLE 2

Taxa present (+) per site and sampling method combining all dates through September 1995 and May 1996. Puerto Viejo de Sarapiquí, Manzanillo and Gandoca de Talamanca, Costa Rica

	Forested										Disturbed							
	1		2		5		6		8		3		4		7		9	
	Si	Su	Si	Su	Si	Su	Si	Su	Si	Su	Si	Su	Si	Su	Si	Su	Si	Su
Ephemeroptera	+																	
Baetidae											+			+				
Camelobaetidus	+	+		+														
Baetis					+													
Baetodes		+																
Cloeodes		+																
sp.1	+	+	+	+			+								+			
sp.2	+		+	+														
Leptophlebiidae																		
Thraulodes	+	+	+	+			+	+			+	+			+	+		
Travarella	+	+	+	+														
Farrodes		+	+	+				+	+		+							
Hydrosmilodon		+																
sp.1	+		+	+			+		+						+			
Leptohyphidae																		
Leptohyphes	+	+	+	+								+	+					
Tricorythodes	+		+	+										+				
Haplohyphes													+					
sp.1	+	+	+	+	+	+		+			+	+	+	+		+		
sp.2	+	+																
sp.3	+																	
Caenidae																		
Caenis					+											+		
Ephemeridae																		
Hexagenia										+						+		
Polymitarcyidae															+			
Trichoptera	+	+	+				+								+			
Helicopsychidae																	+	+
Philopotamidae																		
Chimarra	+																	
sp.1		+																
Hydroptilidae																		
Ochrotrichia				+														
Mayatrichia	+																	
sp.1	+		+															
Hydropsychidae																		
Leptonema		+		+														
Smicridea	+	+	+	+	+				+	+	+		+					+
sp.1	+	+	+						+									
Glossosomatidae	+	+	+	+					+								+	
Macronema																	+	
Leptoceridae											+			+				
Odontoceridae							+											
Calamoceratidae																		
Phylloicus										+					+			+
Coleoptera																		
Gyrinidae																		
Dineutus			+								+							

Cont. TABLE 2

	Forested										Disturbed							
	1		2		4		5		8		3		6		7		9	
Taxa	Si	Su	Si	Su	Si	Su	Si	Su	Si	Su	Si	Su	Si	Su	Si	Su	Si	Su
Coleoptera																		
Elmidae																		
Hexacylloepus									+									
Phanocerus			+															
Microcylloepus			+															
sp.1	+	+	+				+	+					+	+	+		+	
Psephenidae	+	+	+															
Scirtidae																		
Cyphorn		+																
Ptilodactylidae															+			
Hemiptera																		
Belostomatidae																		
Belostoma	+								+									
Abedus			+	+				+										
Veliidae																		
Rhagovelia		+																
Microvelia								+							+			
sp.1		+						+							+			
Odonata																		
Zygoptera		+					+		+						+		+	
Lestidae																		
Archilestes	+		+	+														
Anisoptera																		
Libellulidae																		
Perithemis			+						+								+	
Gomphidae																		
Agriogomphus									+	+							+	+
Perigomphus							+			+					+	+		
Erpetogomphus							+								+			
Progomphus	+		+															
Epigomphus			+															
Megaloptera																		
Corydalidae																		
Corydalus	+		+	+	+									+				
Plecoptera																		
Perlidae																		
Anacronemia			+															
Diptera															+			
Chironomidae																		
sp.1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
sp.2	+		+										+	+				
Tipulidae			+												+		+	
Hexatoma			+										+	+				
sp.1	+	+																
Limoniinae	+																	
Simuliidae				+														
Ceratopogonidae			+															
Dolichopodidae					+													
Ephidridae									+									
Lepidoptera																		
Pyralidae (Crambidae)																		
Petrophila sp.1	+	+	+															
Petrophila sp.2				+														
Crustacea																		
Macrobrachium			+	+	+		+				+		+		+			
sp.1	+	+	+	+			+	+	+		+	+	+	+	+	+		+
Atydae																		
Atya			+		+		+		+		+		+	+				
Decapoda	+		+					+		+		+	+	+		+	+	
Mollusca																		
Gastropoda							+	+	+	+			+		+		+	+
sp.1		+																
sp.2					+			+								+		

Cont. TABLE 2

	Forested										Disturbed							
	1		2		4		5		8		3		6		7		9	
Taxa	Si	Su	Si	Su	Si	Su	Si	Su	Si	Su	Si	Su	Si	Su	Si	Su	Si	Su
Bivalvia														+				
Oligochaeta									+						+			
Total taxa	32	28	36	22	12	6	13	12	16	8	12	9	12	9	20	9	11	7

TABLE 3

Sorensen Similarity Index among sites (a), comparing sampling methods per site (b), comparing sampling dates (Sept, Dec 1995, February, May 1996) (c). Puerto Viejo, Manzanillo and Gandoca de Talamanca, Costa Rica. F= forested, D= disturbed

a.

	Forested					Disturbed			
	1	2	5	6	8	3	4	7	9
1									
2	0.67								
5	0.24	0.27							
6	0.43	0.48	0.35						
8	0.35	0.31	0.33	0.37					
3	0.32	0.45	0.40	0.50	0.35				
4	0.34	0.37	0.37	0.47	0.33	0.67			
7	0.38	0.35	0.77	0.79	0.49	0.36	0.34		
9	0.32	0.28	0.33	0.31	0.59	0.29	0.33	0.41	

b.

		Sampling date				
Site	Vegetation type*	IX/95 vs. XII/95	IX/95 vs. V/96	XII/95 vs. II/96	XII/95 vs. V/96	II/96 vs. V/96
1	F	-	-	0.00	0.57	0.00
2	F	0.66	0.22	-	0.12	-
5	F	0.33	-	-	-	-
6	F	0.50	-	-	-	-
8	F	0.57	0.125	0.27	0.36	0.00
3	D	0.59	0.00	-	0.00	-
4	D	0.4	0.33	-	0.375	-
7	D	0.32	0.22	-	0.32	-
9	D	0.00	0.40	0.00	0.00	0.00

c.

	Forested					Disturbed			
Method	1	2	5	6	8	3	4	7	9
Sieve vs. Surber	0.57	0.59	0.22	0.56	0.33	0.76	0.48	0.14	0.44

number of taxa captured. The species similarity between both sampling methods do not differ between forested and disturbed sites, with a maximum similarity not > 76 % in site 3 (One-Way ANOVA F=0.00, P=0.9945, Table 3c).

Species diversity (H') (Whitaker 1965): Because the diversity of a community is directly dependent upon the total number of taxa present, the species diversity (H') was shown as the diversity relative to the site's maximum possible diversity (H'/H_{max}). (Fig. 7). The relative diversity is high (88.6 % > 0.5 H/H_{max} for forested; and 59 % > 0.8 H/H_{max} for disturbed) with a weak trend towards showing higher values during the rainy months (e.g. May, Fig. 7).

The distribution of individuals among the taxa is a common indicator of community evenness vs. dominance. In all of the sampled sites, except 4, the homogeneity (J) of the community is high (> 60%) with temporal differences that bring the evenness down to only 20 % (Fig. 7). A highly homogeneous community structure is an indicator of little species dominance.

To explain diversity trends it is common to invoke physical (e.g. substrate) and temporal (e.g. intermediate disturbance) heterogeneity. In the studied systems there was not a significant evidence for a positive correlation between substrate heterogeneity (Table 4) and the total abundance of macroinvertebrates present in a site (r_{sieve}= 0.44; r_{surber}= 0.23), or the taxa richness (r_{sieve}= 0.27; r_{surber}= 0.23) or biodiversity (r_{sieve}= 0.00; r_{surber}= - 0.10).

DISCUSSION

State of the freshwater ecosystems draining the coastal area between Puerto Viejo and Gandoca de Talamanca: The benthic macroinvertebrate communities were highly

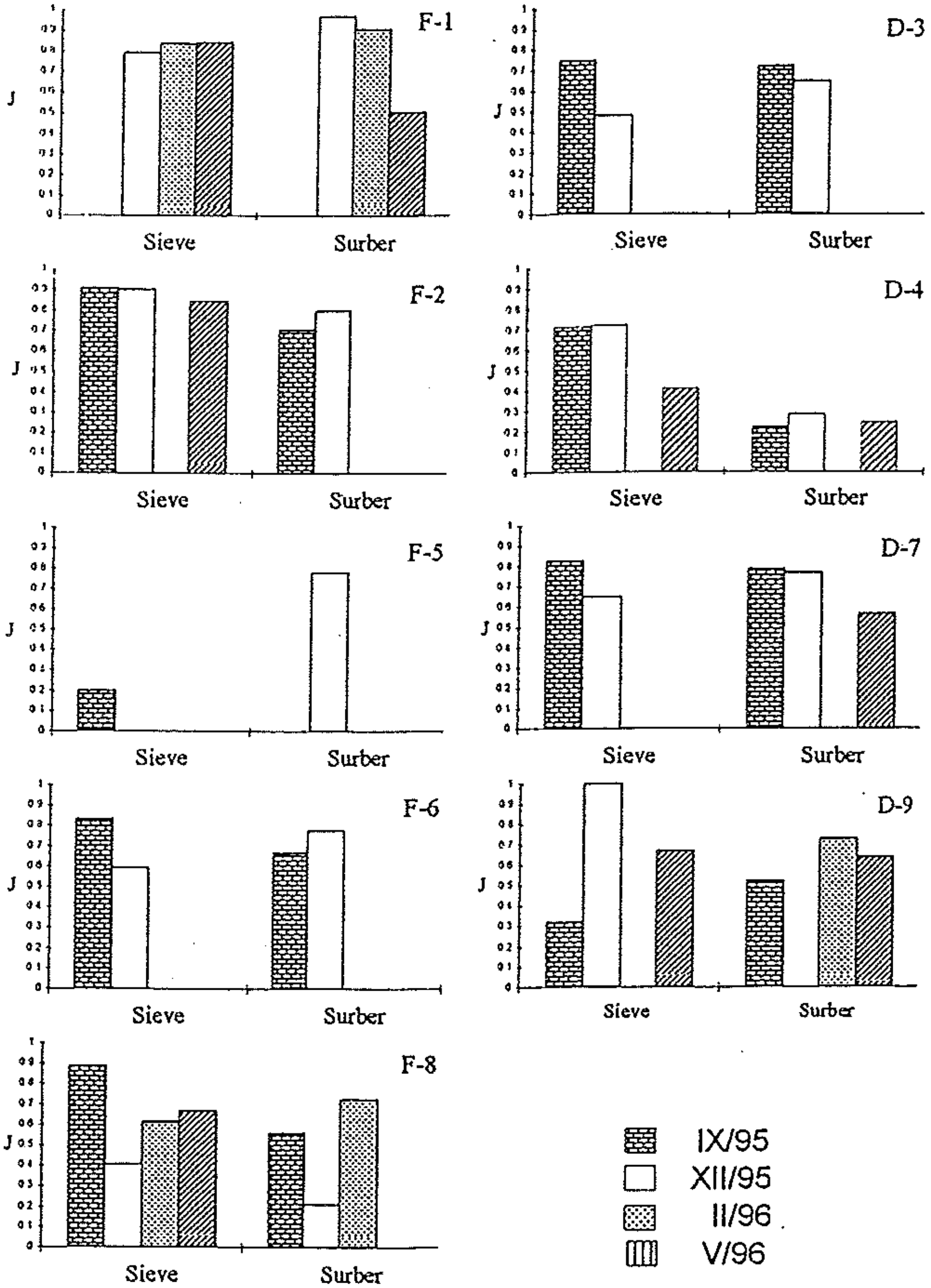

Fig. 7. Evenness Index (J) through time. Sieve method: 4 000 cm^2; Surber method: 3 333 cm^2. September 1995-May 1996. F = Forest sites, D = disturbed sites.

diverse at all the sampled sites in both the forested and disturbed immediate drainage areas. These high values are accompanied by high total abundance in the sites of less disturbance suggesting higher stability and permanence. However, there are very low similarity values between sites and through time suggesting a community in constant change. In addition, there is little evidence supporting the theory that physical heterogeneity (substrate) is currently playing a determining factor in the maintenance of diversity.

The Puerto Viejo, Manzanillo and Gandoca areas are characterized by a very variable rain pattern between years. The sampling year included months with precipitation levels outside any levels reported in the previous 19 years, either with too much rain (e.g. 200 mm distributed in only two days) or too little (< 100 mm/month of December) (Fig. 1). The temporal variance in rain patterns generates direct effects on the riverine systems. Most obviously, the disturbance caused by the heavy rains may result in a reduction or total removal of the benthic community. Consequently, future changes in the structure of the community and subsequent pattern of organic matter transformation will be the result of the pattern of recolonization of individuals and species. The drainage vegetation cover may diminish the effect of heavy rains; however, during this climatic event no differences between forested and disturbed drainages were evident.

The composition of the macroinvertebrate community in the Gandoca-Manzanillo study area is very heterogeneous among sites and sampling times. This heterogeneity means that there is a high species turnover rate within the community, which in turn suggests that the development of the community reinitializes frequently (< 2 months). When disturbances occur within the margin of predictability of magnitude and frequency, the result is a unique successional sequence generated from the initial group of species present. Hence, two sites may share a high proportion of species but differ in the relative abundance of each. However, when the magnitude and frequency of disturbance surpasses the "normal" behavior, the result is the disappearance of species and of communities like was encountered with in the Gandoca/Manzanillo area and found elsewhere by Reice (1994) and Connell (1978). Additionally, the high evenness of the communities observed supports a pattern of disturbance whose turnover rate is shorter than the average age of the resident species. There is an obvious absence of dominant species and a low species similarity between the sampling intervals (2-3 months).

In conclusion, the benthic macroinvertebrate communities of the sampled region evidenced , in their structure and function, constant changes and under great influence by the rains. During the study period, the frequency and intensity of the rains were such that the benthic species were unable to maintain a stable structure through time. Disturbance in biological systems constitutes a mechanism that maintains diversity; however, its positive impact is reversed when the magnitude and the frequency surpasses an intermediate state (Connell 1978; Ward and Stanford 1983). The implications of this in watershed management policy are important because the changes in land use through construction, road opening, forestry plantations, and urbanization, among many, may result in a homogenization as well as in an augmentation of the normal disturbance pattern affecting the aquatic systems. Any of these extremes can have effects on the presence and abundance of the species, the rate and pattern of recolonization, as well as on the species interactions and functioning in the organic matter processing within the system.

Sampling of the benthic community: The kitchen-sieve constitutes a good method to acquire a good representation of the composition of the benthic community, it is accessible to most people, it is easy to handle and transport, and it permits a sampling of more replicates and microsites per site. In the current study, there were 10 replicates per site; however, it is recommended to duplicate this up to at least 20, to increase the probability of capturing rare species in the area as a result of a high disturbance rate.

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RESUMEN

El presente estudio fue realizado en los ríos y quebradas de la zona costera sur-caribeña de Costa Rica, investigándose la comunidad de macroinvertebrados bénticos con los objetivos de determinar el estado de la estructura de la comunidad, la composición a través del tiempo, el efecto de la cobertura de vegetación en el área de drenaje y la comparación de dos métodos de muestreo; el "surber" y un colador. El estudio fue realizado entre setiembre de 1995 y mayo de 1996. Cinco sitios predominantemente con una cuenca forestada muestran una abundancia (promedio = 157.60 /m^2) y riqueza de taxa (promedio=9.65/m^2) significativamente mayor que la encontrada en los sitios con una cuenca perturbada (promedio = 82.08 y 4.62 respectivamente). Todos los sitios muestran un índice de heterogeneidad alto (> 0.80), el cual junto con los bajos valores de similitud (< 0.40) entre épocas de muestreo indican que la comunidad de macroinvertebrados se encuentra sujeta a eventos de perturbación frecuentes que disminuyen la permanencia de especies en el sistema. El método de muestreo utilizando el colador es significativamente más efectivo en muestrear la comunidad de macroinvertebrados (promedio = 165.10/m^2) que el Surber (promedio = 83.03/m^2. Ambos métodos de muestreo, Surber y colador, son igualmente efectivos en el número capturado de taxa, aunque la similitud en la composición de captura oscila entre 0.1379 y 0.7619).

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