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Rev. Biol. Trop. 46, Supl. 6: 201-213, 1998
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Effect of habitat type on benthic macroinvertebrates in two lowland tropical streams, Costa Rica

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(Rec. 11-VI-1997. Rev. 20-I-1998. Accep. 10-III-1998)

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Abstract: Benthic macroinvertebrate community structure was studied with respect to stream habitat type in two lowland tropical streams. Three reaches along the Caribon river and two within the Gandoca stream were chosen as study sites in Talamanca, Costa Rica. Macroinvertebrates were collected from four habitat types: leaf packs in riffles, cobble in riffles, areas of sand in pools, and areas of gravel in pools. Communities were dominated by insects in the orders Ephemeroptera (*Thraulodes*, *Baetis*?), Diptera (Chironomidae, Tipulidae), Trichoptera (Hydropsychidae, Glossosomatidae, Hydroptilidae, Calamoceratidae), and Odonata (*Progomphus*, *Hetaerina*). Non-insect macroinvertebrates were dominated by shrimps (*Macrobrachium*) and snails (Gastropoda). Functional feeding group composition was dominated by collector-gatherers. In most reaches, both habitat types in riffles supported higher macroinvertebrate abundance and biomass than did habitats in pools. Leaf packs in riffles represent an important habitat that is present year-round in these aseasonal tropical systems. Community composition and diversity were similar to that reported for other areas of Central America.

Key words: Community structure, abundance, diversity, biomass, leaf pack habitats, riffle habitats, Talamanca.

A disproportionate amount of research on benthic community structure in streams has focused on cobble-riffles habitats, compared with other habitat types, although a number of studies in temperate regions have assessed benthic community structure with respect to substrate types (e.g. Egglishaw 1969, Minshall & Minshall 1977, Rabeni & Minshall 1977, Hawkins *et al.* 1982, Huryn & Wallace 1987). It is now recognized that streams contain a variety of habitats with different physical and chemical conditions (Pringle *et al.* 1988). The availability of habitats and the nature of their faunal assemblages can be expected to change among reaches along a river continuum. For example, Palmer *et al.* (1991) reported that specific macroinvertebrate assemblages were not always associated with habitats in head-

water reaches, but were evident in middle and lower reaches.

The distribution of benthic macroinvertebrates among stream habitats reflects, to some degree, the distribution of benthic resources (e.g. food, oxygen, predators) (Rabeni & Minshall 1977), and provides information about how communities might respond to changes in environmental parameters such as increased sedimentation and changes in flow. Despite its importance, few studies have been published on the distribution of benthic macroinvertebrates among stream habitats for tropical systems (but see Dudgeon 1982, Arunachalam *et al.* 1991).

In this paper, we examined the distribution of benthic macroinvertebrate communities among habitat types in lowland tropical

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streams draining the region of Talamanca, Costa Rica. We are not aware of any previous published studies dealing with any aspect of the ecology of stream benthic communities in this region (but see Paaby *et al.* 1998, this issue). The objectives of our study were: (1) to describe the structure of benthic stream communities in Talamanca, and (2) to assess the effect of habitat type on community structure.

MATERIALS AND METHODS

Study area: This study was conducted at the Gandoca-Manzanillo Wildlife Refuge and surrounding areas in southeastern Costa Rica (82°45'N, 9°40'W) (Fig. 1). The area is located in the tropical wet forest life zone (Holdridge *et al.* 1971). At a nearby meteorological station at Chase (10 km south, 40 m a.s.l.), the mean annual precipitation over a period of 19 years was 2 110 mm. Rain is evenly distributed throughout the year, with no clear seasonality. At the same station, mean annual air temperature ranged from 22 to 27 °C (Herrera 1985).

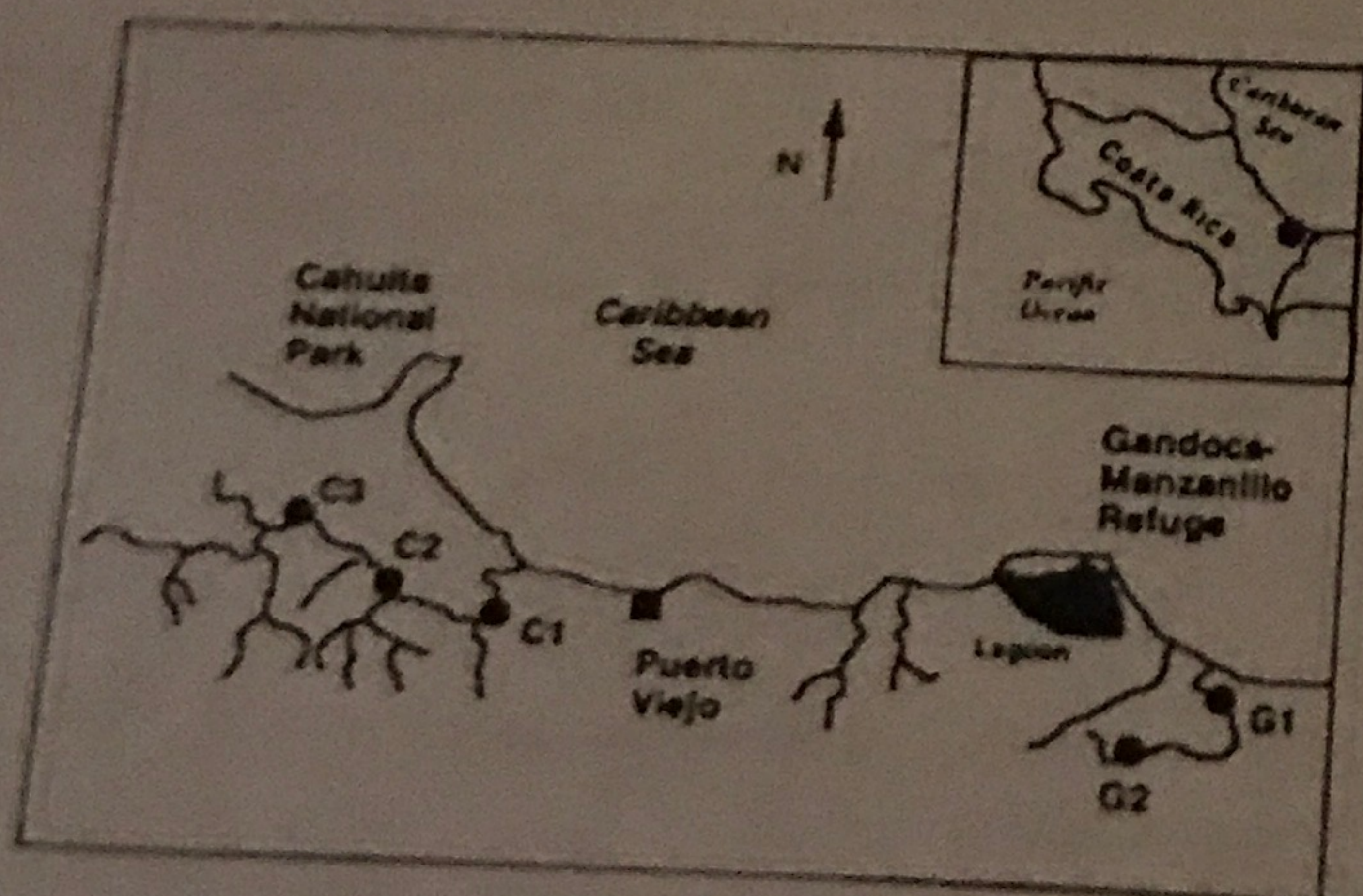


Fig. 1. Location of the study sites in the Caribbean lowlands of Costa Rica.

The Carbón and Gandoca rivers were chosen as study sites. Sampling was done in three reaches in the Carbón and two in the Gandoca river. The main differences among reaches were in stream order and discharge (Table 1). Both rivers have catchments composed of primary and secondary forest, mixed with active pastures and areas of small-scale agriculture. While riparian vegetation was present at all sites, increased sedimentation might be the result of human activities, such as agriculture. A detailed description of sites can be found on

Paaby *et al.* (1998, this issue).

Methods: The five study reaches and all stream habitats were sampled for macroinvertebrates in both December 1995 and May 1996. Stream discharge and water temperature were recorded on both sampling dates (see Paaby *et al.* 1998 this issue). Stream habitat composition was defined as: depositional areas of sand (DS), depositional areas of gravel (DG), cobble substrate in riffles (CR), and leaf pack accumulations in riffles (LP). The relative proportion of each habitat was assessed for each site by making a grid (4 m in length by the river width) with 16 sections, and visually surveying the proportion of each habitat inside each division. The mean habitat proportion was used to weight the obtained sample values.

Two random macroinvertebrate samples were collected from each habitat type (DS, DG, CR, LP), at each site on each sampling date. Samples were collected using a kick net (350 µm mesh), and disturbing an area of near 1 m² of a particular habitat for five consecutive minutes. To prevent build-up of debris and loss of organisms, the net was emptied into a bucket four or five times while sampling and large pieces of wood, stones or leaves were removed. All organisms captured and small debris were preserved in 90% ethanol.

Macroinvertebrates were identified to different taxonomic levels according to available taxonomic information for each group. Non-insects macroinvertebrates were identified only to the class or order level. Among the insects, several groups were identified to genus level using available keys: Ephemeroptera (Flowers 1992), Odonata (Ramirez unpublished information), Trichoptera (Springer unpublished information), and Plecoptera (Baumann 1984). Diptera, Lepidoptera, Hemiptera, and Coleoptera were identified to family level using Roldán (1988) and Merritt & Cummins (1996), and separated into morphotypes. Chironomidae (Diptera) were identified as Tanypodinae and non-Tanypodinae. Functional feeding-groups were assigned to each taxon based on Jackson and Sweeney (1995) and Merritt and Cummins (1996).

Macroinvertebrate abundance was obtained by counting all individuals per taxon and expressing the results as numbers per sample.

TABLE 1

Characteristics of the study sites, Carbon River (C1, C2, C3) and Gandoca stream (G1, G2), Talamanca, Costa Rica

	Carbon River			Gandoca River	
	C1	C2	C3	G1	G2
Stream Order	1	2	3	1	2
Catchment land use	Forest/Pasture	Forest/Pasture	Forest/Pasture	Pasture	Forest
Habitat composition (%)					
Riffle habitats					
CR Cobble	37.5	45	37.5	0	25
LP Leaf Packs	12.5	5	25	25	25
Pool habitats					
DS Sand	37.5	37.5	12.5	75	25
DG Gravel	12.5	12.5	25	0	25
Mean water					
Temperature (°C)	27	27	26	23	24
Discharge (m ³ /s)	0.93	4.5	3.5	< 1	0.8

RESULTS

Macroinvertebrate biomass was obtained by measuring body length (i.e., head to tip of abdomen) of all individuals of all taxa to the nearest 1 mm using a dissecting microscope, and then applying predetermined regressions of length-to-weight relationships, resulting in mg ash free dry mass (mg AFDM) per sample. Predetermined biomass regressions were selected for each taxon found at the study sites, using known and tested regressions and selecting those for the same taxa or of similar body-shape (Smock 1980, Huryn 1986, A.D. Huryn & J.B. Wallace unpublished data). Equations in dry mass were transformed to AFDM by assuming that 1 g DM = 0.9 g AFDM (Benke 1993).

Where necessary and appropriate, variables were log-transformed ($\log [x+1]$). Macroinvertebrate biomass and abundance were compared both between and within habitats, and between and within reaches using separate one-way analysis of variance (ANOVA) procedures, using GLM procedure in SAS (SAS 1988). Orthogonal contrasts were defined to assess significant differences between habitat abundance and biomass. Diversity was calculated using Fisher's alpha of the log series (Fisher *et al.* 1943) since it is independent of sample size and does not give excessive weight to common species (Wolda 1981, Flowers 1991). It also allow us to compare with other studies in Central America (e.g., Flowers 1991, Pringle & Ramírez 1998).

Physical parameters: Habitat composition was found to be different among sites. The proportion of habitats in each site is shown in Table 1. Although, some variation was observed, DS and CR were dominant in most sites. Discharge ranged from less than 1 m³ s⁻¹ in first-order sites to more than 4 m³ s⁻¹ in third-order sites. Water temperature varied around 26°C in Carbón and 25°C in Gandoca rivers (Table 1).

Benthic community composition: Benthic macroinvertebrate communities at all sites were dominated by only a few groups of insects: mayflies (Ephemeroptera) and true flies (Diptera), and non-insect macroinvertebrates: shrimps (Decapoda) and snails (Gastropoda).

Thraulodes (Leptophlebiidae) was the dominant mayfly genera representing more than 10% of total abundance and biomass in the Carbón river (Table 2). *Leptohyphes* (Leptohyphidae) and *Baetis?* (Baetidae) were also collected in smaller proportions in the Carbón river (Table 2). Mayflies were less abundant in Gandoca (Table 2). Chironomidae and Tipulidae were the most common dipterans in both streams. Percent abundance of Chironomidae was greater than 10% at all sites, and represented 56% of all insects collected at C2. However, Chironomidae biomass was never higher than 2% at a single site (Table 2). Larval Tipulidae were found in low

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TABLE 2

Percentage contribution of the main taxa to total habitat-weighted biomass (B) and abundance (A) (>2%) in the Caribón (C1, C2, C3) and Gandoca rivers (G1, G2), Talamanca, Costa Rica

Taxa	C1		C2		C3		G1		G2	
	A	B	A	B	A	B	A	B	A	B
Collector-Filterers										
Hydropsychidae	1.3	0.8	0.0	0.0	8.1	7.8	0.0	0.0	0.6	0.2
Collector-Gatherers										
<i>Baetis</i> ?	3.9	1.5	6.3	4.6	3.0	1.6	0.0	0.0	0.0	0.0
Chironomidae	43.2	1.0	56.5	2.0	30.7	0.5	11.3	0.2	14.7	0.2
Decapoda	3.3	65.5	0.0	0.0	4.0	44.5	0.0	0.0	5.6	73.0
<i>Leptohyphes</i>	15.3	6.0	4.1	4.4	5.6	3.2	0.0	0.0	1.1	6.1
<i>Tricorythodes</i>	0.0	0.0	0.0	0.0	4.6	2.0	0.0	0.0	1.1	6.1
Predators										
<i>Ceratopogonidae</i>	0.0	0.0	0.0	0.0	0.1	0.0	4.9	0.9	1.1	0.2
<i>Corydalis</i>	0.0	0.0	0.6	1.1	0.1	11.8	0.0	0.0	0.0	0.0
<i>Epetogomphus</i>	0.0	0.0	0.0	0.0	0.0	0.0	1.0	19.4	0.0	0.0
<i>Phyllocycla</i>	0.0	0.0	9.0	76.7	0.0	0.0	0.0	0.0	0.0	0.0
<i>Progomphus</i>	0.4	4.3	0.0	0.0	0.6	11.0	0.0	0.0	1.7	2.4
Tipulidae	0.8	8.8	0.0	0.0	0.5	3.4	0.0	0.0	2.2	3.4
Scrapers										
Gastropoda	0.0	0.0	0.0	0.0	0.0	0.0	69.2	74.9	18.3	2.5
Glossosomatidae	0.4	0.1	0.0	0.0	13.9	1.2	0.0	0.0	0.0	0.0
<i>Thraulodes</i>	21.4	10.2	21.7	9.3	10.3	3.8	0.0	0.0	8.6	1.3
Shredders										
Calamoceratidae	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	10.0	1.4
Pyralidae	0.0	0.0	0.0	0.0	2.5	2.4	0.0	0.0	0.0	0.0
Total	93.1	99.6	99.2	99.7	89.3	98.7	99.9	100.0	84.5	100.0

numbers (< 2%) but their biomass varied from 3% to 9% at sites C1, C3, and G2. Caddisflies (Trichoptera) were found at all sites in low numbers. Hydropsychidae were abundant only at site C3, where they composed nearly 8% of the total biomass and abundance. Other families were represented only at one or two sites. For instance, the Calamoceratidae reached high abundance and biomass only at site G2 (Table 2). Odonata were always present in low numbers, and never reached high abundance in any site. However, some large Odonata make a large part of the biomass at some sites. For example, *Phyllocycla* (Gomphidae) make 77% of the total biomass at site C2, but only 9% of the abundance (Table 2).

Among non-insect macroinvertebrates, shrimps (mainly *Macrobrachium*) were dominant, comprising less than 10% of the total abundance. However, large bodied shrimps were collected at some of the sites, where their

biomass increased to more than 40% of the total. Snails were abundant only in the Gandoca river; at G1 snails comprised 69% of the abundance and 75% of the biomass of the benthic community (Table 2).

Effect of habitat type: Different stream habitats supported different benthic community compositions. LP habitats had a fauna composed mainly of collector-gatherers (Chironomidae, Decapoda, Leptohyphidae), filterers (Hydropsychidae), predators (Odonata), and at site G2 by shredders (Calamoceratidae) (Figs. 2 and 3). The fauna in DS habitats contained mainly collector-gatherers (Chironomidae, Decapoda), predators (*Progomphus*) and some scrapers (Gastropoda) (Figs. 2 and 3). DG habitats supported several groups of equal representation, among them filterers (Trichoptera), collector-gatherers (Chironomidae, Decapoda) and predators

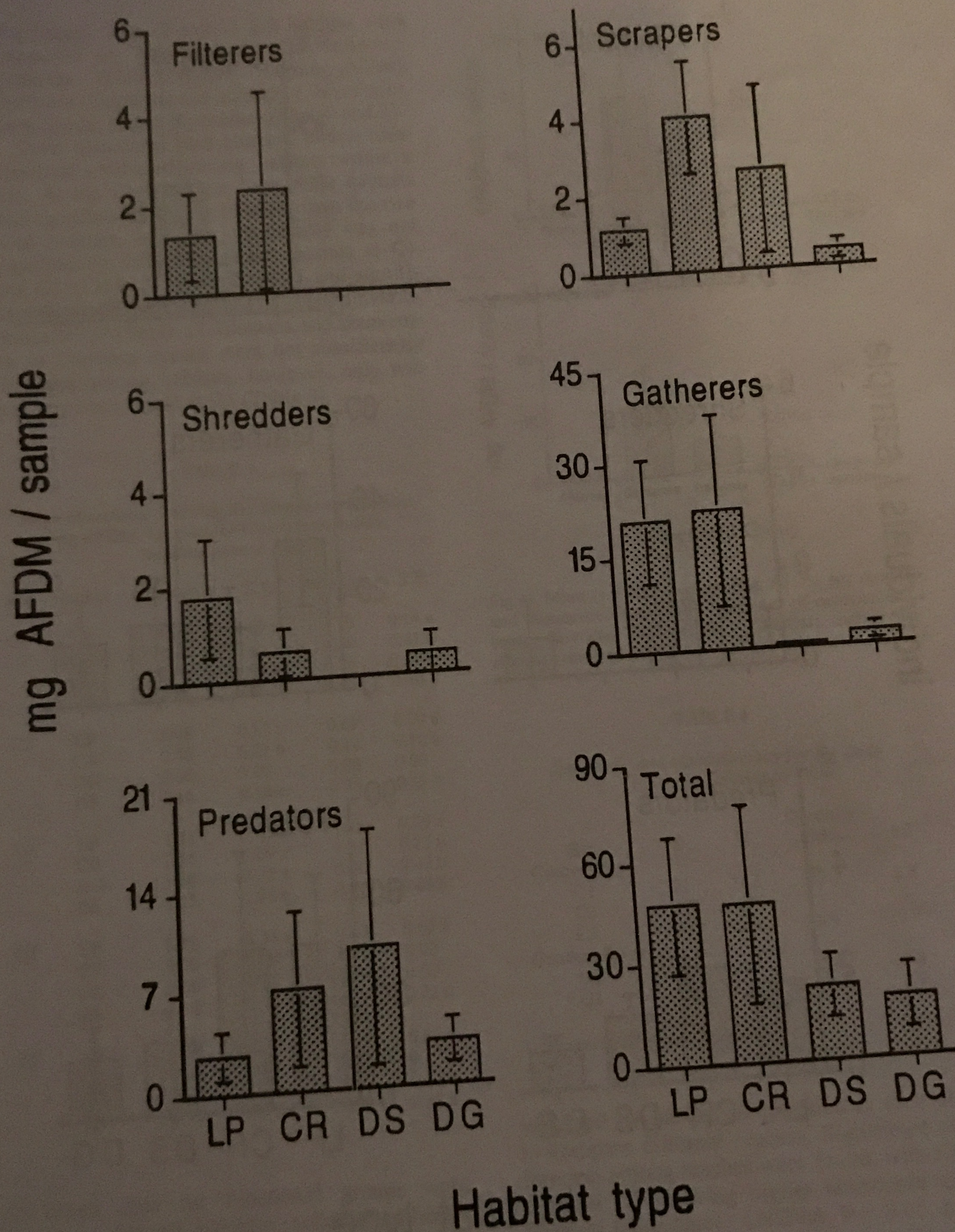


Fig. 2. Mean (± 1 SE) biomass of macroinvertebrates functional feeding group (mg AFDM / sample) in four habitat types (LP, leaf packs; CR, cobble-riffle; DS, depositional sand; DG, depositional gravel) for all reaches combined ($n = 5$). Note the different scales in the vertical (y) axis.

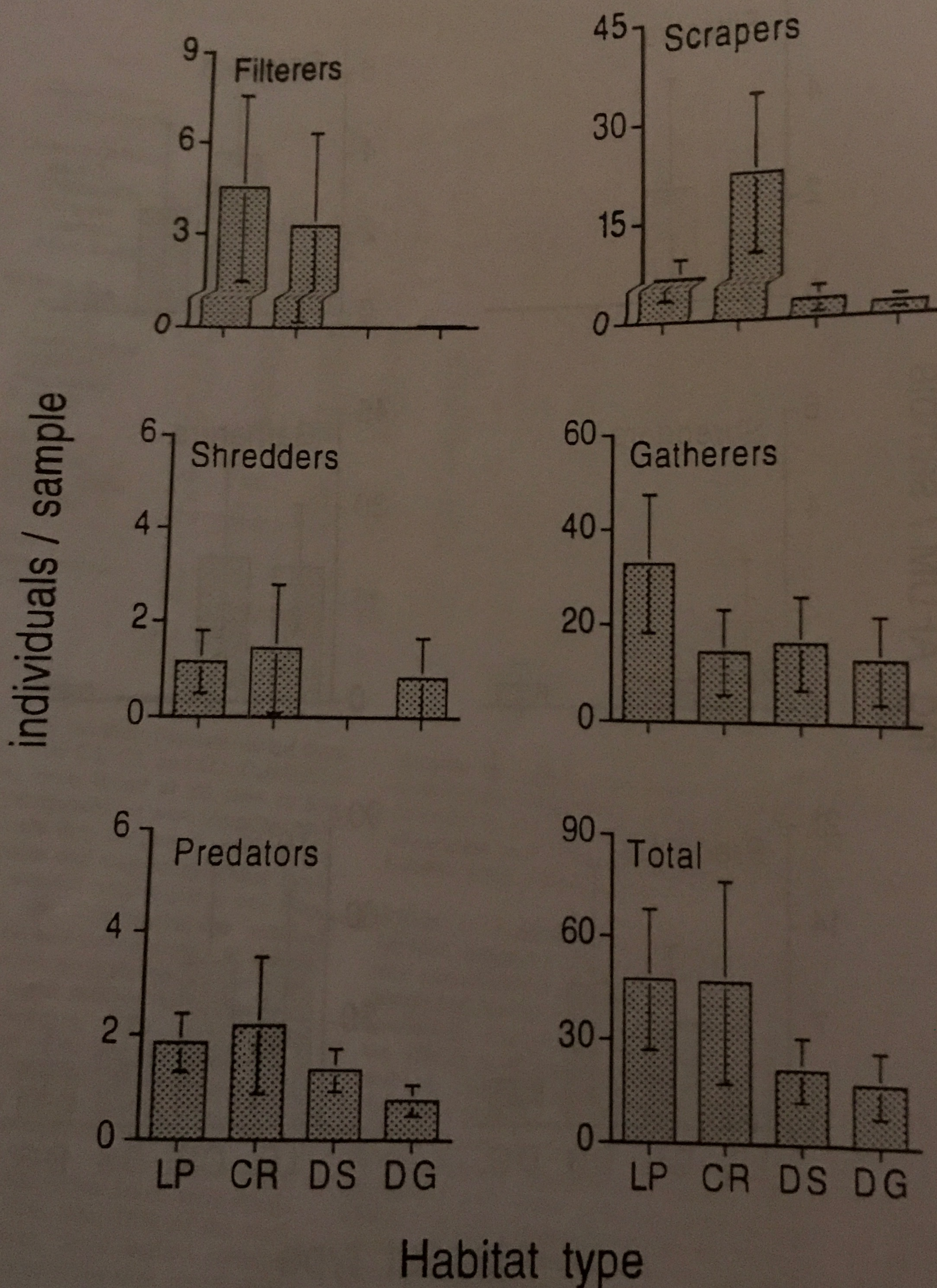


Fig. 3. Mean (± 1 SE) abundance of macroinvertebrates functional feeding group (individuals / sample) in four habitat types (LP, leaf packs; CR, cobble-riffle; DS, depositional sand; DG, depositional gravel) for all reaches combined ($n = 5$). Note the different scales in the vertical (y) axis.

(Tipulidae) (Figs. 2 and 3). CR habitats were composed by large numbers of collector-gatherers (Chironomidae, Leptohyphidae), predators (Odonata) and scrapers (*Thraulodes*, Gastropoda, Helicopsychidae) (Figs. 2 and 3).

Total abundance and biomass of macroinvertebrates differed among habitats within a site. At the Carbone river both riffle habitats had significantly higher biomass than the two pool habitats, however, abundance was not significantly different among habitats at C1 and C3 (Table 3), in contrast C2 had significantly higher abundance of macroinvertebrates in LP (Table 3). Biomass and abundance in Gandoca stream were not significantly different among habitats, however, only two habitats were found at G1 (Table 3).

TABLE 3

Mean abundance (individuals / sample) and biomass (mg AFDM / sample) for each stream habitat sampled at each site

Site	Habitat	Abundance	S.E.	Biomass	S.E.
C1	LP	1.93	0.09 a	1.78	0.14 a
	CR	1.45	0.46 a	1.39	0.41 a
	DG	0.81	0.41 a	0.76	0.39 b
	DS	1.31	0.66 a	0.43	0.30 b
C2	LP	1.48	0.17 a	0.69	0.09 a
	CR	0.46	0.24 b	0.14	0.10 b
	DG	0.00	0.00	0.00	0.00
	DS	0.16	0.16 c	0.35	0.35 c
C3	LP	1.91	0.43 a	1.35	0.25 a
	CR	2.25	0.09 a	1.91	0.23 a
	DG	1.66	0.25 a	0.69	0.42 b
	DS	1.25	0.63 a	0.87	0.69 b
G1	LP	0.38	0.38 a	0.63	0.63 a
	CR	0.00	0.00	0.00	0.00
	DG	0.00	0.00	0.00	0.00
	DS	1.13	0.22 a	1.11	0.22 a
G2	LP	1.38	0.17 a	1.29	0.67 a
	CR	1.06	0.07 a	0.90	0.17 a
	DG	0.80	0.42 a	0.54	0.33 a
	DS	0.77	0.15 a	0.78	0.38 a

When data for functional groups were grouped for all habitats, collector-gatherers and scrapers showed the highest abundance (Fig. 4). Collector-gatherers and predators were highest in terms of biomass.

Biomass and abundance data were also

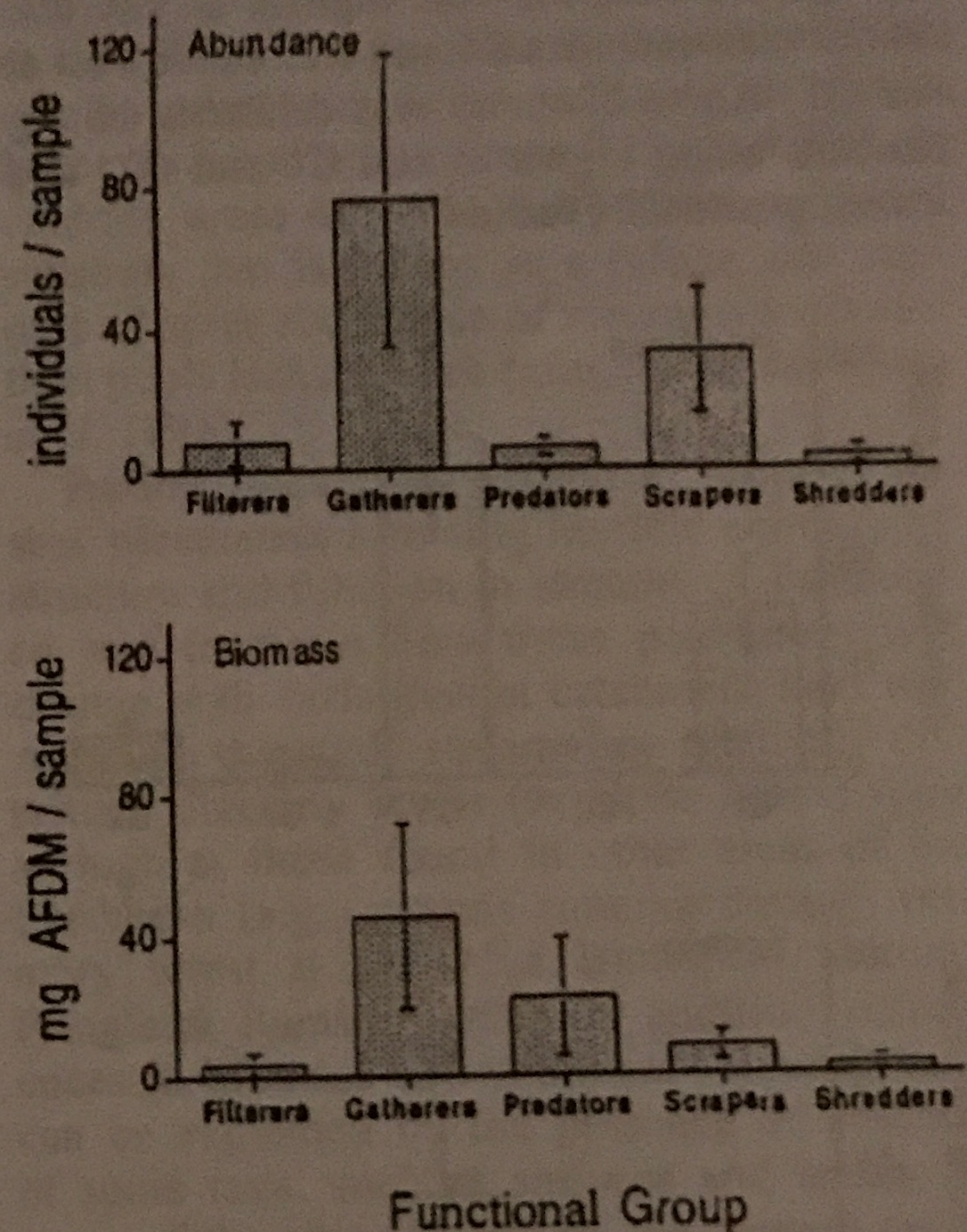


Fig. 4. Mean (± 1 SE) biomass (mg AFDM per sample) and abundance (individuals / sample) of macroinvertebrates functional feeding for all habitats and groups reaches combined ($n = 20$).

TABLE 4

Species (S) and alpha diversity for the study sites in Talamanca

Site	S	N	Diversity alpha	SE
Carbon River				
C1	21	162	12.7	3.8
C2	11	19	-	-
C3	32	331	8.9	0.9
Gandoca River				
G1	9	23	5.4	1.8
G2	22	55	13.5	2.9

S=richness, N=number of individuals

weighted by habitat composition at each site to compare different reaches. Significant differences among reaches were found, with sites C1 and C3 showing higher abundance and biomass (abundance: ANOVA, $P < 0.05$; biomass: ANOVA, $P < 0.05$) than sites C2, G1, and G2, which were similar among themselves (Fig. 5). Comparisons of the reaches showed