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Characterization of some Golfo Dulce drainage basin rivers (Costa Rica)

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Abstract: Basic physico-chemical parameters and benthic invertebrate diversity were measured from several streams that drain into the Golfo Dulce (southern Pacific coast of Costa Rica) during 1996-1997. A total of 15 sites were visited in the Osa Peninsula, and the Esquinas and Coto-Colorado river basins, all under 100 m in altitude. Dissolved oxygen and suspended solids differed among sites, even though dissolved oxygen always showed values within a narrow range above 75% saturation, meaning that no site had oxygen deficit at the time of sampling. Suspended solids varied greatly: rivers with high values also had low values during low discharge. A cluster analysis based on the physico-chemical data yielded two groups separated mainly by the variability and maximum value of suspended solids. The benthic fauna is poor in species and is composed of insect larvae (48 species), crustaceans (seven species, of which three are freshwater species) and other three invertebrate species. The most abundant groups were Ephemeroptera and Decapoda. Total diversity was also quite variable (range 1-22 species depending on site). Diversity is best explained by substrate type and suspended solids load.

Key words: Tropical rivers, benthos, diversity, water quality, temporal variability, Golfo Dulce.

The rivers that drain into Golfo Dulce, south Pacific coast of Costa Rica, are important since they serve as vehicles of transport of materials and nutrients towards the gulf, considered as a unique site in the neotropics given its similitude to a fjord, with a deep anoxic basin in its most internal zone (Thamdrup *et al.* 1996, Córdoba & Vargas 1996). Rivers reflect with great fidelity the environmental situation of its drainage basin, receiving all the impact of human activities as agriculture, forest clear cutting, urbanization and industry (Mason 1984). The materials they receive are at the same time transported downstream finally into the sea.

The study of the rivers in the Golfo Dulce basin was first proposed as a way to evaluate the connection between terrestrial and marine ecosystems. This work gives a brief description of some of the main tributaries of the rivers Coto-Colorado, Esquinas, and those located in the internal arc of Osa Peninsula, among which stand out the rivers Rincón and Tigre.

The rivers in this region have been historically exposed to the impact of human activities in their catchments. These included banana and oil palm plantations, with all the channelization that these crops require (Chamorro 1989). There has been also forest clear cutting for cattle raising, urban growth and gold mining activities (González 1992, Vargas 1992). These activities are supposed to produce alterations in the rivers that receive

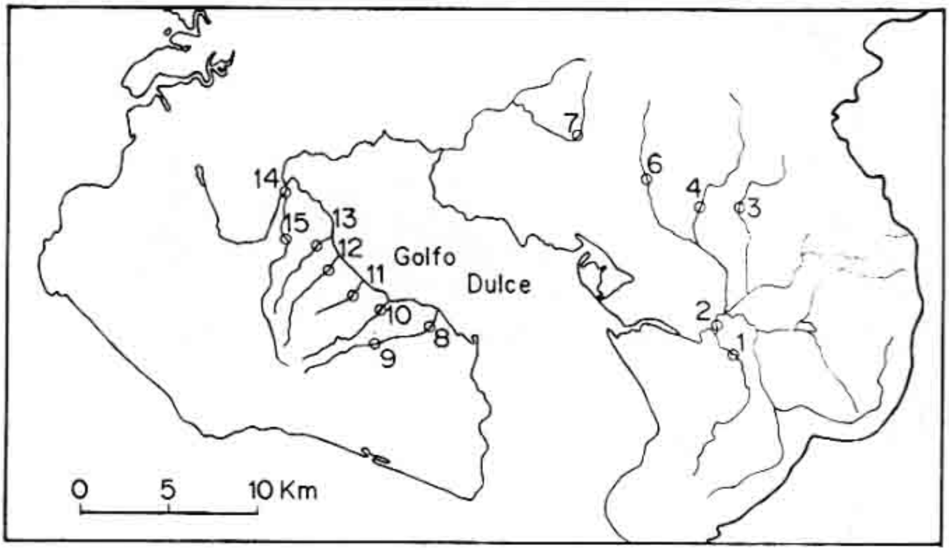

Fig. 1. Map of Golfo Dulce area, showing main rivers and sampling sites. More details on Table 1.

high loads of solids in suspension, organic matter as solid wastes, domestic waste water and fecal matter, as well as toxic wastes from the pesticide treatment of the plantations. Fecal contamination is not expected to be high since the population density is for the most part low (Anonymous 1990) and there are no sewage collecting systems, but most sewage is dealt with in septic tanks or latrines, which slow down the sewage from getting into the surface waters.

During the climax of the banana activities a high load of pesticides are suspected to have reached the rivers, mainly the Esquinas and Coto-Colorado. A high load of cooper was used at the time to control fungi infestation, which rendered the land useless for most agriculture, including the banana itself (Chamorro 1989). Due to several problems including climate, economics and poisoning of the land, the banana plantations run by the main company were closed in the region by 1983 (Chamorro 1989), but some minor fincas remained in activity since then until today. In the Osa Peninsula the mayor impact has been placer gold mining. The site has been considered a productive one and is far from been exhausted from its gold reserves (Berrange 1992). The main impacts of gold mining in Osa have been reviewed by González (1992) and Vargas (1992) and they list the increase in suspended solids load, increase in erosion of river bed and banks, elimination or riverine vegetation and channel rectification. Mining was almost completely stopped in 1986 when most artisanal miners were thrown out of Corcovado National Park (González 1992). The deterioration of the rivers can cause an impact at the sea, for example the sediments that finally deposit at the sea can cause mayor damage in the coral reefs of the gulf (Cortés 1992), also the change in the materials deposited at the bottom from sand to terrestrial clays may cause community shifts in bottom dwelling marine organisms with not yet determined impacts on trophic chains and productivity. Another impact is the increased fertility of the coastal waters with the input of nutrients washed in by the river.

MATERIALS AND METHODS

Sampling: A total of 15 sampling sites were chosen in the tributaries of the main rivers in Golfo Dulce basin: Coto-Colorado, Esquinas, and the internal arc of Osa Peninsula. The complete list is shown in Table 1 and their localization is given in Fig. 1. The sites were visited once to four times between July 1996 and October 1997. All sites were visited

TABLE 1

Geomorphologic and geographic parameters of the studied catchment basins

Site	Site Altitude m	Area of the basin Km^2	Maximum altitude of the basin m	Channel order	Total channel length Km	Forest percent cover %	Mean slope	Drainage density	Substrate type
01-Coto-Colorado (at the Ferry)	20	878.4	1681	5	968.5**	30	1.44	1.10	Sand and clay
02-Conte 1 (at Pavones)*	20	107.2	547	4	99.2	33	1.11	0.93	Sand and clay
03-Caracol	35	18.0	1300	2	15.6	30	6.52	0.87	Boulders to pebbles
04-Claro	18	86.8	1681	3	63.9	60	7.18	0.74	Boulders to pebbles
05-Lagarto	35	49.6	1300	2	33.6	90	10.85	0.68	Boulders to pebbles
06-Coto-Colorado (at the highway)	70	22.8	1676	2	11.8	90	7.77	0.52	Boulders to pebbles
07-Esquinas	80	34.8	1643	3	31.9	80	16.67	0.92	Boulders to pebbles
08-Tigre	5	111.6	745	4	112.8	60	3.38	1.01	Boulders to pebbles and sand
09-Tigre Ar*	70	15.2	745	2	14.1	80	6.37	0.93	Boulders to pebbles
10-Agujas	15	22.0	701	3	29.4	40	4.90	1.34	Boulders to pebbles
11-Sabala	15	7.2	329	1	10.5	0	1.98	1.46	Pebbles and sand
12-Barrigones	15	21.6	615	2	21.8	40	3.24	1.01	Boulders to pebbles
13-Conte 2 (at Osa Peninsula)	18	23.0	380	2	18.6	30	1.58	0.81	Boulders to pebbles
14-Rincon	2	231.6	745	4	104.3	70	2.12	0.45	Sand and clay
15-Rincon Ar*	30	86.8	745	3	70.0	90	3.37	0.81	Boulders to pebbles

* Visited only once. ** Includes 287 Km of artificial drainage channels from banana and oil palm plantations.

within two days in each field trip. The following parameters were measured in each visit: temperature, dissolved oxygen, pH, conductivity, alkalinity and total hardness. Water samples were also taken for total suspended solids, nitrate and soluble reactive phosphate determinations, according to standard methods (Strickland & Parsons 1968). Samples were kept in a freezer and brought to the laboratory for filtering and further analysis. Total solids were measured by filtration in previously dried and preweighted glass fiber filters.

In each site benthic samples were taken using a hand net with 1 mm mesh size, with which the substrate was scraped trying to cover all habitat types present in each site. Sampling was standardize by searching for fifteen minutes en each site, within a reach of 10 m of length. All organisms were sorted from debris at the field and preserved in 70% ethanol, later they were counted and identified to major taxonomic group and separated as morphospecies, for diversity calculations. Specimens were kept at the Museum of Zoology of the University of Costa Rica, for further identification and analysis.

Geographical (such as drainage basin morphometrics, forest percent cover of each basin), weather, and geological information of the drainage basins studied were also gathered from available maps and other sources (Savitsky *et al.* 1995, Tournon & Alvarado 1997, IMN weather data).

Only those sites visited more than once were considered for statistical analysis. Sites were compared for each parameter, including diversity values and species richness, using One Way Analysis of Variance. A Principal Components analysis was used to group the sites according to the physico-chemical and geographical data. The data on species composition was analyzed with the Jaccard simillarity index on the accumulated species list for each site, and a Cluster analysis was performed using the Jaccard similarity transformed into distance by substrating Jaccard from unity.

Rivers: The biggest drainage basin is Coto-Colorado's, and perhaps the most accessible to the different tributaries, so that several stations were located in this basin both in tributaries and in the lower part (Table 1). The river Esquinas was only sampled along the Interamerican Highway. The Osa rivers were sampled along the road to Puerto Jiménez.

Forest cover was calculated using the Habitats of Costa Rica map (Stavinsky *et al.* 1995), which is updated up to 1992. Forest cover was estimated in 10% interval categories. According to Stavinsky *et al.* (1995) forest cover in the region has been reduced in the past, and the lower plains are almost completely deforested, being converted to pastures and agricultural land. Some microbasins are completely devoid of forest cover, such as Sabala brook, river Caracol and Conte (at Osa) (Table 1). Other rivers show high values of forest cover up to 90%, as is the case for Esquinas, Lagarto and Coto-Colorado (at the highway).

The substrate type varied among the sites. The sites located along the Interamerican Highway had substrates comprised of coarser riverbeds with boulders and pebbles. The channels are wide, with abundant sediment banks, and shallow. Coto Colorado river (at the Ferry) showed sandy to clay dominated sediments. In the Osa region substrates were more variable within sites, from boulders to sand banks in the same stream reach. Rincón river was the exception and showed a sandy to clay bottom. These rivers have wide channels, with low slopes and exposed sediment banks during low water periods. All rivers showed clear signs of high floods, specially after Cesar hurricane in September 1996.

The geology of the region is composed of marine deposits over intrusive igneous rocks of different age. Tournon & Alvarado (1997) show the existence of calcareous platform deposits in the lower parts of Talamanca, from the Eocene, and other marine deposits from the Oligocene-Miocene periods in the upper regions. In the Osa Peninsula the mountain tops show toleitic basalts from the Campanian (late Cretacic) to the Eocene period, overlaid by more recent marine sediments. The lower parts of each basin are composed by quaternary alluvial deposits. The weather in the region has been classified as hot (temperatures usually above 23 °C), humid to very humid by Herrera (1985). The region shows a short dry season from January to March or early April. Annual rainfall ranges from 2 700 up to more than 6 800 mm. During 1997 rainfall was reduced by 23% of the historical mean due to the El Niño Southern Oscillation effect according to the National Meteorological Institute data from one station in the region.

RESULTS

Physico-chemical parameters: Fig. 2 summarizes mean values, stantdard deviations, and standard errors of the physico-chemical parameters measured. Temperatures (Fig. 2A) were high, maximum range varied from 26 up to 33 °C; Osa Peninsula sites had higher values ($F= 2.18$, $\alpha<0.05$). Oxygen levels (Fig. 2B) were generally high, varying between 5.6 and 8.6 $mg \cdot l^{-1}$, with saturation values of 73% and 110% respectively. Greater values corresponded to rivers Claro, Caracol and Coto Colorado (at the highway), meanwhile lowest values were normally observed at rivers Rincón, Sabala and Coto Colorado (at the Ferry) ($F=4.49$, $\alpha<0.01$ for dissolved oxygen, and $F= 4.11$ $\alpha< 0.01$ for percent saturation).

pH values were always alkaline, oscillating between 7.75 and 8.0. Values were higher in the Coto-Colorado basin, with 8.0 values normally observed, whereas at the Osa Peninsula values were around 7.75. This is a small difference that was significant among sites ($F= 2.91$, $\alpha<0.05$) due to low variance of this parameter. Alkalinity (Fig. 2C) showed significant differences among sites ($F=5.63$, $\alpha<0.01$). Values varied between 85.5 and 248.2 mg $CaCO_3$ l^{-1}. The rivers Esquinas, Coto (at the highway), Claro and Caracol showed values above 120 mg $CaCO_3$ l^{-1}, rivers in the Osa Peninsula showed values less than that, except for river Sabala.

Total hardness (Fig. 2D) ranged from 85.6 to 213.75 mg $CaCO_3$ l^{-1}, with the values from

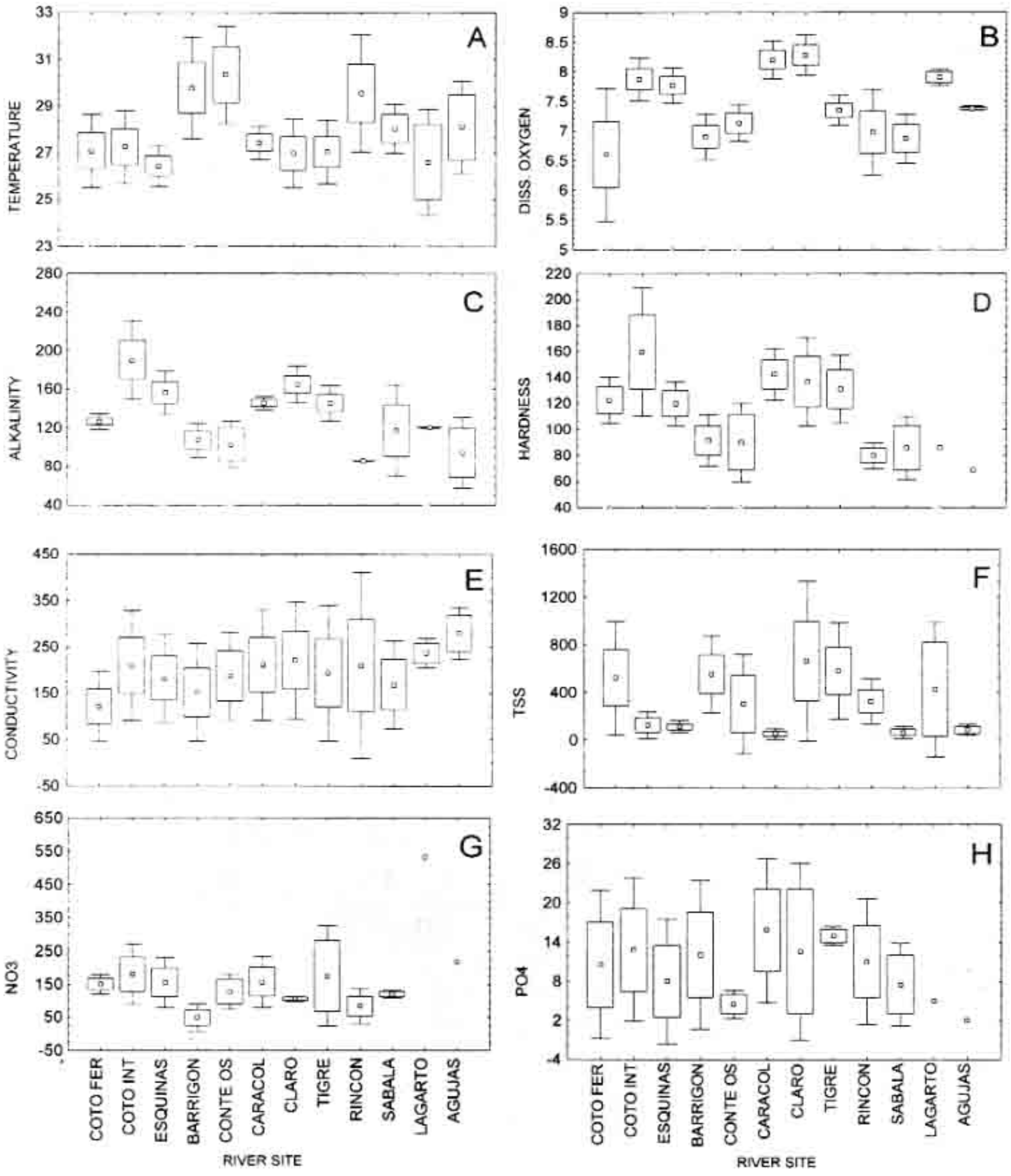

Fig. 2. Variation of physico-chemical parameters of selected sites. Figures show means, standard errors and standard deviations.

Coto Colorado and Esquinas basins greater than the Osa Peninsula ones, with the exception of Tigre river (F=2.77, α< 0.05). Conductivity (Fig. 2E) varied between 114.6 and 500 MSi/cm^{-1}, with a global mean of 191.1 MSi/cm^{-1}. There were no significant differences among sites, in part due to high variability within sites (F= 0.35, α>0.05). In general, sites from the Coto Colorado basin were above the general mean and those from Osa Peninsula or Esquinas basin were lower than the mean. At Rincón river very high values were observed as a consequence of the tide influence since the site was closest to the sea.

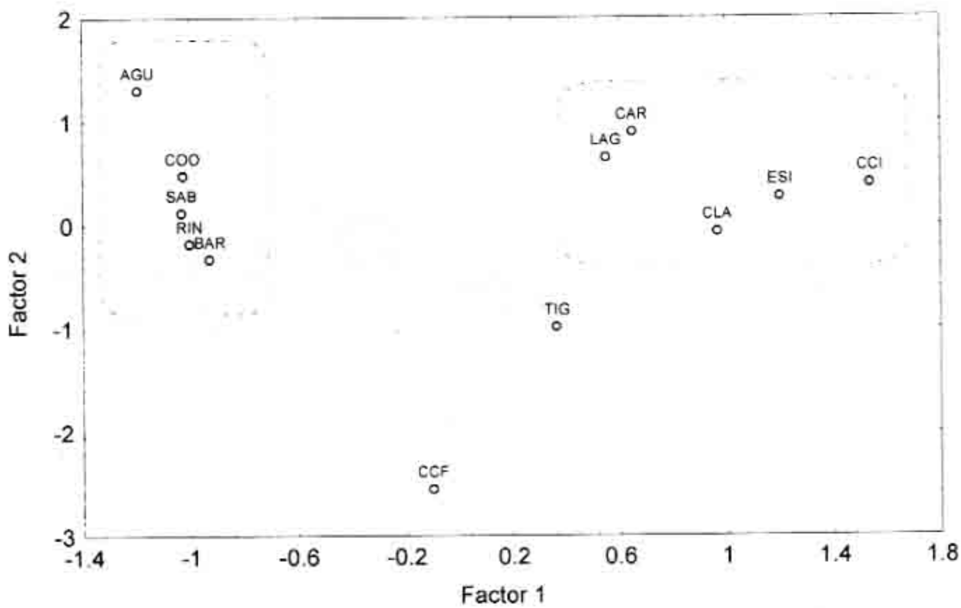

Fig. 3. Factor scores scattergram of those sites more than one sampling date, base on the first two principal components on mean values of the physico-chemical and geographical data ($\lambda_1 = 5.19$; $\lambda_2 = 2.33$; Cumulative percent variance = 62.7%).

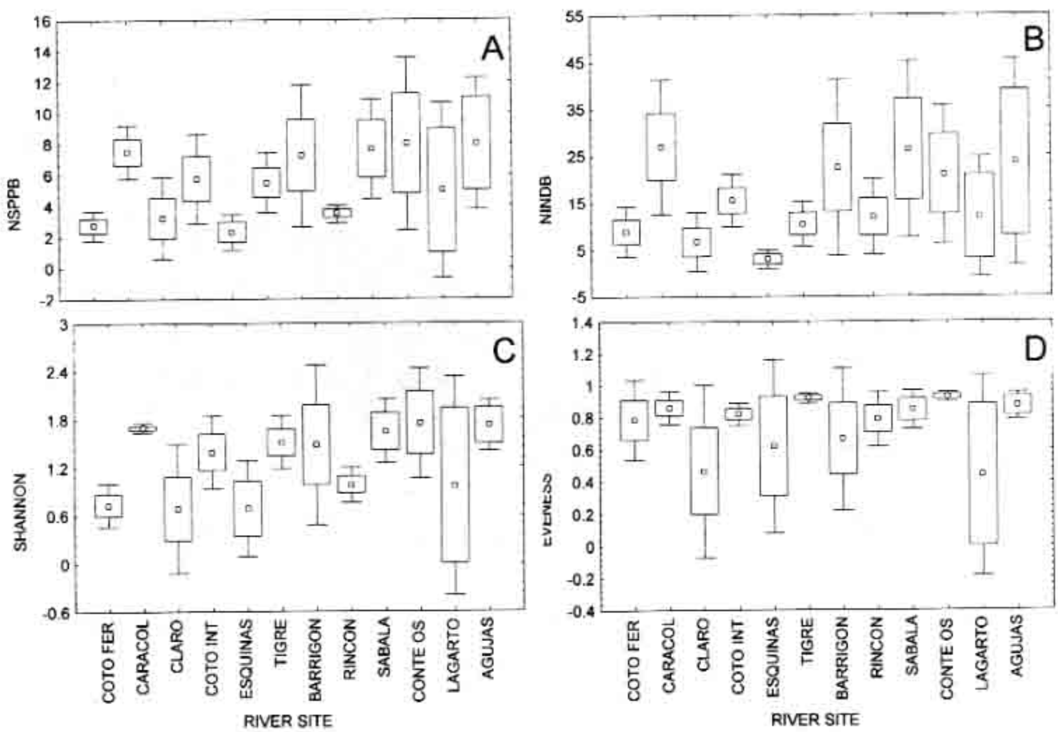

Fig. 4. Variation of biological parameters evaluated on selected sites. Figures show means, standard errors and standard deviations.

Suspended solids (Fig. 2F) varied between 19.5 and 1452.0 $mg \cdot l^{-1}$. An extreme value of 4287.5 $mg \cdot l^{-1}$ in Coto Colorado river (at the highway), was the result of the removal of the river bed by tractors for the construction of dikes during the October 1997 visit, was not included in the analysis since it was not the result of normal conditions in the river. This parameter varied the most among sampling dates in some rivers like Claro and Coto Colorado (at Ferry) and Lagarto. This high variability does not allow to detect statistical significant differences among the sites ($F=1.45$, $\alpha>0.05$), nevertheless, some rivers (Sabala, Esquinas, Coto Colorado at the highway, and Caracol) present, under normal conditions, less variability and lower values of suspended solids than others (Conte (at Osa) Barrigones, Tigre, Claro, Coto Colorado (at the Ferry). These later rivers present also very low values and clear waters during the dry season.

Nitrate (Fig. 2G) oscillated between 30 and 282 mg $N\text{-}NO_3 \cdot l^{-1}$, with an overall mean of 141 ± 99. In general, rivers from the Coto-Colorado basin had values higher than the median (> 111.5). The differences among sites were significant ($F= 3.87$, $\alpha< 0.01$). Soluble reactive phosphate values (Fig. 2H) had little variation, between 2 and 28 mg $P\text{-}PO_4 \cdot l^{-1}$, with a global mean of 11.9 ± 9.02. This parameter didn't show any pattern of variation among the sites.

A Principal Components Analysis with the physico-chemical data for each site yielded the formation of two groups of sites clearly defined (Fig. 3). One group was formed by the stations Barrigones, Sabala, Conte (at Osa), Agujas and Rincón, all whithin Osa Peninsula. The other group contained the sites Esquinas, Claro, Coto-Colorado at the highway, Caracol and Lagarto, all draining from the Talamanca mountains. Two sites did not quite fit the pattern: Tigre and Coto-Colorado at the ferry. Theses results can be explained by the differences in alcalinity, hardness and conductivity among the different drainage systems around the Golfo Dulce.

Biological parameters: A total of 68 morphospecies were observed in a total of 684 specimens. The benthic fauna included besides aquatic insects, several species of mollusks, oligochaetes and crustaceans. The mean number of species per site and sampling date was 5.7 ± 3.4, ranging from 1 to 14 species (Fig. 4A). The accumulated number of species per site varied between 3 and 22, being higher in Barrigones river (with 22), Conte river (at Osa) with 19, and Sabala brook with 17, and lowest at Esquinas river with 6 species, Coto Colorado (at the Ferry) with 6 and Conte (at Pavones) with 3. The number of specimens captured by collecting effort varied between 1 and 46, with a mean of 15.2 ± 12.6 (Fig. 4B). Variability in the catching was high, with variation coefficients that oscillated between 31 and 81%. This variance preclude the detection significant differences among sites. It can be observed notwithstanding that some sites show higher species richness than others, specially the tributaries located at higher altitude like Caracol, Coto Colorado (at the highway), and Sabala brook, Barrigones and Conte rivers at Osa Peninsula.

Shannon's diversity index (H') showed a similar variation pattern as species richness, with no significant differences among sites ($F= 1.61$, $\alpha>0.05$). The global mean was 1.25 ± 0.64, with an absolute minimum of 0.00 in those cases where only one species was caught, and a maximum of 2.43 in Conte river (at Osa) (Fig. 4C).

Some rivers showed a high variation in species richness among dates, specially with a decrease in September 1996, after César hurricane, possibly as a result of the high floods that washed out the sediments and the fauna they harbored. In many cases the fauna had recovered by April 1997, as in rivers Barrigones, Conte (at Osa), Sabala and Caracol. In the rivers Claro, Lagarto and Coto Colorado (at the highway) the extraction of river bed materials and the construction of dikes during 1997 prevented this recovering.

A Cluster Analysis of the sites was performed based on the Jaccard similarity index calculated from the accumulated species list for those sites visited more than once (Fig. 5). In this case sites did not separated in two groups as when using the physico-chemical data, rather some sites appear separated from the rest with different degree of separation, especially Coto Colorado (at the Ferry) and Rincón. The main differences between these sites and the rest is the presence and relative importance of crustaceans in them compared

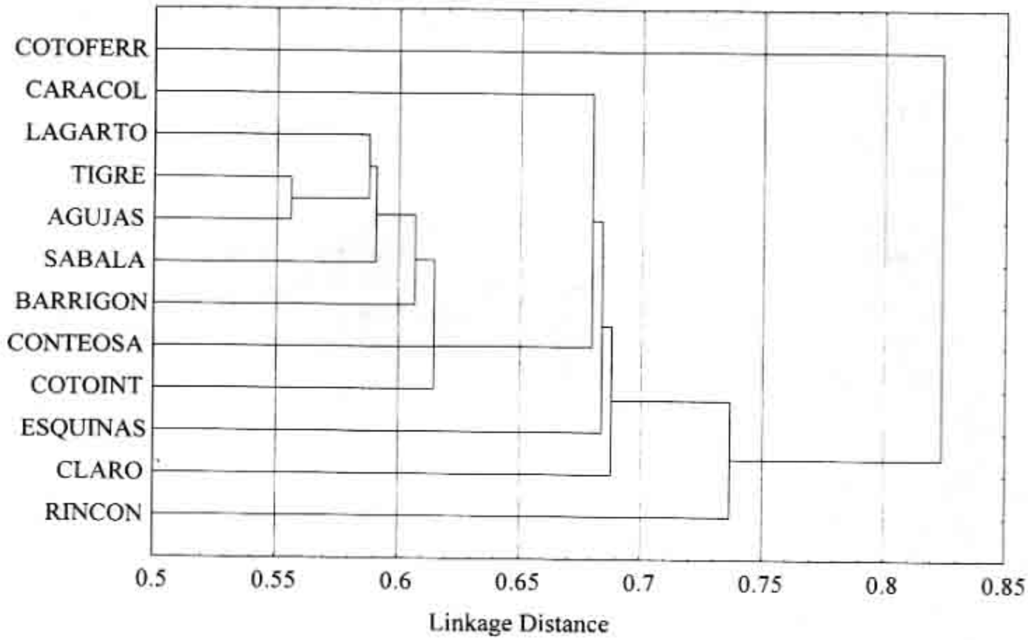

Fig. 5. Clustering of selected sites based on Jaccard similarity index (transformed as a distance by substracting from 1) calculated with the accumulated number of species per site. Clustering was performed with single linkage technique.

with other tributaries at higher elevations, as well as the absence of Diptera. Clossenes of the sampling site to the sea is mainly responsible for theses differences, other variables are substrate type and river bank vegetation, especially in the form of emergent grasses that provide a different habitat type, shelter and food at Coto-Colorado (Ferry).

DISCUSSION

The results of the chemical parameters measured in this study showed that the rivers present little signs of pollution or deterioration. For example oxygen levels were always high, indicating low organic pollution. Phosphate values were always low and nitrate levels were high only on some occasions. The general idea before the work started was thas the rivers in the region had a certain degree of deterioration because of the mining activities in Osa Peninsula in rivers Tigre, Agujas and Rincón (González 1992), and also the presence of the banana and palm oil plantations in the Esquinas and Coto Colorado basins. The parameter that showed some variability which could reflect the environmental situation of the studied rivers was suspended solids. Those rivers like Tigre, Rincón and Coto-Colorado with a greater expected deterioration due to historical known impact from minning and plantations, (Gonzalez 1992, Chamorro 1989) were more variable in suspended solids than those considered as clean or less affected. This effect is the result of deforestation and the localization of the sampling site, since sites located at lower altitudes receive a greater impact from the catchment area. Basin size was also important, since some of the most deforested basins, such as Sabala's basin, yielded low values of suspended solids due to its small size, whereas Esquinas river, as seen from the road to Jiménez, carries a heavy load of suspended solids, even though it has a high percent forest cover in its basin, that also includes part of the Esquinas National Park. As a result of the low values on the environmental parameters, the rivers are hypothesize to be in a b-mesosaprobial to oligosaprobial state according to Kolkwitz and Marson classification (Branco 1984). This is possible because the human population in the region is somewhat low (between 23 and 68 persons per square kilometer, Anonymous 1997), and their use mainly of septic tanks in urban and suburban locations.

The rivers from the Golfo Dulce catchment area have high alkalinity values in comparison with other Costa Rican rivers. An analysis of those sites sampled by Anonymous (1987) at heights less than 100 m above sea level, shows that the mean alkalinity for 26 sites from this data set is 69.12 (range 3.3 to 221.5), and mean hardness was 59.89 (range from 22.24 to 154.36). Sanford *et al.* (1994) report low alkalinity values for low land streams in the northeastern slope at La Selva, whereas Pringle, Triska & Browder (1990) report maximum alkalinity values of 220.0 mgl^{-1} for water flowing over Pleistocene lava flows at La Selva Biological Station, with a mean of 42.7 and a much lower value of 8.0 for water from Pliocene lava flows, as a clear indication of the importance of underlaying geology in the water chemistry of streams. In this study the alkalinity was higher in those rivers draining from the Talamanca Mountain Range than those from the Osa Peninsula mountains. This is an effect of the geological origin of the region, that is mainly composed of lifted marine deposits during several orogenic processes since the late Cretacic period (Castillo 1993, Tournon & Alvarado 1997).

Abundance and diversity was low in most sites. There are few tropical studies with which to compare these results. Stout & Vandermeer (1975) compared the diversity of the benthos at several tropical and temperate streams and concluded that tropical streams are more diverse. They sampled streams in southern Costa Rica, however they concentrated on first order streams in order to sample comparable sites at both latitudes, and used a different method of collecting and for estimating total species richness based on species area curves. They found a higher species richness of benthic insects at mid elevations than at lower elevations; they also report a higher variation between dry and wet seasons in species richness at a lower elevation in Agua Buena river than at a mid elevation site in the same river. The differences were evident however after a considerable collecting effort was simulated with their method. Flowers (1991) sampled streams in the Chiriqui region and concluded that there were no evidence of an altitudinal trend in benthic species diversity and species richness. He also reports values of species richness ranging from 14 up to 70, and found a great degree of similarity between sites, specially at lower elevations. Flowers & Pringle (1995) working only on Ephemeroptera found that even though there are considerable variations of abundance along the year, there is no a clear seasonal pattern since the actual timing of abundance peaks vary from year to year. They also found that river discharge did not predict well abundance changes. Pringle & Ramírez (1998) also found no effect of altitude working on streams at La Selva Biological Station in the north Atlantic slope of Costa Rica. They report species richness values between 20 and 34. Trihadiningrum *et al.* (1996) reports low Shannon index values from the Blawi river (East Java), ranging from 0.60 to 2.10, and species richness between 9 and 28 species. The accumulated number of species observed in this study are lower than those reported from the literature, although sampling procedures were not always equivalent.

Several reasons can account for these low values, not necessarily associated with toxic or organic pollution. One is the nature of the substratum, sites with finer substrata have less developed benthic fauna due to fewer microhabitat diversity and substrate instability (Hynes 1970, Ward 1992). Other reason is frequency and magnitude of substrate disturbance (Stout & Vandermeer 1975, Trihadiningrum *et al.* 1996), either due to high floods or direct human disturbance. There has been a discussion on whether disturbances maintain diversity or not (eg. Begon, Harper & Townsend 1990), in this case, it is the magnitude of the disturbance that prevents the maintenance of an abundant and rich fauna, as discussed by Ward (1992). Some rivers as Esquinas, which had one of the lowest species richness, seemed to suffer frequent high floods and the boulders that covered its bottom were angular, not rounded; besides, during the sampling period flow was concentrated in one central channel, increasing its speed and turbulence. Other rivers such as Claro, Lagarto and Coto Colorado (last date) were being disturbed from mine operations and dike construction. These operations are usually done with tractors entering the river bed, increasing the total suspended load and disrupting the coarser substrate. Other reason, not considered here, may be a high abundance of predators as fish

(Paaby pers. com.) since fish fauna is more diverse and abundant in the lower reaches of Costa Rican rivers (Bussing 1987).

Not all sites recovered equally from the Cesar hurricane spates which occurred in late July 1996, after the first sampling visit. This difference may be due to availability of new colonizing individuals either upstream or whithin the hyporheic zone (Ward 1992), The reduced fauna in those rivers with frequent floodings has been observed for other systems (Hynes 1970, Bishop 1973). This effect should be considered in environmental impact assessments related to river bed mine extractions and other human disturbances on river ecosystems since benthic communities are important in river ecology as food for fishes and in the processing of organic matter in the system (Hynes 1970).

The classification of the sites based on their benthic fauna did not separated the same groups obtained with the physico-chemical data. This is not due to a high similarity among sites, since the highest similarity was of 0.50, and the mean number of species per site is far lower than the total species list. A few more abundant species were also the more frequent ones, being present in almost all sites, except for those with different substrate and current patterns, which are Coto Colorado (at the Ferry), Rincón and Conte (at Pavones). These sites were among the most different of the rest. This implies a little correspondence between water quality, apart from total suspended load, and biotic indices such as species richness and diversity.

Several times it has been expressed the view that aquatic organisms should be good indicators of environmental conditions, since they spend their lives in the water and experience the presence of all pollutants, even if those chemicals are added at intervals to the water so that a chemical analysis may not detect them (Hawkes 1979, Branco 1984, Lampert & Sommer 1993). It seems evident from the present analysis that a more deep understanding of the taxonomy of these invertebrates is needed in order to achieve this level of biological environmental assessment, because it's the composition and not only the total diversity alone which may reflect better the impact of a given environmental disturbance.

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RESUMEN

Durante 1996-1997 se estudiaron algunos parámetros químicos y biológicos en diferentes ríos que desaguan en el Golfo Dulce. En total se han visitado 15 sitios desde la Península de Osa hasta el Río Coto Colorado, todos a altitudes inferiores a 100 m. Se midió temperatura, oxígeno disuelto, alcalinidad, dureza, conductividad, sólidos en suspensión, tipo de sustrato, diversidad del macrobentos. El oxígeno disuelto, su saturación porcentual, y los sólidos en suspensión mostraron diferencias significativas entre sitios, aunque en el caso del oxígeno disuelto el ámbito total de los valores es estrecho, con valores de saturación por encima del 75%, revelando que en los sitios de muestreo este factor no presenta problemas serios al ecosistema acuático. Los niveles de sólidos en suspensión fueron muy variables, especialmente en los ríos que alcanzaron valores altos. Un análisis de grupos con base en los datos químicos mostró que existen dos grupos separados por la variabilidad y valor máximo, principalmente de sólidos en suspensión. La fauna es pobre, se compone de larvas de insectos (48 especies), crustáceos (siete especies, tres de agua dulce) y otros (tres especies). Los grupos más abundantes son Ephemeroptera y Decapoda. La diversidad total es variable, desde sitios con una sola especie hasta sitios con 22 especies. La diversidad parece ser explicada principalmente por el tipo de sustrato y solidos en suspensión.

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