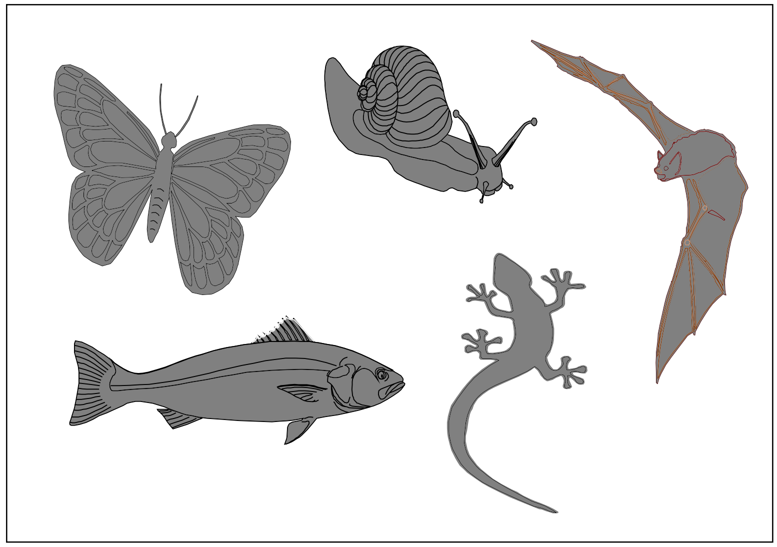

Aquatic Systems: Biodiversity Assessment at the Pagoreni Well Site

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Introduction

Tropical plant and animal communities are usually diverse, displaying a high number of species and complex relations compared to communities in the temperate zone (Lowe-McConnell 1987). The freshwater fish fauna of South America is the most diverse in the world, consisting of approximately 60 families and 5000 species (Bohlke et al. 1978). Biodiversity studies of the neotropical ichtyofauna have increased in Perú during the last decade, particularly assessments of species richness in the Amazon watershed (Ortega and Chang 1992).

Water-quality monitoring methods have traditionally focused on chemical parameters; biological parameters have been secondary to these methodologies. However, chemical analyses represent only the time at which a sample is taken, and they often do not reflect changes in time such as intermittent polluting discharges (Lynch et al. 1988). On the other hand, the evaluation of biological communities provides more accurate information because organisms quickly respond to perturbations, and they can be used to detect changes due to intermittent or chronic pollution (Tuffery and Verneaux 1968). In general, it is recognized that biological and chemical data are complementary in analysis of water quality (Cairns and Dickson 1971).

Freshwater organisms that best reflect environmental quality are those with limited or no mobility; for example, some benthic acroinvertebrates (Hawkes 1978).

One of the main purposes of this study was to evaluate biodiversity in disturbed and undisturbed aquatic systems at the Pagoreni well site, considering species richness and abundance.

Several studies have analyzed the community structure of these creatures to determine freshwater physical and chemical changes (Cross 1984, Johnscher-Foransaro and Zagatto 1987, Guerrero and Lloyd 1992). Analysis of community structure and distribution, based on biological diversity indexes, has provided abundant information regarding a particular water body. Such analysis can indicate 1) chemical pollution or physical perturbation that reduces the number of organisms in the water, 2) substrates that may obstruct the development of benthic communities, and 3) severe organic pollution that prevents the survival of tolerant individuals (Johnscher-Fornasaro and Zagatto 1987).

The objective of this study was threefold—first to evaluate biodiversity in disturbed and undisturbed aquatic systems at the Pagoreni well site, considering species richness and abundance; second to test a standardized protocol that was developed in the Phase IV workshops and methodologies for future monitoring; and third to train young Peruvian biologists in the protocol and methods. The information presented in this paper serves as a reference point for determining the evolution of perturbations at the same site and for comparing with data from similar localities.

Study Area

The study was conducted around Pagoreni well site located between the Urubamba and Camisea rivers (11^{0}42'22.5"S, 72^0 54'10.7"W). Elevations vary between 350 and 465 meters (m). We explored the area using four trails (Camisea, Mirador, Chinook and Boddicker) and studied the following small watersheds within the area of influence of the well site (Fig. 1).

* Chátaro Creek (CHA) flows to the north and receives soil effluents from construction. Two tributaries of Chátaro Creek are Chomenta (CHO) and Oshetoato (OSH) creeks.

* Yopuato 1 Creek (YO1) flows southwest; it was dammed to supply water to the camp. The medium-lower course of the creek receives organic effluents from Unión Creek (UNI). Cristal (CRI) and Irapitare Kimaro (IRA) are tributaries of Yopuato 1 and Unión creeks.

* Yopuato 2 (YO2) flows southeast and receives the majority of organic effluents from the camp. Carachama (CAR) is the major tributary, and we sampled along that waterway.

We also took samples at Jurioato Creek (JUR), which flows northeast over the chinook trail and experiences negligible impacts from the well site. We sampled this stream because it represented an undistrubed system.

The names of the creeks were supplied by members of the Shivankoreni community who were part of the field team.

The hilly topography of Pagoreni favors the formation of steep-sloped watersheds, rocky substrate, and rapid drainge. Along the waterways the steepness of the slopes decreases, and the substrate changes to a more complex formation containing particles of various sizes.

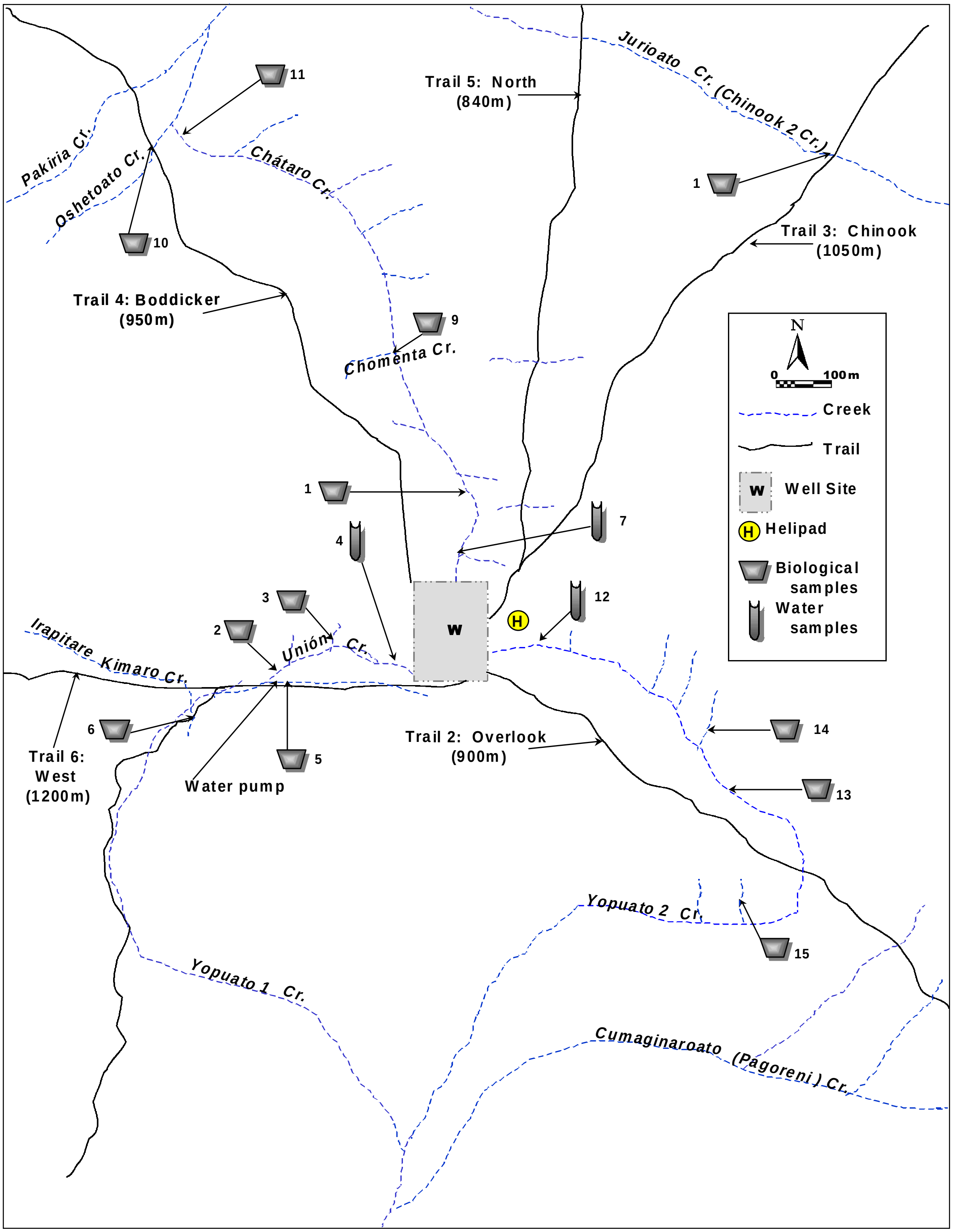

Figure 1. Diagram of Pagoreni well site and surrounding area showing where biological and water sampling was conducted for the aquatic systems study.

Table 1. Sampling stations at the Pagoreni well site

Station	Reference	Distance to platform (m)
PA(CHA)U	Upper Chátaro Creek	100
PA(CHA)M	Middle Chátaro Creek	400
PA(CHO)L	Tributary of Chátaro Creek	500
PA(CHA)L	Lower Chátaro Creek	850
PA(OSH)L	Lower Oshetoato Creek	850
PA(JUR)L	Lower Jurioato Creek	1000
PA(YO2)U	Upper Yopuato 2 Creek	100
PA(YO2)M	Middle Yopuato 2 Creek	400
PA(CAR)L	Tributary of Yopuato 2Creek	400
PA(YO2)L	Lower Yopuato 2 Creek	800
PA(CRI)L	Tributary of Unión Creek	200
PA(UNI)U	Upper Unión Creek	200
PA(UNI)L	Tributary of Yopuato 1 Creek	500
PA(YO1)M	Middle Yopuato 1 Creek	500
PA(IRA)L	Tributary of Yopuato 1 Creek	700

Methods

Establishing Sampling Stations

The sampling was conducted from April 20 to May 4, 1998. During the first four days, we explored the surroundings of the drilling site and located water bodies for sampling. We defined two types of creeks within the watershed system and selected only permanent creeks for evaluation. We then divided the creeks into two categories: treatment creeks and control creeks. Treatment creeks showed evidence of direct impacts from drilling activities at the well site, including organic effluents and sediments that could be seen in the river bed. Control creeks showed no sign of impact from the well site.

We established a total of 15 sampling stations in the following creeks: Chátaro, Jurioato, Unión, Yopuato, and tributaries (Table 1). Sampling stations were located clockwise, departing from the drilling site. Each station was assigned a code composed of three elements, as follows:

PA (_ _ _) U/M/L, where PA=Pagoreni, (_ _ _)=the first three letters of the creek name, and U/M/L=upper, middle, or lower water course of the stream. Thus the code PA(UNI)U represents Pagoreni, Unión Creek, upper course.

Water: Physical and Chemical Evaluation

At each of the sampling stations, we registered the physical features of the creek (depth, width, substrate) and, using a mercury thermometer (-20C to 110C), the water and air temperatures. A handy limnological tool (Hach AL-36B) was used to determine the following chemical parameters:

O_2 (mg/l), pH, CO_2, total alcalinity (grains per gallon [gpg] $CaCO_3$, where grains=0.0648 grams and a gallon=3.785 liters), nitrates (mg/l), and total hardness (gpg $CaCO_3$).

Biological Evaluation
Qualitative Analysis

* Plankton. To conduct the plankton sampling, we considered only major creeks forming permanently irradiated pools. These creeks ensured high productivity and therefore good-quality samples. We swept the pools with a standard net (No. 25) tied to a wide-mouth packet to assist in countercurrent sweeping. All samples were fixed in 5% formaldehyde and placed in sealed, labeled vials.

* Macroinvertebrates. We sampled macroinvertebrates using hand nets and stirring up the water over the substrates (stones, rocks, litter, etc.) as much as possible. Conspicuous organisms were then placed in labeled vials in 70% ethyl alcohol. To minimize the amount of inorganic material, the samples were sifted (see quantitative sampling below). The macroinvertebrate specimens were separated and identified to the genus level from the following identification keys: Benedetto (1974), Flint (1978), Correa et. al. (1981), Merrit and Cummins (1984), Domínguez et. al. (1992), and Magalhaes and Turkay (1996). Analysis for materials such as litter was done in the laboratory.

* Fishes. Fishes were sampled in major creeks, where previously seen, with a sweep net (4 m x 1.5 m; 4 millimeter [mm] mesh size) and a hand net. The sweep net was used in small pools along the creeks, and the hand net was used in running water where the substrate had been disturbed (pebbles and small rocks). Fish samples were fixed in 10% formaldehyde for 24 hours. In the laboratory, the samples were separated by species and preserved in 70% alcohol. Taxonomic identification was completed using keys and descriptions, including Eigenmann (1927), Fowler (1945), Gery (1977), and Burgess (1987).

Further processing and identification of plankton, macroinvertebrate, and fish samples was conducted at the Museo de Historia Natural of the Universidad Nacional Mayor de San Marcos and at the Universidad Nacional Agraria "La Molina."

Quantitative Analysis

Quantitative evaluation was conducted only for benthic macroinvertebrates. The distance between sampling points was determined randomly, and the width was determined using the highest water line or erosion point. Ten sampling points were established at each sampling station along the creek. One sample was taken at each point using a D-shaped sweeping net with an iron rim (30 x 30 centimeters [cm]). The net was located at the random point and the substrate was disturbed for one minute inside the rim area. The sediment was deposited in a 7-liter container with water. The organisms were separated by decantation, then fixed in 70% ethyl alcohol.

Some stations were not sampled because of very steep slopes or pollution.

To calculate biological parameters, the separated organisms were identified to the family level (in some cases, structural damage to the organisms prohibited finer definition) and counted through use of a stereoscopic microscope. We also determined biodiversity indexes such as Shannon (H'), EPT (Ephemeroptera, Plecoptera, Trichoptera), CA (Chironomidae, Anellida), and species richness, total abundance, and density.

Table 2. Physical and chemical characteristics of the creeks at Pagoreni

Station	pH	Alcalinity	CO_2	Total hardness	O_2	Nitrates	Water temp.	Air temp.
PA(CHA)U	7.2	8	25	8	6	0	24.5	25.0
PA(CHA)M	7.8	7	20	5	8	0	24.7	25.5
PA(CHO)L	7.5	5	15	5	8	0	24.0	24.5
PA(CHA)L	8.0	5	10	5	9	0	22.0	21.5
PA(OSH)L	8.0	4	10	4	9	0	22.0	21.0
PA(JUR)L	8.0	5	10	5	8	0	24.0	24.5
PA(YO2)U	7.0	4	50	8	2	0	24.0	24.0
PA(YO2)M	7.5	7	15	4	8	0	24.0	24.5
PA(CAR)L	8.0	7	10	6	9	0	23.8	25.0
PA(YO2)L	7.5	6	15	6	8	0	24.0	24.5
PA(CRI)L	8.0	4	5	5	10	0	24.0	24.5
PA(UNI)U	7.0	5	25	10	7	7.5	24.5	23.5
PA(UNI)L	7.5	3	10	7	8	0	23.5	24.0
PA(YO1)M	7.5	4	10	4	8	0	24.0	24.5
PA(IRA)L	7.5	6	10	5	4	0	24.5	25.0

Diversity (H´), generally defined as a measure of species composition within an ecosystem, was calculated bases on families, using the Shannon-Wiener Index (Margalef 1978):

$H' = - pi \times \log_2 pi$

where pi = Relative abundance of families (i)

The EPT index is simply the proportion of insects corresponding to the Ephemeroptera, Plecoptera, and Trichoptera orders in relation to the total number of insects in the sample. The CA index is the proportion of organisms corresponding to the groups Chironomidae and Anellida in relation to the total number of organisms in the sample. Richness is expressed as the number of families per sampling station. Total abundance is the number of individuals per station, and density corresponds to the total number of organisms per area (individuals/m^2).

Results and Discussion

Water: Physical and Chemical Evaluation

Physico-chemical parameters were recorded from one site at each of the 15 sampling stations. The values are presented in Table 2. The pH values vary between 7 and 8.5, normal values for this forest type. Here, rain has a pH between 5.5 and 6, and the rainwater reacts with the soils and minerals, it becomes lightly alkaline (Renn 1968).

Hardness values significantly below 60 parts per million indicated soft waters, with small mineral concentration. Soft waters derive mainly from the drainage of acid igneous rocks (Renn 1970).

In the lower parts of Unión Creek, one of the creeks where organic matter was deposited, nitrate values (7.5 mg/l) indicated that the creek was recuperating from the effects of waste deposited from the well site in the higher portion of the creek. It is also necessary to determine the relative concentration of nitrites and ammonium in these environments to assess the impacts of development at the well site (Renn 1970).

Station PA(YO2)U showed high CO_2 values and low concentration of dissolved oxygen. These values were caused by organic discharge from the camp at the well site.

Biological Assessment

Qualitative Analysis

* Plankton. Samples were taken at Yopuato 2 and Oshetoato creeks. We recorded 13 algae species belonging to the Cyanophyta and Bacillariophyta divisions. All of these species had a small number of individuals. Therefore, we concluded that productivity is low in the sampled aquatic environments, as is expected in creeks with fast-running water (i.e., lotic).

* Macroinvertebrates. The sampled organisms belonged to eight classes, 19 orders, and 72 families. Additional information related to family richness was obtained from the qualitative surveys (Table 3). We sampled individuals from two classes and several families that were not recorded in the quantitative survey. The majority of families (14) were in the Coleoptera order, followed by the Diptera with 12 families (see Appendix).

We found a relatively large number of benthic macroinvertebrate families, averaging 30 families per sampling station. The numbers were highests in the creeks that were not affected by discharge from the well site. The upper part of Chátaro Creek (the creek affected by sedimentation) had the fewest families, reflecting the effects of physical perturbation in this area. Note that suspended particles are usually found in lotic environments and that macroinvertebrates are relatively tolerant to suspended inert particles (Ward 1992). However, when the discharges are heavy and the particles are big, effects in the biological communities may be severe (Culp et al. 1986). We found this to be true in the upper part of Chátaro Creek. Perturbation was evident up to 200 m from the platform. Further on, the original community gradually recovered because of dilution and particle precipitation. Thus, the medium course of Chátaro Creek at PA (CHA)M showed a relatively high diversity with 22 families. To compare, Zuñiga de Cardoso (1984), recorded 39 families of benthic macroinvertebrates in the Cali River of Colombia, where high-quality physico-chemical conditions existed.

* Fishes. Of the 193 fish specimens sampled, there were eight species, seven genera, three families, and two orders (Super Order Ostariophysi). All specimens were small to medium in size. The Characidae family was best represented, with six species: *Astyanax bimaculatus, Ceratobranchia* sp., *Charax* sp., *Knodus* sp. 1, *Knodus* sp. 2, and *Scopaeocharax* sp. These species are typically omnivorous; their main food items are terrestrial and aquatic arthropods (Goulding 1980), although they also eat algae and aquatic plants. The other families were Loricariidae, with one species (*Ancistrus* sp.), and Astroblepidae, also with one species (*Astroblepus* sp.). These two species

Of the 193 fish specimens sampled, there were eight species, seven genera, three families, and two orders. It is possible that some of the specimens are new records in the region.

Table 3. Physical and biological parameters of sampling sites at Pagoreni (substrate partical size: BD=> 256 mm, PB=16-64 mm, GR=2-16 mm, ST=0.004-0.06 mm

	Physical parameters			Biological parameters						
Station	Depth (cm)	Width (cm)	Substrate	# of families	Abundance (# of ind)	Density (ind/m^2)	EPT	CA	EPT/CA	H'
PA(CHA)M	19.1	211	GR	22	122	136	50.8	18.0	2.82	3.57
PA(CHO)L	11.0	95	GR	24	69	77	33.3	15.9	2.09	4.13
PA(CHA)L	10.7	182	BD	15	49	54	38.8	22.5	1.73	3.43
PA(OSH)L	13.9	187	BD	28	174	193	50.6	4.6	10.99	3.99
PA(JUR)L	18.3	246	PB	26	124	138	33.9	10.5	3.23	3.92
PA(YO2)M	12.1	135	ST	15	380	422	0.8	91.8	0.01	0.87
PA(CAR)L	1.1	157	GR	23	101	112	36.6	27.7	1.32	3.91
PA(YO2)L	13.6	231	ST	15	138	153	1.4	67.4	0.02	1.92
PA(UNI)U	6.3	68	PB	12	19	21	15.8	26.3	0.60	3.32
PA(UNI)L	14.9	273	ST	12	32	36	18.8	21.9	0.86	3.14
PA(YO1)M	7.7	148	ST	17	37	41	43.3	10.8	4.00	3.77

are silurifomes, (i.e., adapted to very fast running water; Ortega 1996).

The seemingly low fish diversity (eight species) in the waters around Pagoreni might have been due to the sampling effort or a small number of habitats suitable for fish communities. The geomorphologic features of the area have led to the formation of lotic environments with narrow riverbeds, steep slopes, and rapid runoff.

It is possible that some of the specimens are new records in the region. Taxonomic review is needed for final identification, particularly for species of the genera *Knodus* (Tetragonopterinae) and *Scopaeocharax* (Glandulocaudinae).

Quantitative Analysis

Table 3 presents data on diversity indexes. At Yopuato 2 Creek (affected by organic materials), station PA(YO2)M showed the lowest diversity indexes (Shannon-Wiener at 0.87 and EPT/CA at 0.01) and high density (422 individuals/m^2) primarily because of the abundance of Chironomidae (Diptera) and Annelida (total 92%). The prevalence of tolerant taxa such as Chironomidae, Syrphidae (Diptera), and Oligoqueta (Anellids) indicates strong organic pollution (Zúñiga de Cardoso 1984).

In comparison, at Oshetoato Creek (not affected by sediments or organic matter), station PA(OSH)L presented the highest EPT/CA value (10.99) and the second highest diversity index (H´) and density values (3.99 and 193 individuals/m^2, respectively). The physical properties of the creek and its chemical composition represented optimal conditions for establishment of benthic organisms.

From our findings, we assume that water bodies with a high diversity index are chemically healthy; i.e., well oxygenated with a low degree of organic and inorganic pollution. Water bodies with a low

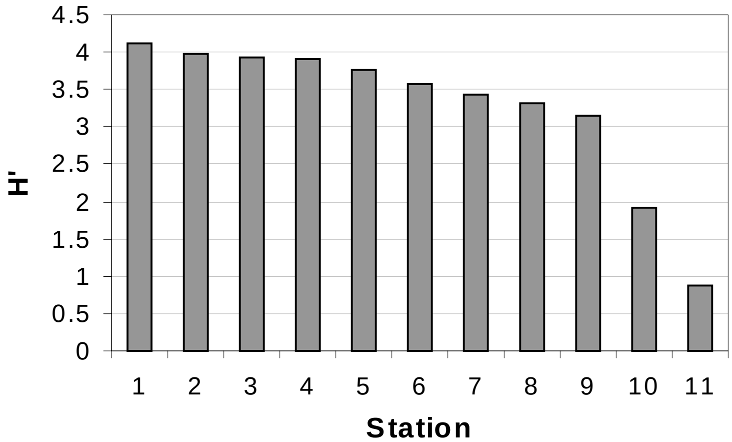

Figure 1. Shannon-Wiener diversity index (H') per station.

Key to Stations

#	Station
1	PA (CHO) L
2	PA (OSH) L
3	PA (JUR) L
4	PA (CAR) L
5	PA (YO1) M
6	PA (CHA) M
7	PA (CHA) L
8	PA (UNI) U
9	PA (UNI) L
10	PA (YO2) L
11	PA (YO2) M

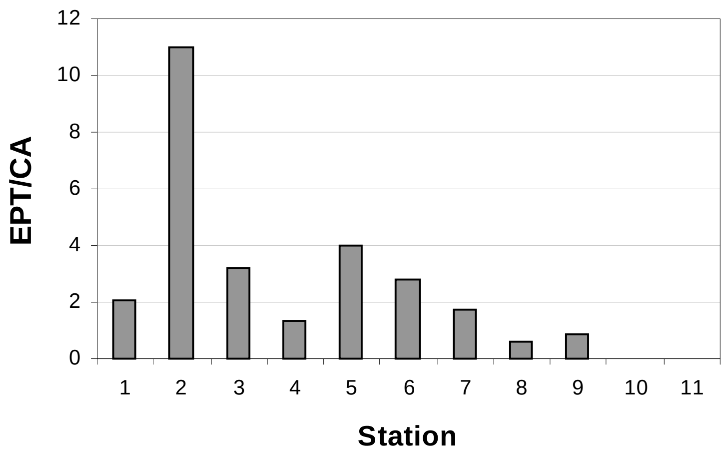

Figure 2. EPT/CA index per station.

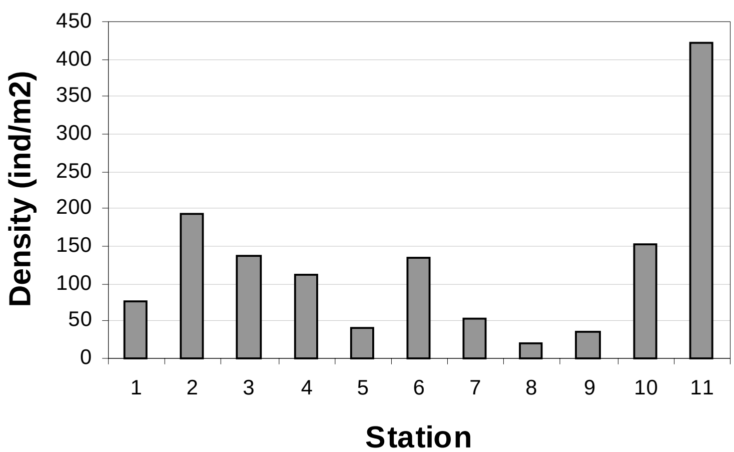

Figure 3. Density (ind/m^2) per sampling station.

diversity index are generally considered polluted.

Figures 1, 2, and 3 show the diversity index (H´), EPT/CA, and density variations, respectively, at each of the 12 stations where quantitative sampling was conducted. Discussion of these findings follows.

* Chátaro Creek (CHA). The diversity index at the medium level of this creek affected by sedimentation (Station 2) was lower than the index found for Chomenta Creek (control creek for Station 2), even though Chátaro Creek is double the width of the Chomenta. The difference may be a consequence of physical perturbation. At Station 4, the lower part of Chátaro Creek, lower diversity, density, and EPT values existed (Table 3), primarily because of rocky substrate and not because of diminished water quality. On the other hand, Oshetoato Creek (control for Station 4) showed considerable differences related to the EPT/CA index, indicating clean water (Table 3).

* Jurioato Creek (JUR). This unaffected creek showed a high diversity index and average density and EPT/CA index values. These may be considered as reference values (Table 3).

* Yopuato 2 Creek (YO2). Biological samples taken at the medium level of this creek (Station 9) reflected a high degree of perturbation because of the deposition of organic matter. Here, we found lower diversity values, an EPT/CA lower than 0.5, and higher density values of Chironomidae (Diptera), which are resistant to organic pollution. Carachama Creek (control Station 8) had a high diversity index and an EPT/CA greater than 1. The lower part of the creek (Station 10) had higher diversity and EPT/CA indexes than did the upper part of the creek (Table 3).

* Unión Creek (UNI). The two stations established in this treatment creek (stations12 and 13) presented average diversity values, EPT/CA indexes lower than 1, and the lowest densities (36 and 24 individuals/m^2) of all stations. The upper part of the creek is perturbed, but results there could be misinterpreted given the type of substrate and the stream width. The EPT/CA values indicated the influence of organic pollution at both stations in Unión Creek.

* Yopuato Creek 1 (YO1). Station 14, located at the middle part of the creek, showed minimum differences in diversity, EPT/CA indexes, and density compared to its control (Irapitare Kimaro, Station15), relecting an undisturbed condition (Table 3).

The stations showing the lower values for individual and family total abundance were those with a substrate composed of fine particles—PA(UNI)L and PA(YO1)L (Table 3). According to Tarzwell (1936), fine-particled substrates support fewer organisms because of their instability and low content of organic matter. Yet, stations PA(YO2)M and PA(YO2)L, also with a fine-particled substrates, show higher total individual abundance, a consequence of the perturbation produced by organic discharge from the well site, which altered the community structure, favoring the development of resistant populations such as chironomides and anelides.

Among the few species recorded in the fine-particled substrates, there were immature individuals from the Gomphidae

(Odonata) family, which is common in well-oxygenated pools with clay substrate. Diptera larvae (Chironomidae, Tipulidae and Ceratopogonidae) were also found in this substrate.

Stations (PA(JUR)L and PA(OSH)L), with higher individual and family total abundance, had coarse-particled prevalent substrates (Table 3), which are relatively stable and contain a variety of microhabitats (Ward 1992). The best represented groups in these substrates were Ephemeroptera (Baetidae, Leptophlebiidae, Leptohyphidae, and Euthyplociidae), Megaloptera (Corydalidae), Plecoptera (Perlidae), Coleoptera (Psephenidae), and Trichoptera (Hydropsychidae).

The influence of particle size on macroinvertebrate distribution is less direct. Other elements such as the presence of natural organic detritus appear to determine insect distribution (Egglishaw 1964). In our evaluation, we found no natural organic detritus associated with coarse-particled substrates—no algae, mosses, or bank vegetation that provide structural support and nourishment for insect communities. The lack of vegetation on the rocks is caused by the fact that little light penetrates to the forest waters. Some insect species are associated more with mosses and algae than with the mineral surface. According to Rooke (1986), these plants supply protection and refuge, and the perifiton that grows on them constitues a food source (Dudley 1988).

Litter in the lotic environments also plays an important role as a high-quality food source for macroinvertebrates (Reice 1980). The high diversity and abundance found at the Jurioato and Oshetoato creeks was due primarily to the presence of litter, associated to the rocky substrate, at the sampling stations. Litter was absent in the other creeks. Macroinvertebrates often found in litter belong to the following orders: Ephemeroptera (Baetidae), Coleptera (Elmidae, Ptilodactylidae, Hydrophilidae, and Dryopidae), Trichoptera (Calamoceratidae and Hydroptilidae), and Diptera (Psychodidae, Tabanidae, and Tipulidae).

To summarize:

* In the aquatic ecosystems evaluated, water pH was neutral and lightly alkaline (7 to 8.5), lower than 60 parts per million. Oxygen, nitrate and CO_2 concentrations were average. These conditions varied in the upper part of Yopuato 2 Creek, given the strong organic discharge. Plankton evaluated in the two creeks was represented in 13 algae species belonging to two groups. The diminished diversity reflected low productivity in fast-running water environments.

* Qualitative analysis for Pagoreni aquatic macroinvertebrates showed a total of 89 species distributed in 72 families, 19 orders, and eight taxonomic classes. The best-represented orders were Coleoptera and Diptera, with 14 and 12 families, respectively.

* Fish diversity appeared low because we only sampled primary creeks. Eight species were found in seven genera, three families, and two orders. The best-represented family was Characidae with six species.

* The biological parameters applied to the benthic macroinvertebrate communities were good indicators of the degree of

perturbation. Physicho-chemical features were useful to the discussion and complemented the biological evaluation.

* Through the Shannon-Wiener diversity index, it was possible to differentiate the perturbed creeks Yopuato and Unión) from the non-perturbed creeks (Chomenta, Oshetoato and Jurioato).

* The EPT index indicated perturbations in the creeks caused by organic residues. However, it could be improved through the addition of a factor representing the proportion of pollution-resistant organisms (Diptera and Anellida).

* High density values for resistant organisms (Diptera-Chironomidae) confirmed high levels of organic pollution in Yopuato 2 Creek, where the proportion of Chironomidae varied between 65% and 88% of the total individuals. Densities varied between 153 and 422 individuals/m^2.

* Yopuato 2 and Unión creeks were the water bodies influenced by domestic organic residues from the Pagoreni well site. Both creeks showed gradual recuperation of diversity values through water dilution along their courses.

* The upper part of Chátaro Creek was strongly disturbed by inorganic sediments from activity at the well site, as reflected by the low number of families recorded. Because of the dilution effect of the creeks, however, the biological communities can recover fairly rapidly, and after 200 m, we found normal values of diversity.

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Appendix. Macroinvertebrates sampled at Pagoreni (April-May 1998)

Taxa	Stations 1 PA(JUR)L	2 PA(UNI)L	3 PA(UNI)U	5 PA(YO1)M	6 PA(IRA)L	7 PA(CHA)M	8 PA(CHA)U	9 PA(CHO)L	10 PA(CHA)L	11 PA(OSH)L	13 PA(YO2)M	14 PA(CAR)L	15 PA(YO2)L
Class Turbellaria													
Order Tricladida													
Family Planariidae		X		X	X				X			X	
ClassNematoda	X												
ClassOligochaeta													
Order Haplotaxida		X		X		X	X	X	X		X	X	X
Class Hirudinea		X				X							
Class Gastropoda	X	X		X		X				X	X	X	X
Order Bassomatophora													
Family Valvatidae				X							X		X
Family Planorbidae		X											
Order Mesogastropoda													
Family Ampullaridae	X	X		X							X		
Family Hydrobiidae	X												
Class Insecta													
Order Collembola			X			X	X	X	X	X	X		X
Family Sminthuridae	X				X								
Order Ephemeroptera													
Family Caenidae													
Brachyceras sp.				X									
Family Euthyplociidae													
Euthyplocia sp.	X	X		X	X	X		X	X	X		X	
Family Leptohyhidae				X		X			X		X	X	X
Haplohyphes sp.	X				X					X			
Leptohyphes sp.		X											
Trichorythodes sp.								X		X			
Family Leptophlebiibae													
Thraulodes sp.	X	X		X	X	X		X	X	X	X	X	X
Family Oniscigastidae						X							
Family Baetidae	X	X					X	X	X	X	X	X	
Baetis sp.				X	X	X							
Family Polymitarcidae						X				X		X	
Family Undeterm.	X			X	X	X		X	X	X			
Order Odonata													
Family Platystictidae													
Palaemnema sp.						X						X	X
Family Gomphidae	X	X		X	X	X		X	X	X	X	X	X
Family Libellulidae	X			X	X	X		X	X	X	X	X	X
Brechmorhoga sp.				X	X	X				X	X		
Family Calopterygidae										X			
Mnesarete sp.		X											

Appendix. Macroinvertebrates sampled at Pagoreni (Cont.)

	Stations												
	1	2	3	5	6	7	8	9	10	11	13	14	15
Family Polythoridae	X	X		X	X					X	X		X
Family Coenagrionidae		X				X			X	X	X		
Argia sp.		X											
Family Megapodagrionidae										X			
Heteragrion sp.		X			X							X	X
Family Undeterm.	X	X		X	X	X		X	X	X	X	X	X
Order Plecoptera													
Family Perlidae													
Anacroneuria sp.	X	X		X	X	X		X	X	X		X	
Order Megaloptera													
Family Corydalidae													
Corydalus sp.	X	X		X	X	X		X	X	X			
Order Hemiptera													
Family Vellidae													
Rhagovelia sp.	X	X			X	X		X	X	X	X	X	
Family Gerridae		X	X			X		X		X			
Family Naucoridae		X		X		X		X	X	X		X	
Ambrysus sp.		X											
Family Saldidae						X							
Family Gelastocoridae				X									X
Order Coleoptera													
Family Elmidae	X		X	X	X	X	X	X	X	X	X	X	X
Neocylloepus sp.					X								
Phanocerus sp.					X								
Neoelmis sp.					X								
Heterelmis sp.		X											
Microcylloepus sp.		X			X								
Macrelmis? sp.		X											
Family Psphenidae	X	X	X	X	X			X		X		X	
Family Ptilodactylidae	X	X	X	X	X	X	X	X	X	X		X	
Family Gyrinidae						X							
Family Helodidae				X								X	
Family Hydraenidae								X				X	
Family Hydrophilidae	X			X				X					X
Family Hydroscaphidae										X			
Hydroscapha sp.		X											
Family Ptiliidae													X
Family Staphylinidae	X										X		
Family Dryopidae	X			X				X					
Family Dytiscidae									X				
Family Heteroceridae		X		X									
Family Undeterm.										X			
Order Trichoptera													
Family Hydropsychidae													
Leptonema sp.	X			X	X	X		X	X	X	X	X	

Appendix. Macroinvertebrates sampled at Pagoreni (Cont.)

	Stations												
	1	2	3	5	6	7	8	9	10	11	13	14	15
Smicridea sp.	X	X	X	X	X	X		X					
Family Hydroptilidae	X		X	X	X			X		X			
Family Leptoceridae													
Atanatolica sp.	X	X		X	X	X				X			
Family Philopotamidae													
Chimarra sp.	X					X		X		X			
Family Calamoceratidae													
Philloicus sp.	X			X		X			X	X		X	
Banyallarga sp.										X			
Family Polycentropodidae												X	
Family Odontoceridae													
Marilia sp.					X								
Undetermined	X												
Family Undetermined	X	X		X	X	X			X	X	X	X	
Order Lepidoptera													
Family Pyralidae										X			
Family Undeterm.											X		
Order Diptera													
Family Athericidae													
Atherix sp.		X											
Family Ceratopogonidae	X	X	X	X	X	X		X	X	X		X	
Family Chironomidae	X	X	X	X	X	X	X	X	X	X	X	X	X
Family Psychodidae	X	X	X	X		X		X	X		X	X	X
Family Simuliidae	X							X					
Family Tabanidae		X				X		X					X
Family Tipulidae	X		X	X	X	X		X	X	X	X	X	X
Tipula sp.													X
Hexatoma sp.		X											
Erioptera sp.		X											
Limonia sp.		X										X	
Family Stratiomyidae		X		X	X							X	
Family Dolichopodidae					X			X					
Aphrosylus sp.		X											
Family Muscidae						X							
Family Culicidae												X	
Family Undeterm.	X	X								X		X	X
Class Arachnida													
Order Acarina	X		X						X	X			
Class Crustacea													
Order Amphipoda	X	X	X	X	X						X	X	
Order Decapoda													
Family Pseudothelphusidae		X		X		X							
Family Atyidae	X	X		X	X			X		X		X	X
# of families per station	40	47	15	42	35	37	6	33	28	40	23	35	25