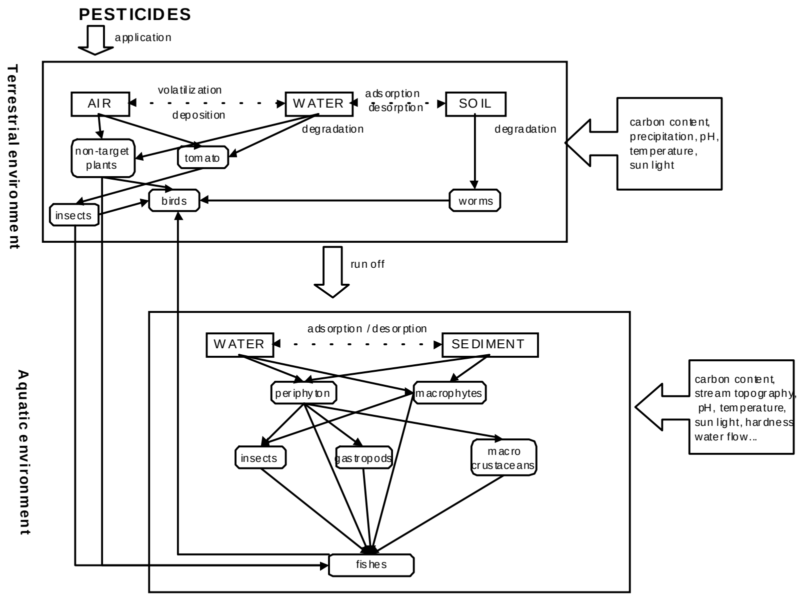

Ecological Risk Assessment in Parque Estadual Turístico do Alto Ribeira, Brazil

Results from field trips and status report – Aug 1999

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Technical Environmental Planning
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg 1999

Report 1999:5

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Abstract

The case study of this ecological risk assessment is about human impacts on ecosystems in a Brazilian reserve of rain forest in the south western part of the State of São Paulo, the *Parque Estadual Turístico do Alto Ribeira* (PETAR). The reserve is of special interest because of the small amount of relatively undisturbed Atlantic rain forest in Brazil and because 1.1% of the area of that biome is officially protected by the government.

This report presents results of two field campaigns that took place during November 1998 and March 1999. Selection of sites was based on presence or absence of known pollution sources, type of stream and accessibility. Physical and chemical water characteristics (pH, alkalinity, temperature, dissolved oxygen, conductivity, hardness, phosphorus and nitrogen concentrations and pesticides) and fish community composition and structure (richness, diversity, evenness, abundance and biomass) of eleven streams at seventeen sites were studied.

Streams are grouped in categories according to size, substrate characteristics and flow velocity. The preliminary discussion of results is based on comparison within and among these groups of streams. A sampling site situated downstream a village which discharge domestic sewage showed higher abundance, species diversity and biomass per area compared to upstream sites. Three fish species sampled downstream a lead-silver mine showed an average biomass higher than the average calculated for the same species from other streams. The fish community downstream a calcareous mine and from a tributary located in an area where pesticides are frequently applied presented low species diversity compared to others similar streams.

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Background information

Parque Estadual Turístico do Alto Ribeira (PETAR) is one of the most preserved areas of Atlantic Rain Forest in Brazil. However, headwaters of the main rivers that cross the park are located in areas where human activities may influence the ecosystems inside the reserve. Those activities are agriculture, mining, human settlements and deforestation. The ERA study aims to perform an ecological risk assessment of those human activities in and around PETAR.

In August 1998 a status report, resulting from half a year's work of literature review and preliminary results regarding the first field trip (June 1998), was submitted to SIDA (Molander and Moraes 1998). The present achievements since August 1998, literature review complements, and the further development of the analysis plan is here reported. Methodology and preliminary results from the recent field trips and laboratory analysis are also described.

Introduction

Ribeira Valley, a region located at the south-east border of São Paulo State and the east border of Paraná State, holds the greatest continuos formation of Atlantic Rain Forest in Brazil, with more than 1 200 hectares of well preserved forest. Together with environmental and cultural elements of great interest, Ribeira Valley presents the lowest values of some social indicators of the States of São Paulo and Paraná, including the highest rates of child mortality and illiteracy. The population of about 350 000 inhabitants, does not have economical alternatives for a sustainable development that could permit the rational usage of the huge existing environmental and cultural heritage (ISA 1998).

One of the most preserved areas of Atlantic rain forest in Ribeira Valley is PETAR (see review of natural resources of the park in Molander and Moraes 1998). However, 29% of its area is occupied by uses considered improper for preservation representing a permanent risk for PETAR ecosystems (SEMA 1996). Three main tributaries to the Ribeira River are crossing the park, and some headwaters are found in areas where certain human activities outside the park may affect the aquatic environment inside the PETAR (Figure 1). The park authorities have been trying to expand the park boundaries to include these areas, but without success due to conflicts with landowners. In those areas, farmers cultivate among other crops, tomatoes and passion fruit. Pesticides are spread and may leak into watercourses, exposing biota.

In November 1997, the Brazilian media showed a serial of documentary TV-programs and articles in newspapers regarding a high frequency of pesticide intoxication among agricultural workers (133 cases per 100 000 inhabitants), some of them leading to death. In Apiaí, a municipality located in Ribeira Valley, north of PETAR around one third of the cases were children and teenagers that had started working in tomato cultivation very early. Even though the numbers caused alarm, no actions were taken to mitigate or even investigate such problem with more details. In November 1998, another documentary program, about the same subject, showed that one year later nothing had changed and agricultural workers were still dying in the region due to the lack of information, equipment and training.

Detailed knowledge of pesticide use in the region is still limited due to the lack of control from competent authorities. According to the Agricultural Secretary of the State of São Paulo, a many different fungicides, insecticides and herbicides are applied in tomato plantations in the region.

The substances belong to different chemical groups, such as organochlorines, organophosphates, pyrethroids, carbamates, phthalimides and others. Many of them are considered highly toxic for humans (e.g., carbofuran, methyl parathion and methamidophos), while some are considered very toxic for the aquatic environment, such as deltametrin and captan. (See list of pesticides used in the region and their chemical, physical and ecotoxicological properties in the Appendix I and II). The kind of pesticides used on tomato fields will vary depending of the cultivation stage (seeding, flourishing, fructification and harvesting). Insecticides are also periodically applied near households by the health authorities to control insect pests in order to avoid outbreaks of vector-borne diseases such as dengue fever.

Since most of the workers are badly informed or trained, dilution of chemicals is not always executed as normally recommended by producers. Consequently pesticides are often applied in higher amounts than needed. Another difficulty is the insufficiency of equipment required for safe handling and application of the substances. The few available safety equipments are totally inadequate in the warm climate conditions of the region. The lack of skilled workers adds to the bad working conditions and has created a critical situation that demands urgent actions.

During March 1999, R. Moraes interviewed two agriculturists in the area. Both of them reported intoxication cases in their families. The non-use of safety equipment was confirmed. In one of the cases, empty pesticides containers were left in an open area, less than 10 meters from the house where a couple and an one six-months child lived. Crop fields were located in the top of the hill, and a small stream received all leached pesticides downhill. However, even after application of high amounts of pesticides (which almost made the crop unprofitable), most of the fruits were infected by insects and couldn't be sold.

Mining is another important source of pollution for aquatic ecosystems in the reserve. According to the *Superintendência do Desenvolvimento do Litoral Paulista* (SUDELPA 1985), PETAR subsoil was always of focus of interest for the mine industry and, in 1985, approximately 80% of PETAR areas was considered as interesting for mining. Since mining in that area requires new road construction, topography adjustment, and use of heavy machines and explosives and generates toxic leachate from the waste rock, mining inside the park is considered to be illegal (SUDELPA 1985).

Lead was the most extracted metal in Ribeira Valley from many mines in the Ribeira, Iporanga and Apiaí municipalities. During the 80^{ths}, lead production declined on the international level, which affected lead production in Vale do Ribeira as well (Engecorps 1996). Even though the lead mining had stopped in the region during the last decades, it may still be threatening the environment due to waste rock with high contents of heavy metals, which were left near the rivers. Silver, gold and zinc were other metals extracted in the region, normally associated with natural lead deposits, such as in the Furnas mine (Engecorps 1996). According to CETESB (1991), sediments collected at the bottom of Furnas stream, the stream near the mine, had a concentration of arsenic, mercury, lead and zinc, much higher than the limits recommended by CONAMA for preservation of the aquatic life.

Limestone mining is currently one of the most important extractive activities in Ribeira Valley (Engecorps 1996). Some calcareous mining, which production is intended for cement, lime and soil additive production, is still active in the region, some of them even inside or close to PETAR. They do not release toxic components in the environment, but after explosions, a considerable amount of particles is released to the air and is deposited on surface water, increasing water turbidity or is washed away with the run-off. The suspended solids may over time settle out on the bottom, increasing the nutrient, metal and toxic levels of the settled sediments (Kiely 1997). Those activities also represent a threat for the calcareous caves, which represents one of the main richness of PETAR (SUDELPA 1985). For instance, Pelizzari and Depetris non-active mines, located inside the park in the Iporanga watershed caused environmental problems due to deforestation, explosions with destruction of geological structures and illegal construction of a small hydroelectrical power plant for electricity generation (SEMA 1991). Furthermore, TNT is commonly used as explosive which can cause an increase of nitrogen concentration in nearby streams.

Studies on effects of siltation on stream fish communities showed that as percentage of fine-substrate increases the number of individuals of typical riffle species decreases (Berkman and Rabeni 1987). The effects are related directly or indirectly to disruption of substrate conditions reducing the abundance of benthic insectivores and herbivores.

In a study performed by the PETAR administration in 1986, there were approximately 14 small villages composed by groups of families inside or in the vicinity of the park. Most of them survived on subsistence agriculture, but their main activity is poaching and gathering. Some of the villages, such as Maria Rosa and Pilões, both located in Pilões watershed consists of *quilombos*, which are reminiscent of escaped slaves from the last century. In 1986 a total of 39 families lived in those two villages (SEMA 1991).

Untreated domestic sewage from small villages located inside the park and in areas near the park is discharged directly into watercourses. The larger village is Bairro da Serra, which population increased considerably during the last decades after the fall of the mining activities in Iporanga municipality when many families moved to the village and started activities related to tourism (SEMA 1996). The number of inhabitants in Bairro da Serra increases enormously during holidays when many tourists come to PETAR to visit caves and swim in the rivers, living in the camping areas or small hotels (*pousadas*).

Deforestation is also an environmental problem for the park. Studies have shown that deforestation in developing countries is associated both with development and scarcity (*e.g.* Tole 1998) since development is required if countries are to alleviate scarcity-driven forms of forest exploitation but, on the other hand, development is itself a major cause of forest loss. The situation in PETAR area is not different. Irregular license for deforestation inside or in the vicinity of the park were sometimes given by the authorities (*Instituto Brasileiro de Desenvolvimento Florestal*, IBDF) in the past which opened space for illegal land invasion and palm tree exploitation and logging (SEMA1991).

All the problems mentioned above can be detected in many of the environmental protection areas in the Brazil. There are 91 federal conservation unites of indirect use (where natural resources can not be exploited) in Brazil, which together represent only 1.85% of the national territory (WWF 1999). According to WWF, 41% of the officially protected areas have more than 50% of their surroundings already deforested; 22% of them have problems regarding the land use in their neighbouring areas (50% of surrounding areas occupied by agriculture, industrial or mining activities or urban centers); and 12% of them presented systematic resources exploitation in more than 10% of their area. For that reason, the methodology used in this study case may also be applied in other areas of rain forest in Brazil or other tropical areas, contributing to biological conservation in larger scales.

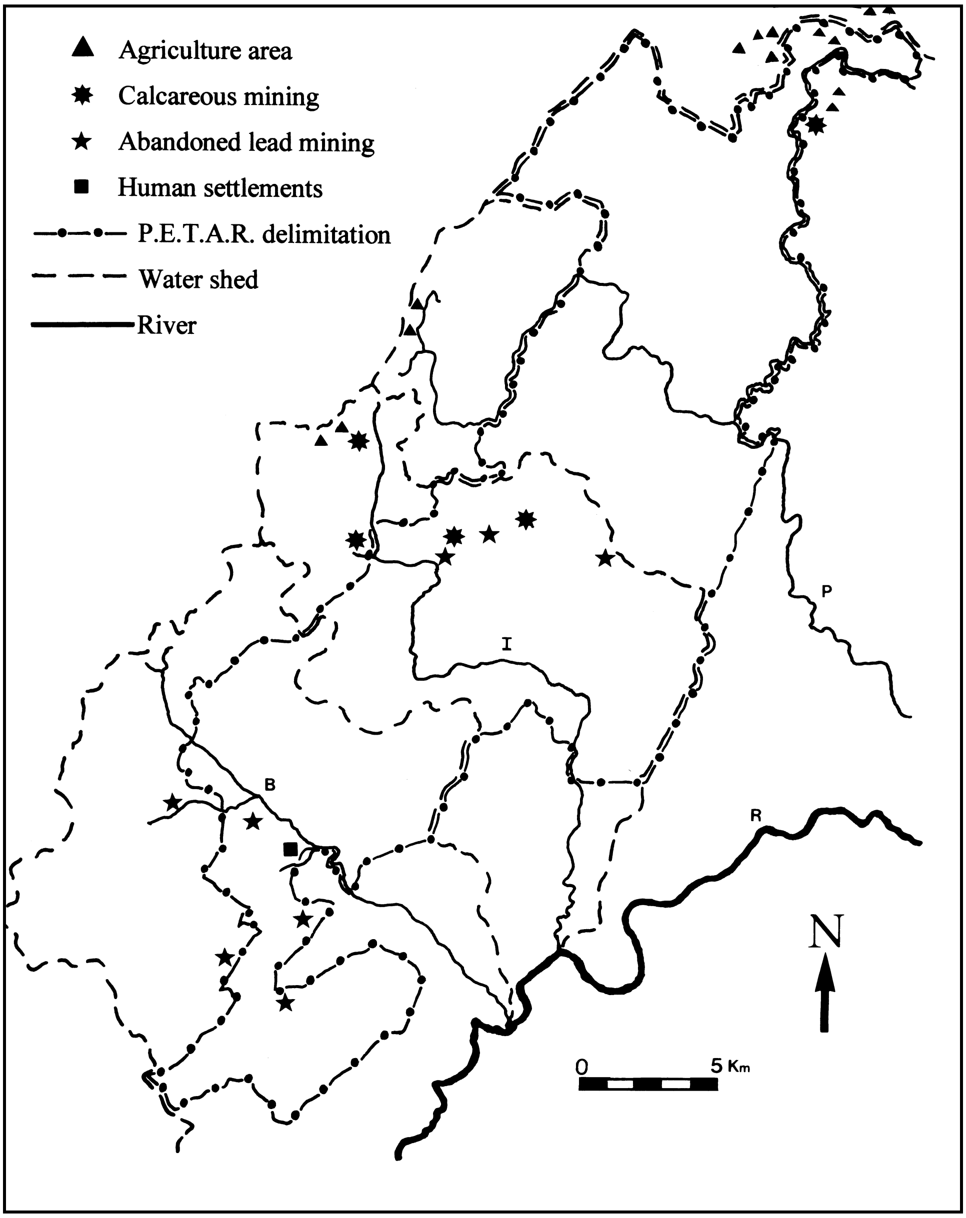

Figure 1: Schematic map of the study area showing the main rivers (B:Betari, I:Iporanga, P:Pilões and R:Ribeira), sources of pollution and limits of the park.

A summary of the problem formulation of PETAR ERA-project

The Problem Formulation phase of this ERA is completed, but a few changes are expected when new data are gathered. Its main steps are summarised below. A detailed discussion about each topic each presented in Molander and Moraes (1996).

Selection of assessment endpoints. The selected assessment endpoint in this study is the fish community, with focus on two groups of siluriform catfishes, the predator catfishes (Fam. Pimelodidae, Portuguese *"bagres"*) and the periphyton grazing catfishes (Fam. Loricarridae, Portuguese *"cascudos"*). The choice was based on several considerations related to management, ecological and methodological arguments.

Ecosystems potentially at risk. Betari, Iporanga and Pilões are the three main rivers that drain PETAR. Many of their tributaries have their origins outside the park, first flowing through areas that are influenced by humans in different ways.

Source of stressors and stressor characterization. The stressors of this study are related to anthropogenic sources connected to land-use close to the borders of PETAR, and also inside the reserve. The choice of stressors (*i.e.*, plant nutrients, pesticides, heavy metals and particles) has been guided by an analysis of the possible ways in which human activities (*i.e.*, lead and calcareous mining, agriculture as well as human settlements) can influence the ecosystem of the park. The main assumption is that transport processes are required to carry stressors from outside the park into the park area, and that the major transport medium is water. Atmospheric transport of stressors from both close and more remote areas cannot be totally disregarded but the likelihood of effects caused by such stressors is judged as small compared to effects caused by activities where stressors are transported by water.

Conceptual models. A general conceptual model linking the endpoints to possible anthropogenic sources of stressors was presented in Molander and Moraes (1998). It describes the general relationships between land use activities, stressors, exposure pathways and ecological receptors. Two other detailed conceptual models, one for pesticides and one for nutrients can also be found in that report.

It is evident that a focus on a part of a large ecosystem is not the same thing as a choice of endpoints from different parts of the terrestrial and aquatic ecosystems. However, for many reasons an ERA must reduce the amount of information to gather and handle without compromising the scientific validity of the assessment. Due to reasons of practical limitations or social or scientific relevance stressors and endpoints can be disregarded. Despite this the number of possible stressors and endpoints remaining to the analyst for consideration are huge. The choice of endpoint may therefore be preceded by some considerations. The choice of the fish community as endpoint was guided by both practical (methodology, knowledge) and social preferences (food for humans and otter) but also by the fact that reasonable long-lived organisms will integrate exposure over time, at the same time exposure may be evened out. Reasons for considering the entire fish community as endpoint include the fact that many species together have a wider range of sensitivity for stressors than a single species, possibly resulting in increased detection of stressor effects on the community compared to a randomly chosen species. Stressor effects acting on interactions among fish species should also be detected with this approach, but whether stressor effects may be amplified or masked in a community are open questions. Further arguments for this choice of an endpoint in the aquatic ecosystem is the “collection” of the exposure. Precipitation, from the entire area, will collect stressors from the land-based sources and direct them to the fish community regardless of if a specific source is emitting directly to the watercourse or to land or to air. In the case of pesticides their persistence, mobility and partitioning between environmental compartments will greatly influence the rate at which they enter the waters, but nevertheless they will in many cases be found in streams occasionally. There are of course other problems with the ephemeral exposure in running water, which is related to the strength of the cause-effect links. It is hard to establish a strong link between measured exposure and observed effects since sampling seldom can be sufficiently frequent to cover intense but short exposure episodes regardless of type of stressor.

There are also possible effects in the terrestrial ecosystem that probably never will be found as signals in the aquatic part, or as signals that will be regarded as related to the stressors under study. For instance a slow shift in plant community composition, due to changes in agricultural disturbance of dispersal will not necessarily be detected as a signal in the aquatic part of the ecosystem.

Another problem is that since an ERA shall also be useful for management, give a basis for actions, stressors or changes caused by factors beyond reach of reasonable management actions may be seen as of little interest, but they may be important to compare with factors that can be managed. Leaving naturally fluctuating factors known to influence the endpoint may therefore be inappropriate, putting further emphasis on the question how to reduce the amount of information needed to fulfil the assessment. There seems to be a difficult trade off between qualities such as ecological and scientific relevance or coverage of large spatial and temporal scale and the feasibility of an ERA that is linked to practical and economical limitations.

Present state of the project

Description of ecosystem. Beside the results regarding water quality parameters that is presented belwon and that will be further elaborated in the master´s thesis by Johanna Lundqvist, water flow and discharge in each surveyed stream will be calculated using measurements of flow and stream dimensions taken during the field trips. Streams and stream habitats that have been preliminary classified will be classified according to the framework presented by Frissell and collaborators (1986) for systematic interpretation and description of watershed-stream relationships. A MFS-study of vegetation in parts of the PETAR is planned and will be performed during the fall of 1999.

Analysis of pesticides in surface water. Henrik Kylin (Swedish Agricultural University, Uppsala) will perform analyses of pesticides in water (and sediments?) in samples from November 1998 and March 1999.

Data analysis. Statistical hypothesis testing will be use to compare site condition with a reference site (*e.g.* Messer *et al*. 1991). A multivariate analysis of exposure, fish community parameters and habitat characteristics will be used by R. Moraes and S, Molander for identification of factors contributing to differences between fish communities. The analysis aim to detect which variables (exposure, local habitat, land-use, etc) that are more important for explaining the variability observed in fish community.

IBI. R. Moraes, S Molander, S. Buck and P. Gerhard will develop methods for applying the concept of Index of Biotic Integrity (IBI) to fish data. According to Steward and Loar (1994), IBI is a good example of a biological monitoring analysis that essentially focus on relevant and directs it to the advantage of the investigator or regulator. Furthermore, using IBI, biological monitoring data obtained through time may be reasonably collapsed and still allow the generation of strong statements about the biological integrity of rivers. However, the sensibility of the IBI to particular contaminants or conditions has not been determined.

Description of the stressor sources. Remote sensing techniques (satellite images) will be used (Fuller *et al.* 1998). The intention is to identify different stressor sources, such as mining activities, human settlements and agriculture, which may affect the streams situated nearby. Geographic Information Systems (GIS) will be used for integrating spatially explicit environmental data (Dale *et al.* 1998).

The role of the field trips according to the analysis plan

This ERA is mainly retrospective and based on field observations and sampling. There are, however, possibilities to extend the analysis with predictive components (*e.g.* an evaluation of the possible effects stemming from increasing population or increasing tomato cultivation).

According to the planning schedule for the project which was presented in the original analysis plan (Molander and Moraes 1998) two field trips should be performed during the year 1998 and two others during 1999. The main goals of these trips was to: (1) gather data for a more accurate description of sources of stressors and ecosystem characteristics; (2) perform field measurements (nutrients and pesticides concentration in water) that will be used for calibration of transportation models of contaminants in order to describe the spatial-temporal distribution of the stressors; (3) perform field measurements (water physical and chemical characteristics) in order to describe factors affecting stressors which will be used as input for transportation models of contaminants; and (4) collect data on fish community that will be used for receptor characterization and effects analysis.

The following chapters presents the results of two field trips (second November 1998 and third March 1999). Several of the results obtained during the first trip in June 1998 was already presented in Molander and Moraes (1998), but some of the data are presented in this report again in order to compare data from different seasons.

Field Trips

The first field trip to PETAR took place in June 1998 (07-17.06.98; see methodology and preliminary results in Molander and Moraes 1998). A second field trip was made in November 1998 (13-22.11.98). Sverker Molander, Rosana Moraes, Johanna Lundqvist (master student at Technical Environmental Planning, Chalmers University) and Pedro Gerhard (master student at Biosciences Institute, Universidade de São Paulo) participated in the sampling campaign and data collection. The main objective of the second trip was to sample the fish community and to measure pesticides and nutrients concentration in streams together with physical and chemical characteristics of the water and to compare those with data from the dry season (June). However, 1998 was quite unusual in terms of precipitation. November normally correspond to the beginning of the rainy season (average rainfall in November during the years1972 to1997 was 130 mm, Figure 2) but in 1998 it rained only 48 mm in November. On the other hand, the total precipitation during the months August, September and October was together 650 mm, which is almost the double compared to the earlier 16 years (average 320 mm).

Rosana Moraes, Pedro Gerhard and Sonia Buck (doctoral student at Biosciences Institute, Universidade de São Paulo) performed the third field trip in March-April 1999 (from 25.03-04.04.99), during the period corresponding to the end of the rainy season. The main objective of that trip was to collect water samples for pesticides analysis and to sample fish community.

March and April normally correspond to the end of the rainy season, but in March 1999 (Figure 2) precipitation levels (352 mm) were higher than the average rainfall for that month between 1972 and 1997 (172 mm). High precipitation was responsible for many land slides and bridge falls, which, in some extent, brought some difficulties in accessing some of the sampling sites.

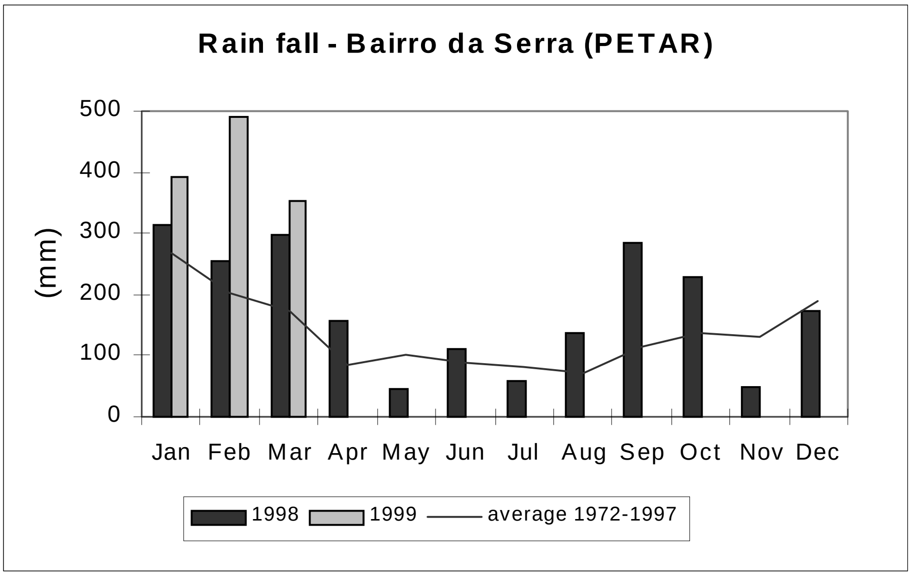

Figure 2: Precipitation in Bairro da Serra, Betari valley (as monthly average of 1972-1997 and total monthly precipitation of January 1998 - March 1999). Source: Water and Electrical Energy Department of the State of São Paulo (DAEE).

Methodology

Selection of sampling sites

The number of sites was reduced compared to the first field trip (June 1998) due to weather and road conditions. There was also a need for selection of new sites that could be compared in terms of fish community. For that selection, factors that could influence fish community such as stream size, bed material, riparian vegetation, breadth, flow speed and shading were taking into consideration as well as accessibility to the site and presence/absence of pollution sources. Figure 3 is a schematic representation of sample sites location relatively to the main sources of pollution.

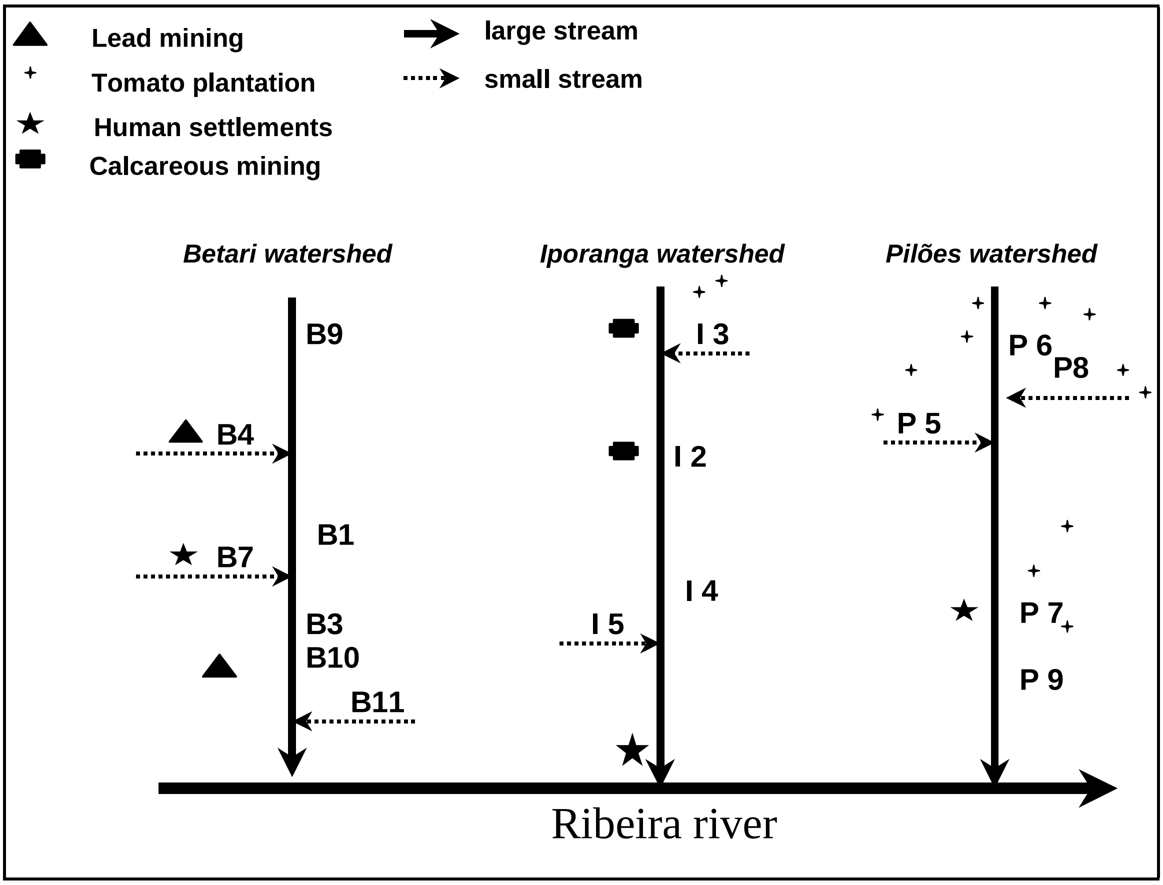

Figure 3: Schematic representation of sample sites and location of main sources of pollution.

Description of sample sites

Latitude and longitude of each site was determined using a GPS receiver (Silva GPS Compass XL 1000 Forest).

Description of the sampling sites was based on several characteristics of the habitat. They were: (1) average *river depth and width*, measured at different points in the stream section studied; (2) *current speed*, measured by a mechanical flowmeter (General Oceans Model 2030R - Standard Mechanical); (3) *type of channel*, simplified from Bisson and Montgomery (1996) classification: pool/riffle, plane/bed, step-pool or cascade; (4) predominant *bed material*: bedrock, boulder, cobble, gravel and silt; (5) *marginal vegetation*: primary or secondary forest, grass or no vegetation; (6) *water turbidity*, based in visual observation: transparent, little turbid or turbid; and (7) percentage of *shading*, based on visual observation of vegetation in the surroundings.

Habitat structure was evaluated on basis of river breadth, bed material and marginal vegetation. Each one of those three characteristics were divided into 4 categories (Table 1) to facilitate computation of a habitat structure complexity index. The index, calculated for each surveyed site, resulted from an average of the scores given to those three parameters (river breadth, bed material and marginal vegetation). Higher scores (4) represented more complex habitats (wider, heterogeneous in terms of substrate and margined by primary forest), The scoring system will be used to discuss habitat-fish community relationship in PETAR streams. It follow the assumption that larger patches of habitat which contains a larger array of habitat configuration and food resources provide more niches and support more species (Willians a964 *apud* Angermeier and Scholosser 1989). The possibility of inclusion or exclusion of other habitat parameters in the analysis is still under discussion.

Table 1: Characteristics of the habitat used for scoring of habitat structure complexity of PETAR streams.

Habitat characteristic	***Category 1***	***Category 2***	***Category 3***	***Category 4***
River breadth	*< 2m*	*>2 and <5m*	*>5 and <7 m*	*>7m*
Bed material	*Very homogenous (only sand, only bedrock, etc.)*	*Mostly homogeneous (mostly sand, but also gravel or cobble, etc.)*	*Heterogeneous (gravel and sand, etc.)*	*Very heterogeneous*
Marginal vegetation	*No vegetation*	*Very disturbed*	*Secondary forest a little disturbed*	*Primary forest*

Analysis of physical and chemical water parameters

Water conductivity, pH, dissolved oxygen, and temperature were all measured in the field by a multipurpose instrument (Horiba U-10 Water Quality Checker).

Four liters of water were collected from each site using polypropylene bottles. Alkalinity, hardness, nitrate, nitrite and phosphorus were measured in a temporary laboratory at one of the houses in PETAR using a Hach Portable Colorimeter (the model DR/700 was used in June and the model DR/890 in November). Analyses were carried out as soon as possible (maximum 24 hours later).

Water samples (3 plastic bottles, 50 ml, from each sampling site) were acidified with 0.2 ml of H_2SO_4 (9 M), frozen and later transported to Sweden for analysis of total nitrogen, total phosphorous, ammonia, sulphate and chemical demand of oxygen at the laboratory of the Department of Sanitary Engineering at Chalmers University of Technology by Johanna Lundqvist. For testing another preservation technique 10µl of $HgCl_2$ solution (50 mM) per 10 ml sample was added in some water samples that would be used for total phosphorus analysis. Those samples were kept at room temperature.

Water samples were also collected for pesticide analysis using polypropylene bottles (2 L of sample per site, 2 replicates per site). Samples that presented pH higher than 7 were acidified with approximately 0.1 ml of H_2SO_4 (9M) or HCl (32% m/m) to avoid hydrolysis of silica in the columns. pH was once again measured after acidification. After adding 7 µl of internal standard, samples were extracted with solid phase columns using a pressure filtration apparatus. On the outlet of the pressure container a pre-filter and silica based solid-phase extraction column (Env^+ 200 mg or 1 g) were placed. Two pressure filtration apparatuses were set in parallel in order to run two extractions at the same time. Columns were activated with a few millilitres of methanol before extraction started. After extraction, columns and filters were wrapped in aluminium foil and kept in plastic bags at approximately 6^{o}C. Tests on tap water and distilled water were performing adding 7 µl of standard solution 1, 7 µl of internal standard (etion) and approximately 0.1 ml of H_2SO_4 (9M). Columns and filters were sent to the Institute of Environmental Analysis of Swedish Agriculture University and the analysis will be performed by Ph.D. Henrik Kylin using gas chromatography with EC-detector.

Table 2 shows methodology and instruments used for analysis of different water parameters and number of samples.

Definition of hardness of water was based in the following classification (Bydén 1990): very soft (0-2 ^{o}dH), soft (2-5 ^{o}dH), medium hard (5-10 ^{o}dH), hard (10-21 ^{o}dH) and very hard >21 ^{o}dH).

Table 2: Selected parameters, methods and number of sampling sites and replicates for water physical and chemical characteristic analysis.

Parameter	***Instrument***	***Method***	***Range***	***Local of analysis***	***Number of replicates per site***
pH	*Horiba*	*Electrode*	*0-14*	*Field*	*3*
Water temperature	*Horiba*	*Thermistor*	*0-100mS*	*Field*	*3*
Dissolved oxygen	*Horiba*	*Electrode*	*0-19.9 mg/L*	*Field*	*3*
Conductivity	*Horiba*	*Electrode*	*0-50^{o}C*	*Field*	*3*
Alkalinity		*Orion Test Kit*	*0-225 ppm$CaCo_3$*	*PETAR lab*	*1*
Hardness		*Aquanal-Plus, Complex Formation*	*1-21odH*	*PETAR lab*	*1*
Nitrate	*Hach*	*Cadmium reduction, Diazotization*	*0-0.5 mg/L*	*PETAR lab*	*3*
Nitrite	*Hach*	*Diazotization*	*0-0.350 mg/L*	*PETAR lab*	*1*
Phosphorus Reactive	*Hach*	*PhosVer 3 (Ascoric Acid)*	*0-2.50 mg/L*	*PETAR lab*	*3*
Total Nitrogen	*Hach*	*Persulfate Digestion*	*0-25 mg/L*	*Chalmers lab*	*3*
Total Phosphorous	*Hach*	*PhosVer 3 with Acid Persulfate Digestion*	*0-3.50 mg/L*	*Chalmers lab*	*3*
Ammonia	*Hach*	*Salicylate*	*0-0.50 mg/L*	*Chalmers lab*	*1*
Chemical Demand of Oxygen	*Hach*	*Reactor Digestion*	*0-1500 mg/L*	*Chalmers lab*	*3*
Sulphate	*Hach*	*SulfaVer 4 Method*	*0-0.70 mg/L*	*Chealmers lab*	*3*

Fish community sampling

An fishing survey was conducted at 11 sites in November 1998 (fishing was not possible at P7 due to weather conditions) and 13 sites in March 1999 using an electro-fishing equipment and an electricity generator (1000 watts, Honda). During both trips sampling efforts were standardised (approximately 25 minutes in small streams and 45 minutes in larger streams) in order to compare different sites. The downstream margins of the selected areas were blocked with nets to prevent fish escape. Upstream margins were also blocked when river currents were slow. In streams larger them 10 m, a lateral net was used and only a segment of the stream was sampled.

Three downstream passes were made along the length of the blocked stream segment. This technique, commonly used for estimation of fish population size, is called quantitative depletion sampling. The principle is that a known number of individuals are removed from a habitat on each sampling occasion, thus effecting the subsequent catches. The rate at which the catches fall off is directly related to the size of the population and the number removed (Cowx 1983). Sampling efficiency of a similar technique (Schlosser 1982 *apud* Angermeier and Scholosser 1989) indicated that at least 80% of the species and individuals captured after five passes were usually captured in the first two passes.

After each pass, individuals were preliminary identified and counted. All sampled fishes were narcotized and preserved in containers filled with formaldehyde (10%). In the laboratory of University of São Paulo, the specimens were re-counted and weighted and their identification was confirmed. The material was preserved in 70% ethanol and sent to *Museu de Zoologia de São Paulo.*

Analyses of fish the communities

Analyses of fish communities were based on *richness* (number of species), *diversity*, *evenness* and *biomas*s.

Species richness index was calculated according to Odum (1988) as:

$$D = \frac{S - 1}{\ln n}$$

where S is the number of species and n the number of individuals.

Diversity was calculated using Shannon´s index (Odum1988):

$$H' = -\sum_{i=1}^{S} \left[(ni/n) \log 2 (ni/n) \right]$$

where n_i is the number of individuals in taxon *i*; and *n* is the total number of individuals in the sample.

Evenness was calculated using the index of Pielou (Odum 1988):

$$e = \frac{H'}{\log S}$$

where *H'* is Shannon´s diversity index and *S* is the number of species.

Total fish abundance was estimated using the quantitative depletion sampling approach based on regression analysis according to Leslie and Davis (1939 *apud* Cowx 1983). The number of fish caught in the *i*th sample (c*i*) is plotted on *y*-axis against the previous total catch (*x*-axis). From the resulting straight line, initial population size (corresponds to the point where the line crosses the *x*-axis and the catchability (slope of the curve) can be estimated. According to Mahon (1980 *apud* Cowx 1983) any estimate of the population size made by the regression method should be considered as a minimum value.

According to Cowx (1983), fish which are normally bottom-living or feeding tend to be less vulnerable to electrofishing than mid-water and surface dwelling species, probably because benthic species, once stunned remain on the bottom and are often difficult to see and collect. For that reason, the quantitative depletion sampling technique is normally used for estimation of population studies aimed at species. However, in this study, the estimations were made at community level because the abundance of each single species were often too small to allowed the application of the method.

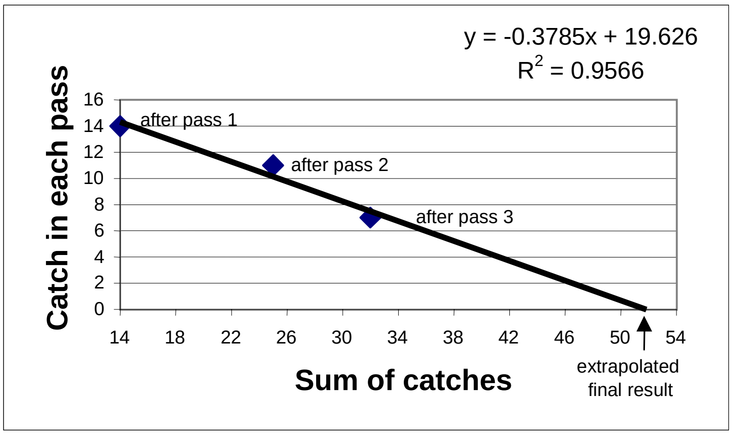

Figure 4: An example of total fish abundance in one sample site.

Example: Monjolos stream (B7), March 1999. Based on three consecutive passes using electrical fishing. Abundance of fishes in the sampling area equal to 52 individuals.

One of the drawbacks with the regression analysis is that data points often do not show a trend towards a straight line, and consequently, regression curves show poor correlation to the points (Cowe 1983). During the present study, there were occasions when the method for estimation of abundance described above could not be used (positive slope of the regression curve and/or R^2 less than 0.5). That was the case at sites B1, B7, B9 and B11 during November 1998 field campaign and B9, B11and I4 during March 1999 trip (See Appendix VII). In order to estimate the fish abundance on those cases the following steps were adopted:

1.1 Calculation of estimated populations in all sites when the graphical method described above could be applied;

1.2 Calculation of a factor by dividing of the estimated population by total number of fish caught in those sites mentioned on step 1.1;

1.3 Calculation of an average conversion factor for each sampling campaign (one for March 1999 and one for November 1998) using the figures obtained during step 2; and,

1.4 Application of such conversion factors in the total amount of fishes sampled on sites where the graphical method could not be applied;

1.5 The conversion factors applied were 1.41 (average of 7 sites, standard deviation 0.44, range 1.00-2.30) for November 1998 and 1.64 (average of 10 sites, standard deviation 0.65, range 1.07-3.40) for March 1999 samples.

In order to estimate fish density, the estimated population abundance was divided by the sampled area for each site.

The total number of individuals of each species, from each sampling site was weighted for calculation of total biomass. The comparisons between sites and between sampling periods were performed in five different ways:

2.1 *Total biomass of sampled fishes*, as the sum of all individuals of all species sampled at each site in each field campaign.

2.2 *Estimated total fish biomass*, as a product of the factor used for estimation of population abundance (item 1.1.or 1.4) by the total biomass of sampled fishes (item 2.1.).

2.3 *Sampled fish biomass per area* (g/m^2), as the division of total biomass of sampled fishes (item 2.1.) by the sampled area.

2.4 *Estimated fish biomass per area* (g/m^2), as the division of estimated total biomass of fishes (item 2.2.) by the sampled area.

2.5 *Average weight of the species*, as the division the total biomass of one species by the number of individuals of the same species sampled in each site. The analysis was performed only for the most abundant species.

Preliminary results

Site description

A detailed description of each site in presented in Table 3.

Streams were classified in three groups according to their bed conditions, flow speed [1]and breadth. One group was composed of larger rivers (breadth larger than 10 m), fast flow speed and beds consisted mostly by bedrock or rocks. Betari (B9, B1, B3, B10), Iporanga (I4) and Pilões (P7 and P9) rivers belong to this class (Figure 5).

Another group was formed by small fast flow streams (breadth smaller than 10 m) with substrate consisted mostly by bedrock or rocks. Furnas (B4), Monjolos (B7), Passagem do Meio (B11), Soarez (I5) streams as well as one of Pilões tributaries (P8) represented that group (Figure 6).

The third group of river was composed of low speed small streams that presented beds mostly covered by sand. Iporanga rivers near its head-waters (I2) and one of its tributaries (I3) together with two of Pilões tributaries (P5 and P6) are included in the group (Figure7).

The habitat structure of each site was evaluated on basis of river breadth, bed material and marginal vegetation (Table 4). The highest score for habitat complexity (4) was given to I4, followed by B9 (3.7) and B1, B3, B11, P7 and P9 (3.3.). The lowest scores were given to P5 (1.3) and I3 and B7 (1.7).

Figure 5: Betari rivers (B9), an example of a large stream with rocky bed. (S. Molander)

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[1] Stream flow presented here is only based on visual estimation (median or slow riffle). Estimation of stream flow based in water flowmeter measurements will be calculated.

Figure 6: Furnas stream (B4), an example of a small stream with rocky bed. (R. Moraes).

Figure 7: Iporanga tributary (I3), an example of a small stream with sandy bed (P. Gerhard).

Table 3: Name, location (watershed, latitude and longitude) and type of stream of the sampling sites visited during November 1998 and March 1999.

Site Number	Watershed	Type of stream	Stream Name	Sampling Date		Lat 24°- S	Long 48° - W
B1	Betari	Large, rocky bed	Betari	20.11.98	03.04.99	32,00	41,92
B4	Betari	Small, rocky bed	Furnas	18.11.98	26.03.99	32,14	42,17
B7	Betari	Small, rocky bed	Monjolos [2]	15.11.98	26.03.99	33,21	40,66
B9	Betari	Large, rocky bed	Betari	18.11.98	01.04.99	31,91	42,20
B10	Betari	Large, rocky bed	Betari	13.11.98	03.04.99	33,45	40,32
B11	Betari	Large, rocky bed	Passagem do Meio	20.11.98	02.04.99	34,09	38,74
I2	Iporanga	Small, sandy bed	Iporanga	19.11.98	28.03.99	26,85	39,26
I3	Iporanga	Small, sandy bed	Iporanga tributary	16.11.98	04.04.99	24,70	39,41
I4	Iporanga	Large, rocky bed	Iporanga	14.11.98	31.03.99	29,85	35,35
I5	Iporanga	Small, rocky bed	Soarez		03.04.99	33,24	36,10
P5	Pilões	Small, sandy bed	Córrego Preto	16.11.98	27.03.99	23,57	37,92
P6	Pilões	Small, sandy bed	Pilões tributary	17.11.98		20,19	30,05
P7	Pilões	Large, rocky bed	Pilões tributary	21.11.98		32,00	30,42
P8	Pilões	Small, rocky bed	Pilões		24.03.99	17,85	29,93
P9	Pilões	Large, rocky bed	Pilões		30.03.99	29,15	29,02

Table 4: Classification of sample sites according to different categories of habitat structure used for calculation of index of habitat complexity.

Score 1: river width < 2m, bed very homogenous; no marginal vegetation. Score 2: river width >2 and <5m; bed mostly homogeneous; marginal vegetation very disturbed). Score 3: river width >5 and <7 m; heterogeneous bed; secondary forest a little disturbed marginal as vegetation. Score 4: river width >7m, very heterogeneous bed; primary forest as marginal vegetation.

	I4	B9	B1	B3	B11	B4	P9	P7	P8	B10	I5	P6	I2	B7	I3	P5
River width	4	4	4	4	2	2	4	4	2	4	2	3	3	1	2	1
Bed material	4	4	4	4	4	4	4	4	4	3	4	2	2	2	1	1
Marginal vegetation	4	3	2	2	4	4	2	2	3	2	3	3	2	2	2	2
Index of habitat complexity	4.0	3.7	3.3	3.3	3.3	3.3	3.3	3.3	3.0	3.0	3.0	2.7	2.3	1.7	1.7	1.3

[2] B7 was called Jaguatirica by mistake in Molander and Moraes (1998).

Table 5: Sampling site description (P. Gerhard, S. Buck and R. Moraes).

Site	*B9*	*B1*	*B3*	*B10*	*B4*	*B7*	*B11*
Stream	*Betari*	*Betari*	*Betari*	*Betari*	*Furnas*	*Monjolos*	*Passagem do meio*
Marginal vegetation	*Eastern: primary forest; western: camping*	*eastern: secondary forest; western: secondary forest very disturbed*	*very disturbed*	*very disturbed*	*secondary forest a little disturbed*	*grass, few trees*	*primary forest*
Human impacts	*Tourism (camping, tracks)*	*lead mining in tributary, tourism (camping, tracks)*	*human settlements, lead mining in tributary*	*human settlements, cattle, lead mining in tributary*	*lead mining*	*human settlements, road*	
Type of channel	*step-pool*	*Step-pool/pool-rifle*	*Step-pool/pool-rifle*	*Step-pool/pool-rifle*	*step-pool*	*Step-pool/pool-rifle*	*step pool*
Bed material	*cobble and boulder*	*Boulder and cobble*	*gravel and boulder*	*gravel and sand*	*Boulder and cobble*	*bedrock*	*bedrock, boulders, cobble*
Flow speed	*median riffle*	*median riffle*	*median riffle*	*median riffle*	*median riffle*	*median riffle, slow riffle*	*slow riffle*
Turbidity	*transparent*	*transparent*	*transparent*	*transparent*	*transparent*	*transparent*	*transparent*
Shading	*<40%*	*<40%*	*20%*	*20%*	*>80%*	*50%*	*90%*
Depth (m)	*0.5*	*0.2 – 0.6*	*0.5*	*0.3-0.4*	*0.2-0.5*	*0.5*	*0.6 – 0.2*
Breadth (m)	*10*	*0.9*	*13*	*15*	*2.5-6.0*	*1*	*1-5*

Site	***I3***	***I2***	***I4***	***I5***	***P5***	***P6***	***P8***	***P7***	***P9***
Stream	*Tributary Iporanga*	*Iporanga*	*Iporanga*	*Soarez*	*Córrego Preto*	*Pilões tributary*	*Pilões tributary*	*Pilões*	*Pilões*
Marginal vegetation	*first 20 m with high grass, last 10 m secondary forest*	*disturbed secondary forest*	*eastern: primary forest, right: disturbed secondary forest*	*disturbed secondary forest*	*disturbed secondary forest*	*eastern: disturbed secondary forest; right: grass*	*disturbed secondary forest*	*right: disturbed secondary forest, eastern: grass*	*right: disturbed secondary forest, eastern: grass*
Human impacts	*agriculture, deforestation, road*	*calcareous mining, deforestation*		*human settlements (one house), insecticides application*	*agriculture, road*	*agriculture*	*agriculture*	*agriculture, human settlements, deforestation*	*agriculture, human settlements, deforestation*
Type of channel	*Plane-bed*	*Plane-bed*	*Step-pool*	*Step-pool*	*Plane-bed*	*Plane-bed, pool-riffle*	*Plane-bed; bedrock; step-pool*	*Step-pool*	*Step-pool*
Bed material	*sand*	*cobble and sand*	*Boulder and cobble*	*cobble and few boulders*	*sand*	*sand and gravel*	*Boulder and cobble*	*Boulder and cobble*	*Boulder and cobble*
Flow speed	*slow riffle*	*median riffle*	*slow riffle*	*median riffle*	*median riffle, slow riffle*	*slow riffle*	*median riffle, points of slow riffle*	*median riffle, slow riffle*	*median riffle, slow riffle*
Turbidity	*transparent*	*little turbid*	*transparent*	*transparent*	*turbid*	*transparent*	*transparent*	*transparent*	*transparent*
Shading	*50%*	*70%*	*<40%*	*70%*	*90%*	*50%*	*90%*	*20%*	*20%*
Depth (m)	*1*	*0.3*	*0.4*	*0.3*	*0.5 - 0.7*	*0.5*	*0.3- 0.6*	*0.5*	*0.5*
Breadth (m)	*2.5*	*7*	*11*	*4*	*2*	*8*	*4*	*30*	*30*

Physical and chemical water parameters

Comparisons between measurements of pH, temperature, hardness, dissolved oxygen, alkalinity and conductivity in samples taken from different sites in different periods of the year are presented in Figures 8, 9, 10, 11, 12 and 13. Large streams (Betari, Iporanga and Pilões) showed lower variability in terms of physical and chemical characteristics when compared with their tributaries. That is expected since water conditions of rivers of higher order should reflect a combination of characteristics of their tributaries, while low order stream normally reflect local characteristics more directly.

June was the month with the lower water temperatures (mean 16.5, stdv. 1.6, max. 18.5 and min. 14.2 C^{o}) and March, the higher water temperatures (mean 21.2 C ^{o}, stdv. 1.2, max. 23.2 and min 19.5 C ^{o}). Mean water temperature in November was 19.5 C ^{o} (stdv. 1.5, max. 22.1 and min. 16.6 C ^{o}).

Values for dissolved oxygen (DO) ranged between 6.4 and 11.8 mg/ L and were above the recommended values for preservation of aquatic life (5.0 mg/L, CONAMA 1986). Large streams presented higher DO (mean 9.2, stdv. 0.6 mg/L) than small streams either with rocky bed (mean 8.6, stdv 0.5) and sandy bed (mean 8.3 and stdv. 3.1). Lowest DO value was for I3 (7.7, 6.4 and 6.8 mg/L), which is a stream with a very slow water flow.

Values for pH varied between 8.7 and 6.5. In all cases, values are within the range suggested by CONAMA for preservation of aquatic life (range 6.0 to 9.0, CONAMA 1986). Nearly all sites presented pH higher than 7, which was expected since those rivers are running in bedrock consisting of limestone in most of their extension. Only two sites presented water with pH slightly below 7: I3 and B11. Passagem do Meio stream (B11) presented the lowest pH value (mean 6.6, standard deviation 0.2), low hardness (1^{o}dH), no alkalinity and very low conductivity (0.017 mS/cm). Those characteristics are probably related with the bedrock, which consists of phyllite, which is a metamorphic rock (H. Shimada, *pers. comm.*). Reasons for a slightly low pH detected in I3 (mean 6.9) still need to be investigated.

Water from Betari, Iporanga and Pilões presented soft or very soft water, excepted for B4 (Furnas stream) and B7 (Monjolos stream). Water samples from B4 taken in November presented hardness 0 ^{o}dH (very soft) and 6 in March (medium hard).

Conductivity values ranged from 0.016 (B11) to 0.290 mS/cm (B7). The Monjolos stream (B7) presented comparatively high conductivity (0.290

mS/cm) and hardness (7 and 11) which are probably related to release of ions in sewage water from the Bairro da Serra village.

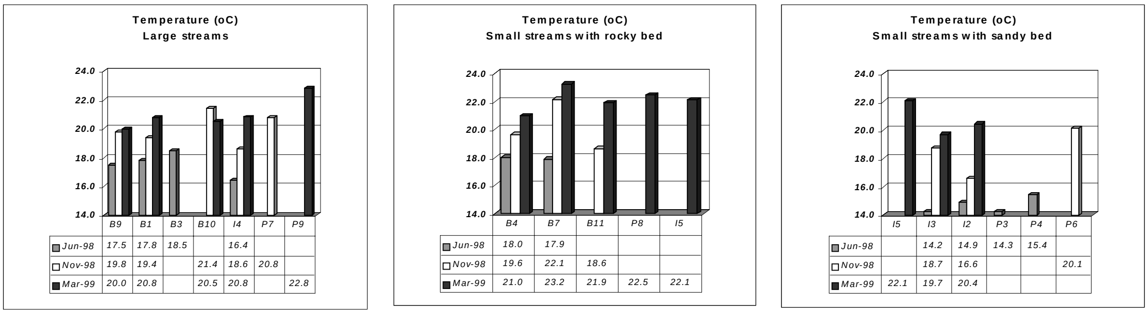

*Figure 8**:** Temperature in PETAR streams.*

Values represent average of three measurements. Empty cells represent cases where no measurements are taken.

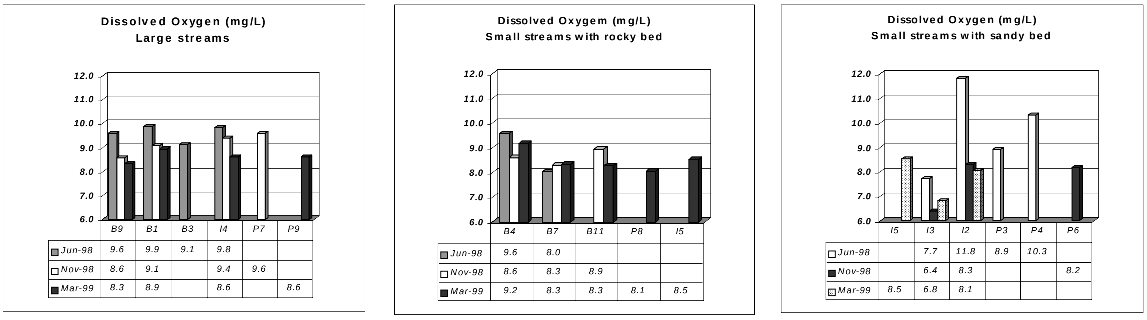

Figure 9: Dissolved oxygen in PETAR streams.

Values represent average of three measurements. Empty cells represent cases where no measurements are taken.

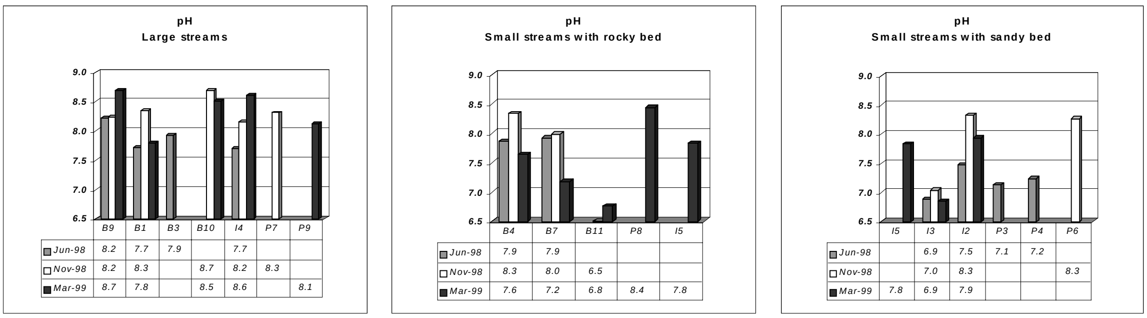

Figure 10: pH in PETAR streams.

Values represent average of three measurements. Empty cells represent cases where no measurements are taken.

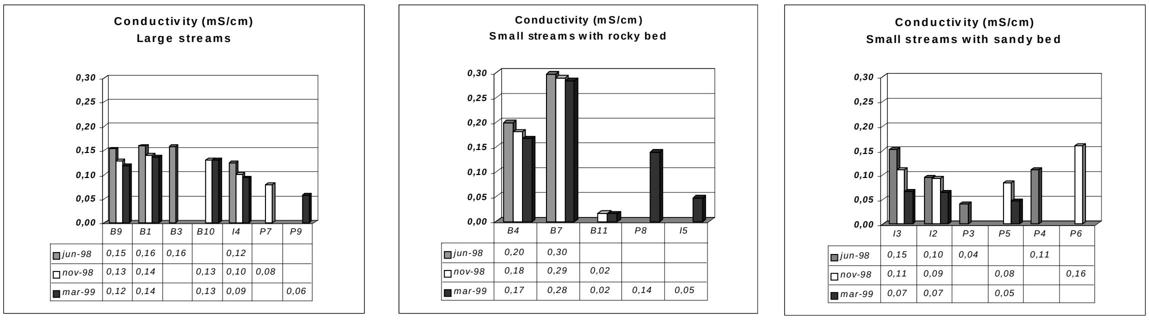

Figure 11: Conductivity in PETAR streams.

Values represent average of three measurements. Empty cells represent cases where no measurements are taken.

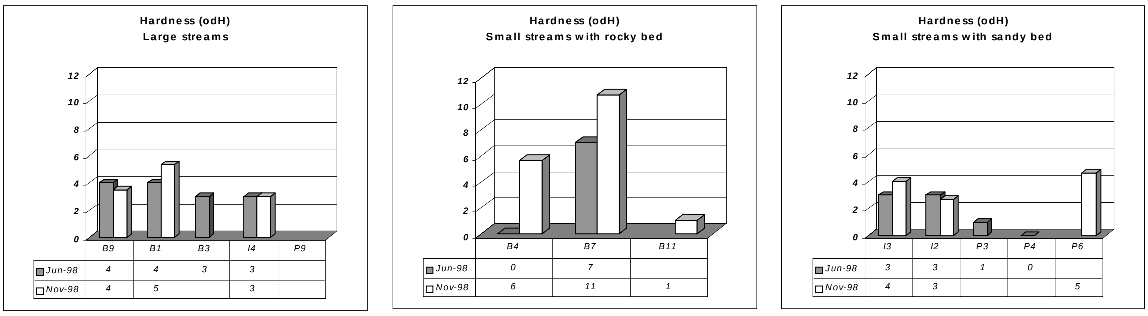

Figure 12: Hardness (^{o}dH) in PETAR streams.

Values represent one measurement. Empty cells represent cases where no measurements are taken.

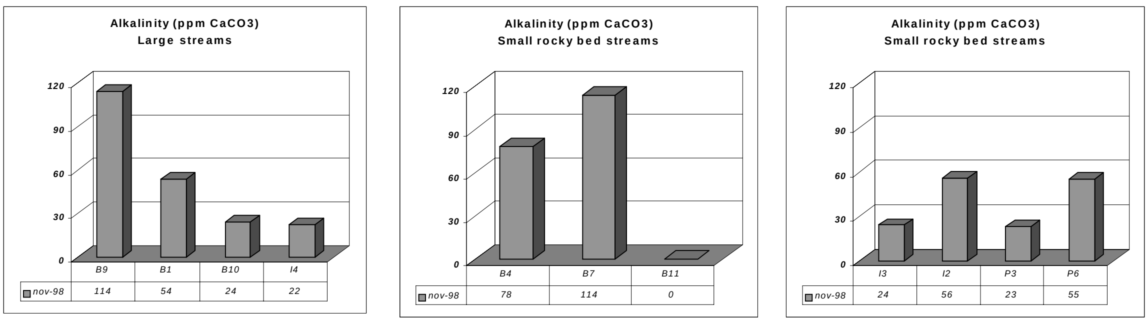

Figure 13: Alkalinity (ppm $CaCO_3$) in PETAR streams.

Values represent average of three measurements. Empty cells represent cases where no measurements are taken.

Nutrients concentration

Measurements of nitrate, phosphate, total nitrogen and phosphorus were performed by Johanna Lundqvist and will be discussed in her master thesis (in preparation). Preliminary results are showed in the graphs below.

Nitrate is the most common form of plant available nitrogen. Nitrate concentration in some of PETAR streams during June and November 1998 are presented in Figure 14. The highest values were found in B9, B1 and B4 in June 1998 and in B11 in November 1998. In many sites (B9, B1, B4 and B7), measured values of nitrate were higher in June than in November. On the other hand, total nitrogen measurements were higher in November at 5 of the sites (B9, B1, B4, I3 and I2).

In natural waters, the plant available forms of phosphorus are the inorganic orthophosphates, $H_2PO_4^-$, HPO_4^{2-} and PO_4^{3-}. They are together called phosphate-phosphorus (PO_4-P). The highest concentrations of phosphate were measured at B4 and B7 during November 1998.

The total amount of phosphorus in a stream is a potential nutrient source, since there are a number of processes that can transform it into orthophosphates. P5, P6 and I2 presented the highest concentration of total phosphorus during November 1998.

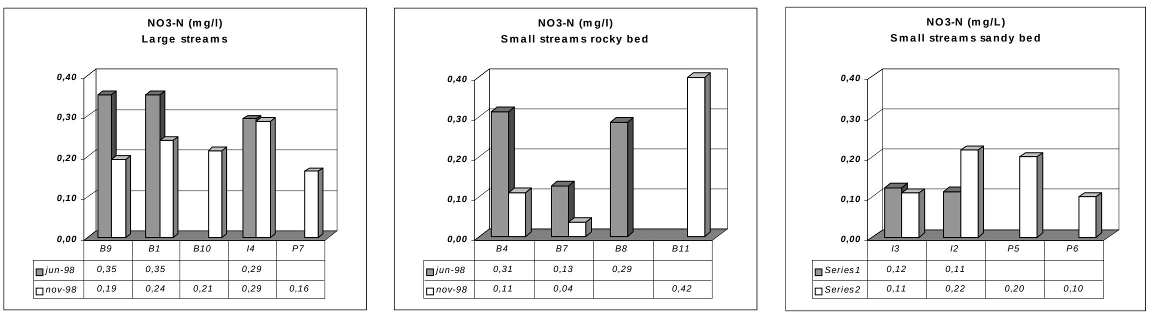

Figure 14: Nitrate concentration in PETAR streams.

Values represent average of three measurements. Empty cells represent cases where no measurements were taken.

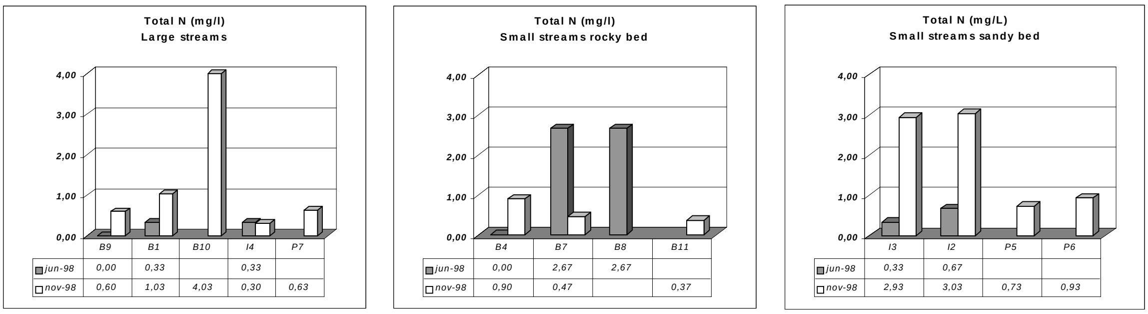

Figure 15: Total nitrogen concentration in PETAR streams.

Values represent average of three measurements. Empty cells represent cases where no measurements were taken.

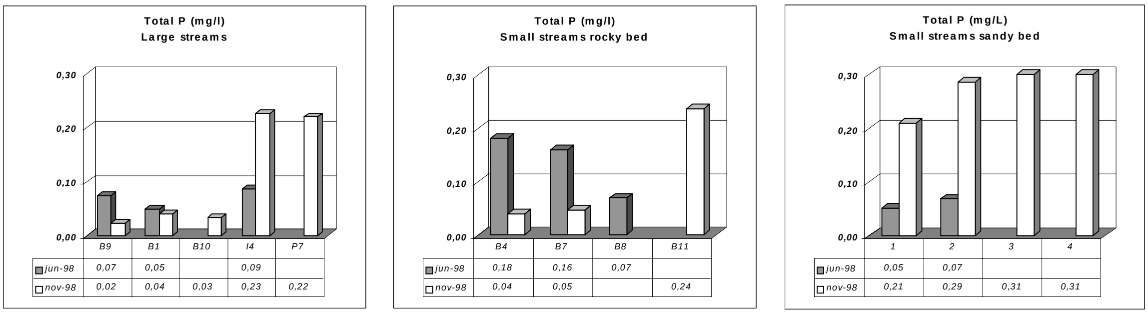

Figure 16: Phosphate concentration in PETAR streams.

Values represent average of three measurements. Empty cells represent cases where no measurements were taken.

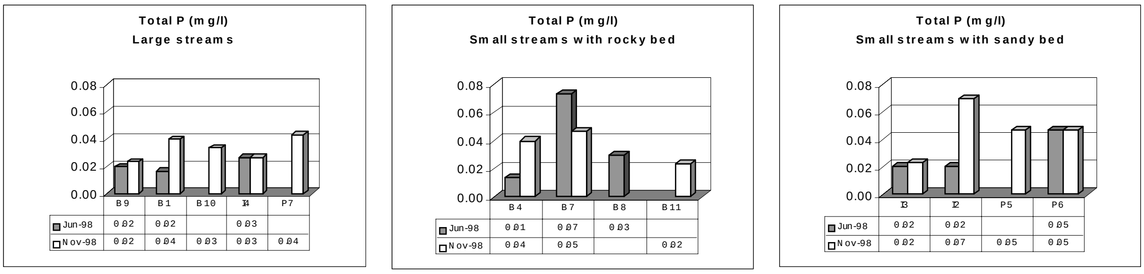

Figure 17: Total Phosphorus in PETAR streams.

Values represent average of three measurements. Empty cells represent cases where no measurements were taken.

Further literature review regarding geology of the region as well discussion of nutrient measurement results is needed for a better interpretation of the water parameter results. Statistical tests will be used to detect differences between sites and seasons.

Pesticides concentration

Table 6 presents results of pesticides analysis in water sampled in June 1998 (see also description of sites B3, B5, B6, B8, B9, I1, P2 and P4 in Molander and Moraes 1998). Chlorotalonil and permetrin were found dissolved in water in all sampled sites. Traces of chlorotalonil were found in particles from four (P2, I4, B7, B8 plus B9) out of thirteen sample streams. There was no information about use of pesticides in streams such as B4 and B5. Possible contamination of the samples during extraction needs to be investigated.

Table 6: Concentration of chlorotalonil and permetrin in water and particles (filter) samples in June 1998.

Traces mean concentration below 0.0 5µg.

Sampling site	*Water*		*Filter*
	chlorotalonil (µg)	*permetrin (µg)*	*chlorotalonil (µg)*
P2	traces	0.74	Traces
P4 (B)	traces	*0.15*	0.00
P4 (B)	traces	0.48	0.00
I1+I2	traces	1.03	0.00
I3	traces	1.17	0.00
I4	0.10	0.30	Traces
B1	0.08	0.18	0.00
B3	traces	0.83	0.00
B4	traces	0.59	0.00
B5	traces	0.43	0.00
B6	traces	0.43	0.00
B7	traces	0.42	Traces
B8+B9	0.08	0.31	Traces

Fish community analysis

Icthyofauna composition

A total of 3,109 fish specimens were sampled during the field campaigns (915 in November and 2,190 in March). They were identified to the species level when possible. A list of species collected and their taxonomic relations are presented below.

Order Characiformes

Characidae

Astyanax sp
Bryconamericus sp
Deuterodon sp
Hollandichthys sp
Mimagoniates sp
Characidium sp

Order Siluriformes

Siluroidei

Callichthyidae

Corydoras sp

Loricariidae

Ancistrus sp
Ascentronicthys sp
Harttia kronei
Hisotonus sp
Hypostomus sp
Kronichthys sp
Neoplecostomus sp
Paratocinclus sp
Pareiorhaphis sp
Rimeloricaria sp

Pimelodidae

Chasmocranus lopezi
Imparfinis sp
Rhamdiioglanis frenatus
Microglanis sp
Pimelodella transitoria
Rhamdia sp

Trichomycteridae

Trichomycterus dawisi
Trichomycterus sp1
Trichomycterus sp2

Gymnotoidei

Gymnotidae

Gymnotus sp

Order Cyprinodontiformes

Poeciliidae

n.i.

Order Perciformes

Cichlidae

Geophagus sp
Crenicichla sp

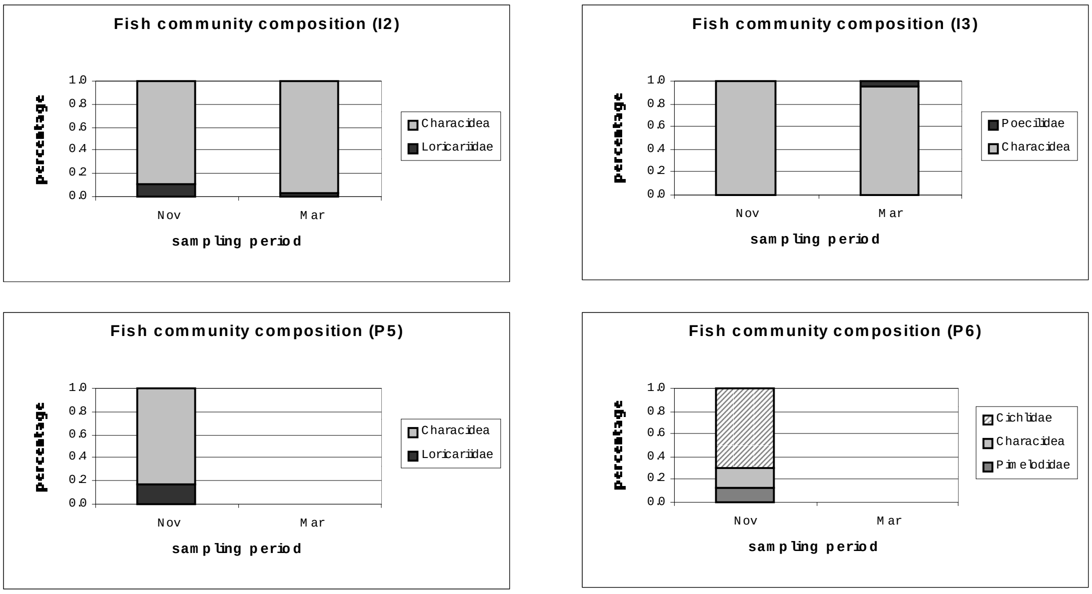

Figure 18: Fish community composition in surveyed small PETAR streams with sand bed (sites I2, I3, P5 and P6) in terms of percentage of sampled individuals of each family during November 1998 and March 1999.

The composition of the fish community at each sampling site in terms of fish family are represented in Figures 18, 19 and 20; Tables 7 and 8 in Appendix III and IV. Five or six families were sampled in larger streams (Betari at B1, B9, B10; Iporanga at I4 and Pilões at P9). The most common families in these streams are Loricariidae, Characidae and Pimelodidae.

Three fish families were sampled in each one of the small streams with rocky bed (B11, B4, B7 and P8), exceptionally by I5 were 6 families were found. The most common family fished in B11 and B4 was Pimelodidade; in B7, Trichomycteridae; in P8, Characidae; and in I5, Loricaridae and Characidae.

Two fish families were found in the small streams with sand bed I2, I3 and P5, being Characidae the most common one. At P6, three families were found, Cichlidae being the most abundant.

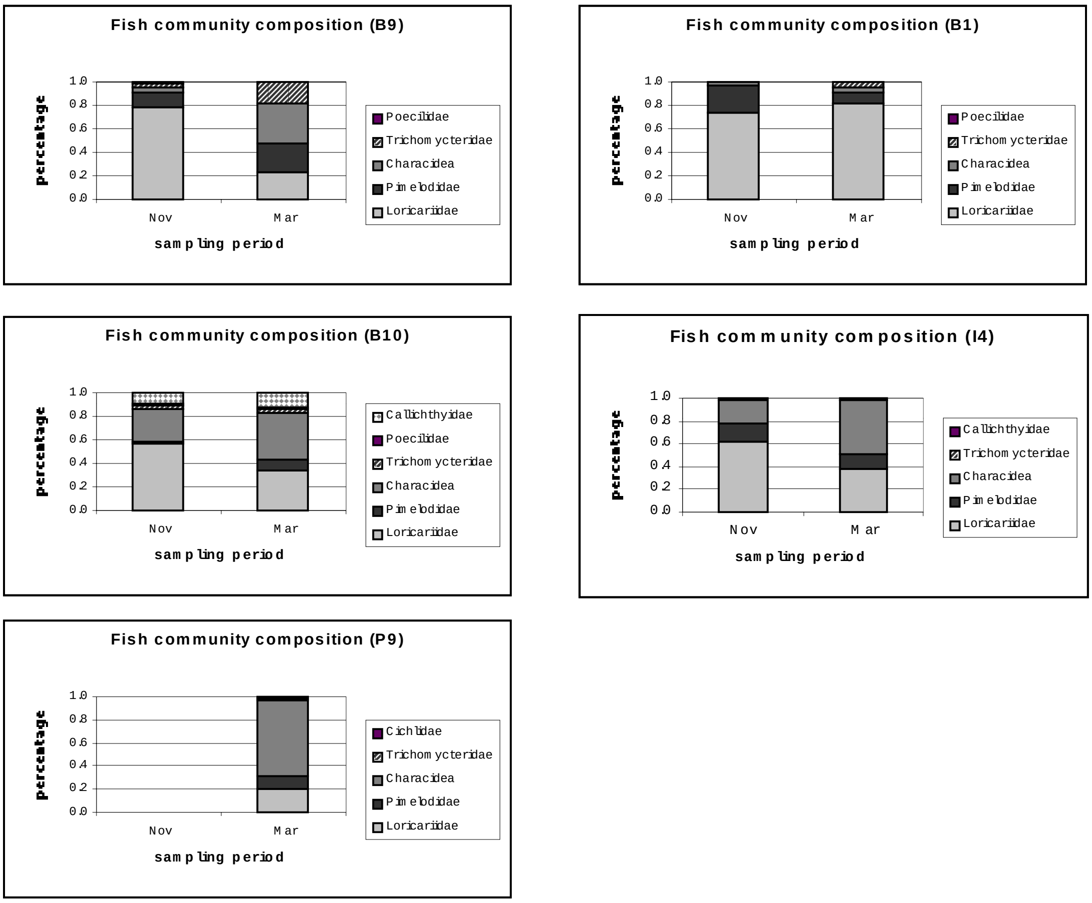

Figure 19: Fish community composition on surveyed large PETAR streams (sites B1, B9, B10, I4 and P9) in terms of percentage of sampled individuals of each family during November 1998 and March 1999.

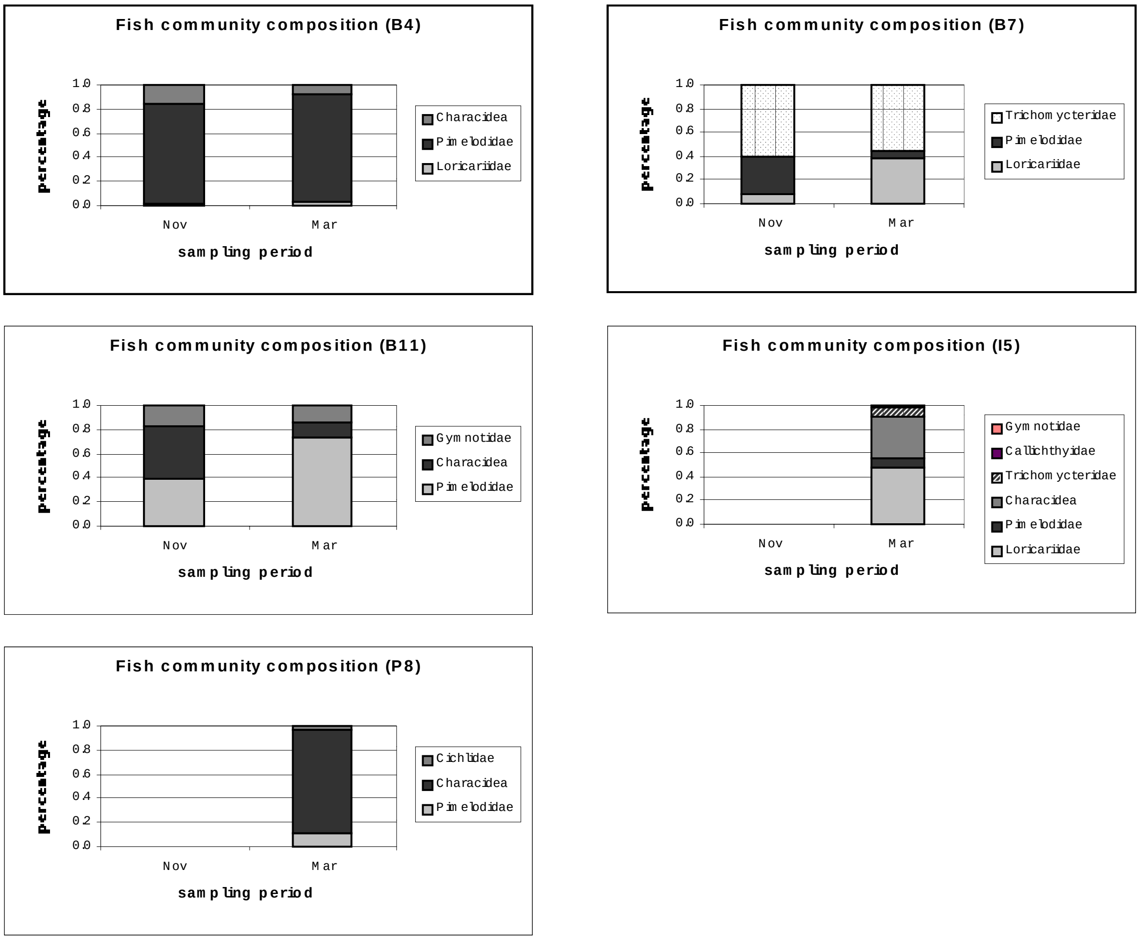

Figure 20: Fish community composition on surveyed small PETAR streams with rocky bed (sites B4, B7, B11, P8 and I5) in terms of percentage of sampled individuals of each family during November 1998 and March 1999.

Table 7: Fish species composition (in percentage) in PETAR streams in November 1998.

Taxa		*Sample sites*										
Family	*Species*	*B1*	*B4*	*B7*	*B9*	*B10*	*B11*	*I2*	*I3*	*I4*	*P5*	*P6*
Characidae	Astyanax *sp*		*15.1*		*1.7*	*4.8*		*88.2*	*54.8*			*17.4*
	Bryconamericus *sp*	*3.3*			*1.7*	*4.2*						
	Deuterodon *sp*				*0.6*	*0.5*				*7.5*		
	Hollandichthys *sp*											
	Mimagoniates *sp*									*0.6*		
	Characidium *sp*				*0.6*	*19.6*	*47.1*		*45.2*	*20.5*	*83.3*	
Callichthyidae	Corydoras *sp*					*9.5*				*1.9*		
Loricariidae	Ancistrus *sp*									*0.6*		
	Ascentronicthys *sp*									*0.6*		
	Harttia kronei	*6.7*	*1.9*		*8.3*							
	Hisotonus *sp*									*9.3*		
	Hypostomus *sp*			*15.2*		*1.6*					*16.7*	
	Kronichthys *sp*	*5.0*		*8.7*	*6.6*	*35.4*				*11.2*		
	Neoplecostomus *sp*					*1.1*						
	Paratocinclus *sp*					*3.7*						
	Pareiorhaphis *sp*	*65.0*			*64.6*	*3.7*		*11.8*		*39.1*		
	Rimeloricaria *sp*				*0.6*	*10.6*				*1.9*		
Pimelodidae	Chasmocranus lopezi	*8.3*	*9.4*		*3.9*					*2.5*		
	Imparfinis *sp*											
	Rhamdiioglanis frenatus	*10.0*	*56.6*		*7.7*	*0.5*	*35.3*			*3.7*		
	Microglanis *sp*											
	Pimelodella transitoria	*1.7*	*17.0*			*0.5*				*0.6*		
	Rhamdia *sp*			*15.2*								*13.0*
Trichomycteridae	Trichomycterus dawisi				*2.2*	*1.6*						
	Trichomycterus *sp*1					*1.1*						
	Trichomycterus *sp*2			*60.9*	*0.6*	*0.5*						
Gymnotidae	Gymnotus *sp*						*17.6*					
Poeciliidae	*n.i.*				*1.1*	*0.5*						
Cichlidae	Geophagus *sp*											*69.6*
	Crenicichla *sp*											
Total number of sampled fishes		*60*	*53*	*45*	*181*	*189*	*17*	*144*	*42*	*161*	*6*	*23*

Table 9: Fish species composition (in percentage) in PETAR streams in March 1999.

Taxa		Sample Sites												
Family	Species	B1	B4	B7	B9	B10	B11	I2	I3	I4	I5	P5	P8	P9
Characidae	*Astyanax sp*		8.1		4.8		3.0	82.4	82.4		3.2	16.7	85.1	5.2
	Bryconamericus sp	2.7			28.3	4.2			0.4	4.5				
	Deuterodon sp					1.8				4.2	1.9			
	Hollandichthys sp												1.5	
	Mimagoniates sp									1.3				
	Characidium sp	1.1			5.9	28.6	13.3		12.7	36.3	12.5	80.0		60.3
Callichthyidae	*Corydoras sp*					13.2				1.6	0.6			
Loricariidae	*Ancistrus sp*					0.7				10.0	14.1			1.7
	Ascentronicthys sp										0.3			
	Harttia kronei	5.6			2.1	0.2								3.4
	Hisotonus sp					1.4				1.0				
	Hypostomus sp			31.3						0.3	0.6			
	Kronichthys sp	1.1		3.1	3.7	19.6				8.0	5.1			12.1
	Neoplecostomus sp	0.4			0.5	0.5								
	Paratocinclus sp					1.4								1.7
	Pareiorhaphis sp	73.1	2.7	3.1	16.6	10.2		97.0	12.2		3.3			
	Rimeloricaria sp	0.4			0.5	6.9				6.1	4.5			1.7
Pimelodidae	*Chasmocranus lopezi*	6.5	5.4		7.5	0.5				1.0	0.3			4..3
	Imparfinis sp										0.3			
	Rhamdiioglanis frenatus	3.6	62.2	3.1	16.0		73.3			7.1	3.2			5..2
	Microglanis sp									0.3	0.3			
	Pimelodella transitoria	0.2	30.4		0.5	0.5				4.5	0.3			0.9
	Rhamdia sp		2.7			0.5					0.3		10.4	
Trichomycteridae	*Trichomycterus dawisi*	4.5		56.3	13.9	2.5				1.0	4.2			
	Trichomycterus sp1	0.2			3.7	1.4				0.6				0.9
	Trichomycterus sp2	0.2				0.2								0.9
Gymnotidae	*Gymnotus sp*	0.4					13.3				0.3			
Poeciliidae	n.i.					0.5	0.5							
Cichlidae	*Geophagus sp*								4.6				3.0	0.9
	Crenicichla sp													0.9
Total number of sampled fishes		**449**	**37**	**32**	**187**	**433**	**15**	**66**	**284**	**311**	**163**	**30**	**67**	**116**

Species richness

Figure 21 and 22 present the number of species and the richness index (according to Odum 1988) in each one of the surveyed streams in PETAR in November 1998 and March 1999. Larger streams (Betari at B9, B1, B10, Iporanga at I5 and Pilões at P9) presented a relatively larger number of species compared to small streams. Average number of species was 13 in November and 16 in March (richness index D 2.34 and 2.62, respectively). These results were expected since, typically, headwater streams carry fewer species than the lower stretches (Lowe-McConell 1987, Stanford 1996).

Rocky bed streams carried higher number of species (4 in November and 8 in March, richness index 0.83 and 1.48, respectively) than slow flow, sandy bed streams (2 in November and 3 in March, richness index 0.42 and 0.45). This was also expected since rocky bed streams are comparatively more complex habitats. I5 (Soarez stream) represented an exception among the small rocky bed streams for presenting a very high number of species (17, richness index 3.14) which is even higher than the index calculated for large streams. I2 (Iporanga stream) presented the lowest value of richness index, 0.20 and 0.24.

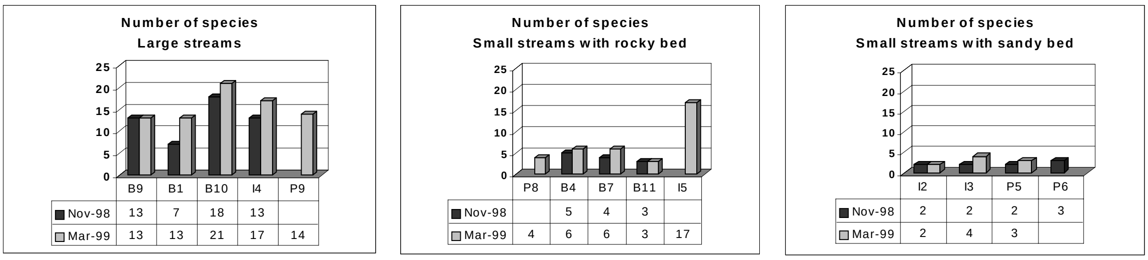

Figure 21: Number of species in surveyed PETAR streams.

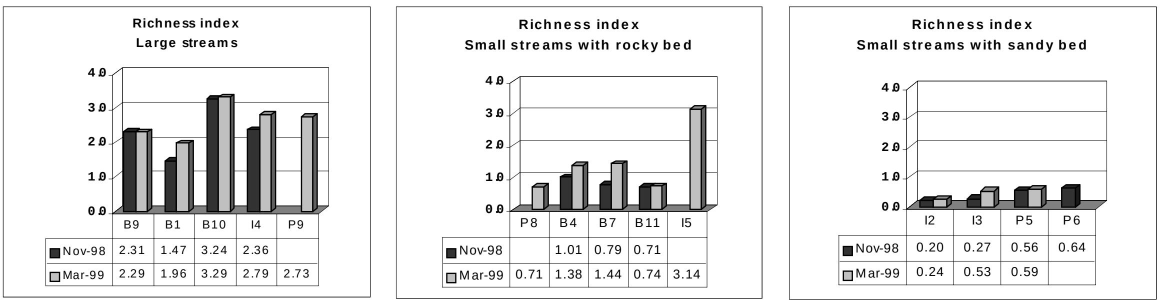

Figure 22: Richness index in surveyed PETAR streams.

Estimated Abundance, Diversity and Evenness

The number of fishes sampled during March 1999 (2,190) was nearly the double of the number fished during November 1998 (915). This could be a reflection of sampling effort, since more people were involved in fishing in the last field trip (3-5 instead of 2). For that reason the method for estimation of population in the surveyed areas (see description in the methodology chapter) was applied on samples from both campaigns, which allowed further comparisons.

The estimated number of fishes in large rivers was much higher than is small streams (Figure 23). Among the last ones, sandy bed streams seem to carry a larger number of individuals than rocky bed streams.

Large streams with rocky beds presented, in average, a higher number of individuals per area (mean of November and March 1.4 ind/m^2) in comparison with small streams (0.7 for streams with rocky beds and 0.9 ind/ m^2 for sandy beds; Figure 24), based on estimations of total abundance of fish.

I5 (Soarez stream) was again an exception among small stream with rock bed, presenting a very high density of individuals (2.3 ind/m^2). The highest density observed was in Iporanga river (I3), 3.3 ind/ m^2 during March 1999.

Fish diversity, as Shannon's index, (Figure 25) was higher in large streams (2.35 in November and 2.61 in March). Sandy bed streams presented the lowest diversity (0.84 and 0.63, respectively). Once again, I5 represented an exception within the group of small rock bed streams (1.52 and 1.65, respectively) due to its high diversity (3.07 in March). Even though the sampling effort was higher during the field trip carried on in March 1999, which resulted in a larger number of sampled specimens, the calculated diversity indexes were comparable during both campaigns.

Calculated evenness index (Pilou's index) was similar in large streams (average 2.16 in November and 2.19 in March) and in small rocky bed streams (2.57 and 2.07, respectively) as showed on Figure 26. The lowest values were calculated for sand bed streams (average 1.28 and 1,28) where most of the sampled community was represented by few species.

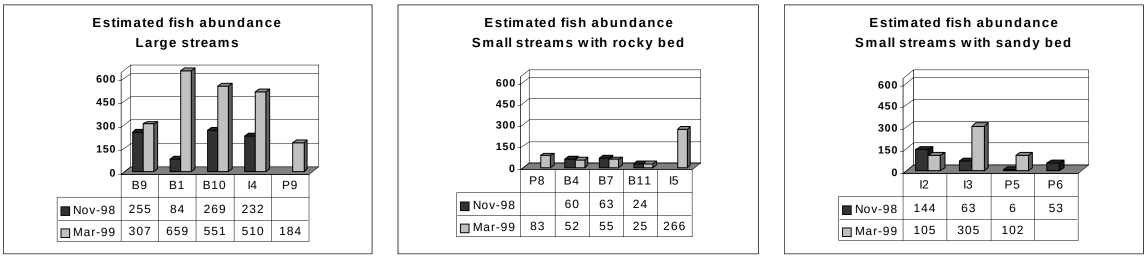

Figure 23: Estimated fish community abundance (number of individuals) in PETAR streams.

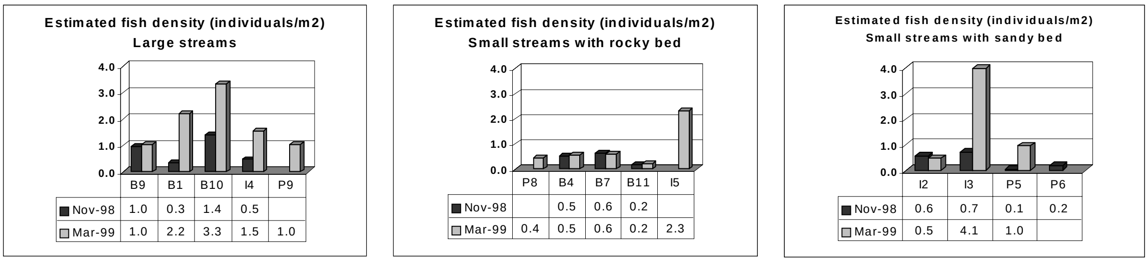

Figure 24: Estimated fish density (individuals/m^2) in PETAR streams.

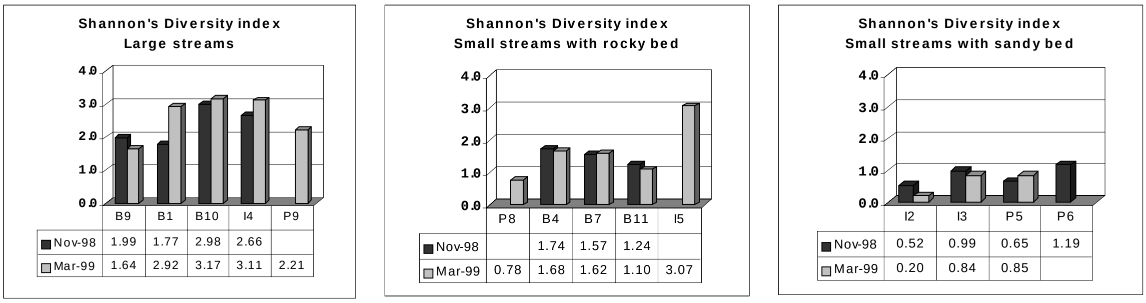

Figure 25: Shannon´s diversity index in PETAR streams.

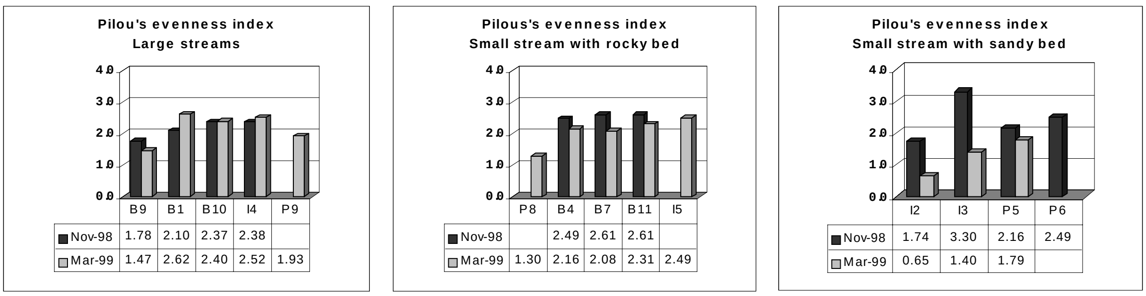

Figure 26: Pielou´s evenness index in PETAR streams.

Biomass

The total biomass of caught fishes in all sites was twice higher in March (7,837 g) than in November (3,727 g). This may be a reflection of sampling effort, since more people were involved in fishing during the last field trip. The average biomass of all sampled fish was 40.5 g in November 1998 and 3.54 g in March 1998, which reflects the presence of higher number of small individuals, juveniles, at least of some species, during the second field trip.

The total biomass of sampled fish (Figure 27) were higher in larger streams (in average 495.2 g in November and 1038.9 g in March) than in small rocky bed streams (respectively 367.7 and 478.4 g). The lowest measured biomass was found in sandy bed streams (respectively 160.7 and 53.9). A similar situation is found when one compares estimated total biomass (703.1 g in November and 1496.0 g in March in large streams; 444.6 and 714.0 g, respectively, in small rocky bed streams; and 224.7 and 92.6 g in small sandy bed streams) as showed in Figure 28.

The total biomass of caught fish was divided by the sampled area in each surveyed site. Results are presented on Figure 29. Slow flow streams with sand beds showed lower values of sampled biomass per area (average 0.7 g/m^2 in November and 0.6 g/m^2 in March). The sampled total biomass per area increased considerably in Betari river (B9, B1 and B10) and Iporanga (I4) from November 1998 (respectively 2.3; 1.1; 7.3 and 1.2 g/m^2) to March 1999 (2.4; 5.4; 2.8 and 3.0 g/m^2). The highest biomass density was found in B4 in November (7.0 g/m2) and in B10 in March (7.3 g).

In terms of estimated biomass per unit of area, small sandy bottom streams presented the lowest values (1.0 g/m^2 in November and 0.9 g/m^2 in March) compared to large streams (2.6 and 6.4 g/m^2 respectively) and small rocky bed streams (4.0 and 6.1 g/m^2). Within the small rocky streams, I5 presented the highest biomass density (13.9 g/m^2).

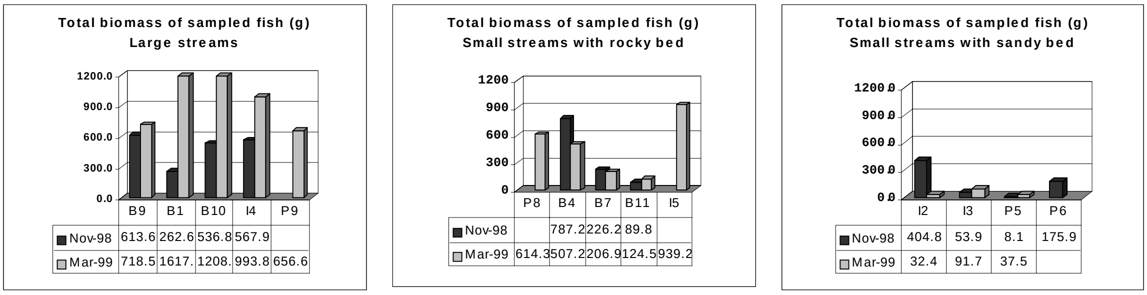

Figure 30: Total biomass (g) of sampled fish in PETAR streams.

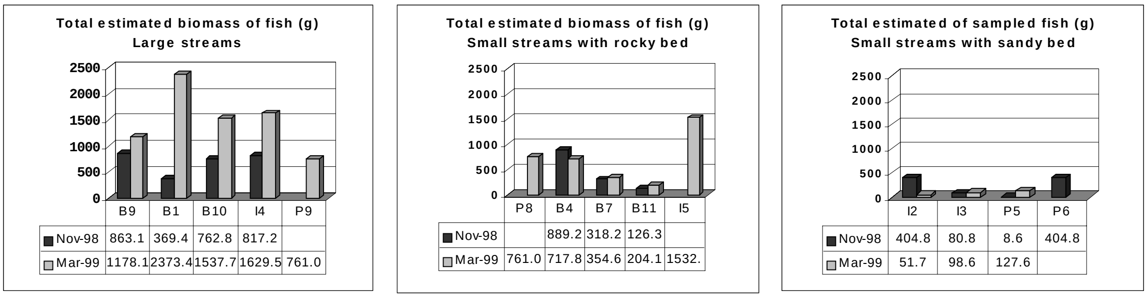

Figure 31: Estimated fish biomass (g) in PETAR streams.

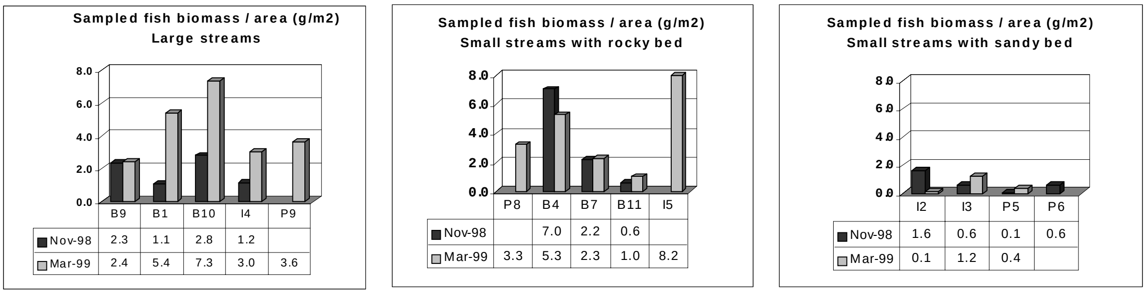

Figure 32: Sampled fish biomass per area (g/m^2) in PETAR streams.

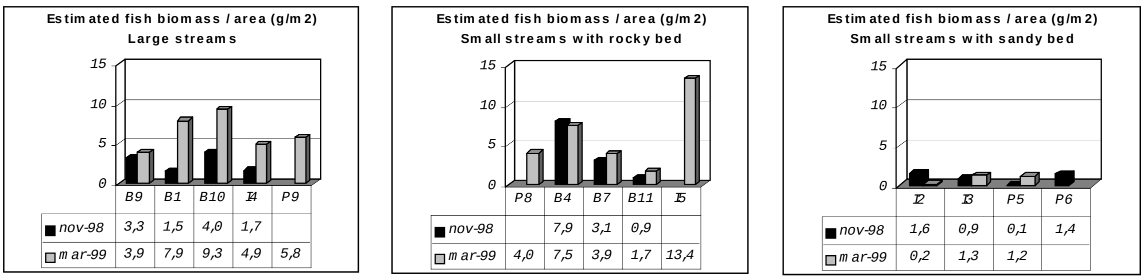

Figure 33: Estimated fish biomass per area (g/m^2) in PETAR streams.

Table 9: Average fish weight (g) in PETAR streams during November 1998 and March 1999 field campaigns.

Site	*November 1998*			*March 1999*		
	No.sampled fishes	*Total Biomass (g)*	*Average (g)*	*No.sampled fishes*	*Total Biomass (g)*	*Average (g)*
B9	181	613.6	3.4	187	718.5	3.8
B1	60	262.6	4.4	449	1617.1	3.6
B10	189	536.8	2.8	433	1208.4	2.8
B4	53	787.2	14.9	37	507.2	13.7
B7	45	226.2	5.0	32	206.9	6.5
B11	17	89.8	5.3	15	124.5	8.3
I2	144	404.8	2.8	66	32.4	0.5
I3	42	53.9	1.3	284	91.7	0.3
I4	161	567.9	3.5	311	993.8	3.2
I5				163	939.2	5.8
P5	6	8.1	1.4	30	37.5	1.3
P6	23	175.9	7.6			
P8				67	614.3	9.2
P9				116	656.6	5.7
TOTAL	740	3113.2	4.2	2003	7029.6	3.5

The average weights for 3 out of the 6 species found at Furnas (*Astyanax* sp, *Chamocranus lopezi* and *Pimelodella transitoria*) were much higher than the average weight of all specimens samples during both field campaigns (Figure 31,32 and 33 and Tables 10,11 and 12). They are also quite higher than the mean calculated for the same species caught at Betari (B1, B9 and B10).

The average fish biomass sampled in I2 (Iporanga) decreased from 2.8 g in November to 0.5 g in March (Table 9). During the sampling taking in November 98, *Pareiophaphis* sp. represented 12% of all fish community at that site (average weight 1.4). In March 99, 97% of all fishes caught at I2 were *Pareiorhaphis* sp (average weight 0.5). That may be related with reproduction cycle of the species since most of the fished individuals were juveniles. However, the same was not observed at other sample sites (B1, B10 and I4) and the average weight for that species for all sites has increased from 2.0 to 2.7 g from November to March.

The average weight of *Astyanax* sp., the other genus found at I2 also decreased from 2.4 g in November to 0.6 g in March. The number of specimens of that genus also decreased at that site. *Astyanax* sp. represented 88% of the sampled fishes at I2 in November and only 3% in March. When one observes the data on *Astyanax* sp from I3, Iporanga tributary, it is also possible to see a decrease of the mean weight between the two sampling campaigns (1.1 g in November and 0.6 g in March), but the number of caught individuals of than genus increased considerably. *Astyanax* sp. represented 55% of the sampled fishes at I3 in November and 83% in March.

Table 10: Comparison between average weight (g) of the most common Characidea.

Site	*Astyanax*		*Characidium*		*Bryconamericus*	
	Average biomass in g (Number of specimens)		*Average biomass in g (Number of specimens)*		*Average biomass in g (Number of specimens)*	
	November	March	November	March	November	March
B9	17.9 (3)		5.7 (1)	2.2 (11)	3.7 (3)	3.0 (53)
B1				2.9 (5)	3.2 (2)	4.1 (12)
B10	6.0 (9)	12.5 (21)	0.2 (37)	1.2 (124)	13.6 (89	1.7 (18)
I4			1.9 (33)	1.5 (113)		0.7 (14)
P9		15.6 (6)		3.5 (70)		
B4	17.9 (8)	25.3 (3)				
B11			2.8 (8)	0.9 (2)		
I5		12.3 (10)		1.8 (39)		
P8		5.5 (57)				
I2	2.4 (127)	0.6 (2)				
I3	1.1 (23)	0.2 (234)	1.3 (19)	1.1 (36)		0.5 (1)
P5		1.0 (5)	1.2 (5)	1.3 (24)		
P6	7.2 (4)					
Total	3.5 (174)	2.7 (338)	1.3 (103)	1.8 (424)	3.6 (13)	2.5 (98)

Table 11: Comparison between average weight (g) of the most common Pimelodidae.

Site	*Chasmocranus lopezi*		*Pimelodella transitoria*		*Rhandioglanis frenatus*	
	Average biomass in g (Number of specimens)		*Average biomass in g (Number of specimens)*		*Average biomass in g (Number of specimens)*	
	November	*March*	*November*	*March*	*November*	*March*
B9	2.0 (7)	4.5 (14)		2.0 (1)	15.0 (14)	5.8 (30)
B1	5.3 (5)	6.0 (29)	2.9 (1)	7.5 (1)	15.4 (6)	14.2 (16)
B10				3.4 (1)		
I4	3.6 (4)	4.6 (3)	8.2 (1)	4.3 (14)	24.7 (6)	10.2 (22)
P9		0.7 (5)		2.4 (1)		2.0 (6)
B4	12.5 (5)	10.9 (2)	5.8 (9)	10.7 (7)	17.4 (30)	14.0 (23)
B7					7.8 (6)	9.5 (11)
I5		2.0 (1)		22.2 (1)		
Total	5.6 (21)	5.2 (54)	5.7 (11)	6.4 (26)	15.8 (73)	10.4 (121)

Table 12: Comparison between average weight of the most common Loricariidae.

	Ancistrus sp.		*Hypostomus sp.*		*Pareiorhaphis sp.*		*Kronichthys sp.*	
	Average biomass in g (Number of specimens)		*Average biomass in g (Number of specimens)*		*Average biomass in g (Number of specimens)*		*Average biomass in g (Number of specimens)*	
Site	*November*	*March*	*November*	*March*	*November*	*March*	*March*	*November*
B9	12.4 (1)	9.6 (3)			2.0 (11)	6.6 (31)	2.4 (18)	5.3 (14)
B1					2.3 (39)	2.9 (328)	4.0 (3)	3.4 (5)
B10					1.2 (7)	2.5 (44)	2.0 (67)	2.5 (85)
I4	6.3 (1)	6.9 (31)		5.2 (1)	2.1 (63)	2.0 (38)	5.1 (18)	3.2 (25)
P9		3.6 (2)						5.3 (14)
B4								5.5 (1)
B7			10.7 (7)	14.6 (10)		1 (0.0)	0.9 (4)	
I5		7.9 (44)		4.9 (2)				2.4 (16)
I2					1.4 (17)	0.5 (64)		
Total	9.5 (2)	7.4 (80)	10.7 (7)	12.4 (13)	2.0 (243)	2.7 (506)	2.6 (104)	2.5 (153)

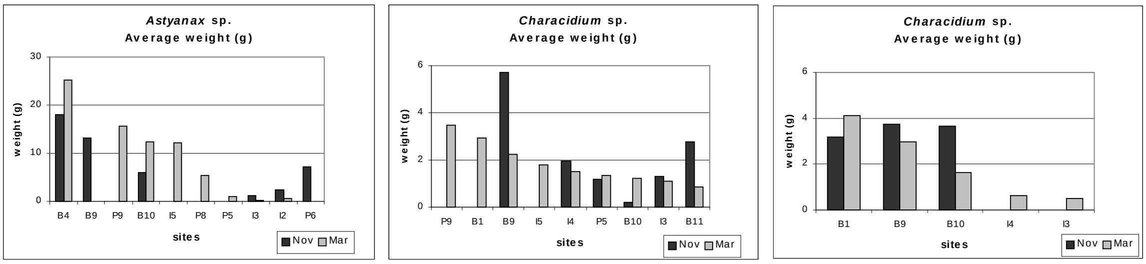

Figure 34: Average weight (g) of Astyanax sp, Characidium sp. and Bryconomericus sp samples in PETAR streams.

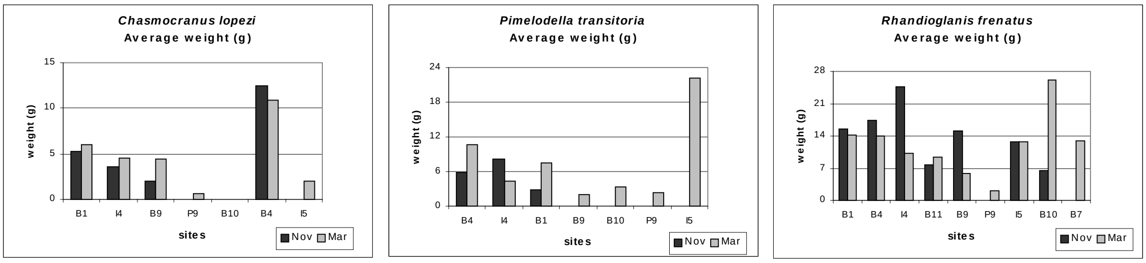

Figure 35: Average weight (g) of Chasmocranus lopezi, Pimelodella transitoria and Rhandioglanis frenatus in PETAR streams.

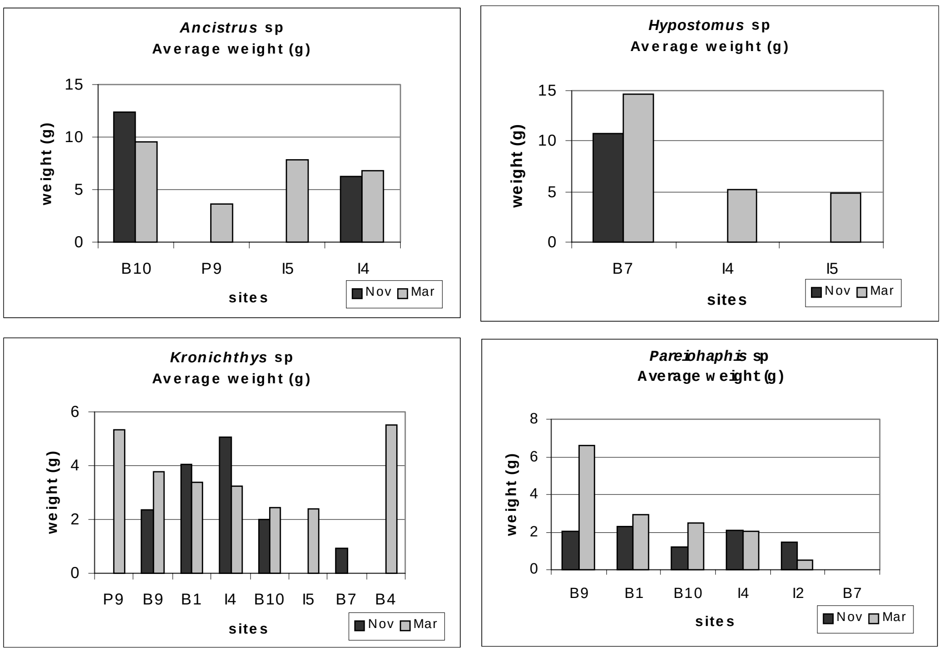

Figure 36: Average weight (g) of Ancistrus sp, Hypostomus sp, Kronichthys sp and Pareiorhaphis sp sampled in PETAR streams.

Discussion – preliminary remarks

Stream fish communities are very variable in composition due to natural factors (long-term factors such as isolation and speciation and short term influences of natural variability in physical and chemical factors such as flow regime, stream morphology, etc). Differences in fish community composition can be significant even within streams. For instance, riffles are often structurally simple, shallow and with low microhabitat diversity for fishes. Pool habitats are structurally more complex (often with debris, roots, etc.) and invariably deeper (Martin-Smith 1998). Those characteristics may be reflected in the community and can be observed in parameters such as fish species richness, diversity and abundance.

Atlantic Rain Forest streams usually have a specific fish fauna with high levels of endemism due to geographical isolation (Sabino 1996). Overlaid on this background is the influence of humans and distinguishing between natural and human induced causes of variability between sites is very difficult (Grossman et al. 1990). According to Fausch *et al.* (1990), Moyle (1994), Wichert and many other authors fish community nevertheless can be used to monitor ecosystems. Fish communities are good indicators of aquatic ecosystem conditions since fish are sensitive to many different stressors and they integrate those effects on other components of the ecosystems manifesting the ecological significance of the perturbation (Karr 1981). Furthermore, fish have a relatively long life span providing a long-term record of environmental changes and, due to their economical and aesthetic value, they can be used to evaluate societal costs of environmental degradation (Fausch *et al.* 1990).

The river continuum approach (Vannote *et al.* 1980) states than communities should follow a predictable pattern along the longitudinal gradient of a stream. Habitat diversity and volume increase from upstream to downstream and from rifle to pool (Schlosser 1992). Community composition along these gradients, particularly the relative abundance of functional feeding groups, should change in response to a shift from heterotrophically structured communities upstream as the role of the primary production increases with stream size. However, in drainage basins altered by anthropogenic activity aquatic community composition may not exhibit the species and feeding group changes typically expected along the longitudinal gradients of a stream (Delong and Brusven 1998).

The influences of land use activities on stream ecosystems, which are often concentrated at the terrestrial-aquatic interface, are particularly important to fish in headwater streams (Schlosser 1991). Those activities can decrease the spatial heterogeneity and connectivity of physical habitats, shift functional interactions between terrestrial and aquatic landscape elements and between trophic levels, increase the instability of the physical-chemical environment, and reduce the availability of refuges. As results of those interactions are, many times, reduction of fish diversity, shift in fish trophic structure, and increase in temporal variability of fish abundance in stream ecosystems.

Following Lammert and Allan (1999), both local and regional (subcatchment) conditions should be considered when measuring the influence of land use and habitat structure on aquatic communities, showing the importance of multiscale studies. However, their findings suggest that habitat measurements (local scale) do not reflect variability in stream structure at a scale meaningful to fish. The mobility of fish and their possible linkage into larger metapopulations may reduce their sensibility to the patchiness of stream habitat (Angermeier and Schlosser 1989).

Under the assumption of small scale land use perturbation and considering the theoretical arguments mentioned above, a preliminary discussion of data collected from PETAR streams is presented below.

Among sample sites located in Betari river, B10, downstream Bairro da Serra, was the one that presented the highest species richness, diversity, abundance per area and biomass per area. That can be related to the increasing water volume in downstream direction and/or increasing nutrient availability due to sewage discharges (Bairro da Serra village). High primary production is expected since the site is situated in an area where the river is wide and receives a high quantity of insulation due to lack of riparian vegetation.

Among the small streams, Soarez (I5) presented the highest species richness, diversity, abundance per area and biomass per area. Even though the sampling site was located only a few meters from a house in a clearance, headwaters of that stream are located in areas of protected primary forest inside the park where no human influence could be detected.

The Passagem do Meio stream (B11) presented low species richness, abundance and biomass. That may be related to characteristics of the water (pH lower than 7.0; low hardness and low conductivity) , which probably reflects bedrock peculiarities.

Average biomass of fishes from Furnas downstream the lead mine were higher than from other similar sites. Average weight of *Chasmocranus lopezi*, *Pimelodela transitoria*, and *Astyanax* sp. were superior to average weight of the same species in other streams. Those results could be related to heavy metals contamination, but further investigations are needed before any conclusion can be drawn.

The Monjolos stream (B7) receives non-treated domestic sewage discharges from Bairro da Serra. Some of the measured water parameters (for conductivity, hardness, phosphate concentration and COD, see Molander and Moraes 1998) were higher when compared to the other Betari tributaries (Furnas and Passagem do Meio). Those differences are probably related to discharges of sewage. However, after a preliminary analysis, it seems that this is not affecting the fish community structure and composition.

The sampling site at in one of Pilões tributary (P8) presented low species richness and biomass compared to other similar streams surveyed. Even though pesticides analysis are not finished, application of pesticides near headwaters of P8 was observed and may be affecting the fish community in that stream.

The station at Iporanga headwaters (I 2) is located downstream a calcareous mine. The fish community at that site presented low diversity and species richness when compared to other slow flow streams (I3, P5 and P6). Averaged biomass of *Pareiorhaphis* sp (which represents approximately 90% of the community) was much higher in November than in March, but the number of individuals per area was approximately constant. Since most of the fished individuals were juveniles, it is probably related to the reproduction cycle of the species. The same results were however, not observed in the other streams were *Pareiorhaphis* sp. was sampled.

It is possible that the fish community at I2 is being affected by the increase of solid particles in the stream, which result from limestone mine activities, but further investigations are required.

The number of *Astyanax* sp sampled in I3 (Iporanga tributary) increased tremendously from November (23 individuals) to March (234 individuals), which was reflected in the fishes density (0.7 ind/m^2 in November and 4.1 ind/m^2 in March). The average weight of that species decreased from 1.1 to 0.2 g, which is reflecting the higher percentage of small juveniles in the sample from March.

P5 (Corrego Preto) and P6 (Pilões tributary) presented similar richness and diversity index and biomass and abundance of individuals per area. When compared with I2 and I3, they have higher number of species but lower number of individuals per area.

Acknowledgements

We thank the Instituo Florestal de São Paulo e PETAR staff and Purical mining administration for logistical support and permission for sampling fish and water. We also thank the research collaborators Pedro Gerhard, Sonia Buck and Johanna Lundqvist for many interesting discussions and a lot of hard work during field trips; Jura, Modesto, Anésio, Alina, Silvia and Marina for the great help during field work; and Helio Shimada and Alexandre Carnier who kindly provided maps and reports about the area.

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Appendix

Appendix I: Nomenclature and physic-chemical properties of pesticides used in PETAR region (Hayer and Laws 1991; Tomlin 1994 and EXTOXNET Extention. http://ace.orst.edu/cgi-bin/mfs/01).

Common Name	*Type*	*Group*	*CAS RN*	*Mol. wt.*	*Mol. Formula*	*Vapor pressure (µ Pa) (25°C)*	*Water solubility*	*Toxicity Class*
Benomyl	*Benzimidazole*	*Fungicide*	*17804-35-2*	*290.3*	$C_{14}H_{18}N_4O_3$	*<4.9*	*4 mg/kg*	*WHO III* *EPA IV*
Carbofuran	*Carbamate*	*Insecticide* *Nematicide*	*1563-66-2*	*221.26*	$C_{12}H_{15}NO_3$	*2x10^{-5} mmHg*	*0.07% (w/w)*	*WHO III* *EPA IV*
Captan	*N-trihalomethylthio*	*Fungicide*	*133-06-2*	*300.6*	$C_9H_8C_{l3}NO_2S$	*<1.2*	*3.3 ml/l*	*EPA IV*
Cartap	*2-dimethylaminopropane-1,3-dithiol*	*Insecticide*	*15263-53-3*	*237.3*	$C_7H_{15}N_3O_2S_2$			*WHO II* *EPA II*
Cartap hydrochloride	*2-dimethylaminopropane-1,3-dithiol*	*Insecticide*	*15263-52-2*	*273.8*	$C_7H_{16}ClN_3O_2S_2$	*Negligible*	*200 g/l*	*WHO II* *EPA II*
Chlorothalonil	*Aromatic Hydrocarbon*	*Fungicide*	*1897-45-6*	*265.9*	$C_8C_{l4}N_2$	*76*	*0.9 mg/l*	*EPA IV*
Cooper oxychloride	*Inorganic*	*Fungicide*	*1332-65-6*	*213.6*	$ClCu_2H_3O_3$	*Negligible*	*<10^5 mg/l*	*WHO III* *EPA III*
Cyanamide		*Herbicide plant growth regulator*	*420-04-2*	*42.0*	CH_2N_2	*500 000*	*4.59 mg/l*	
Lambda-cyhalothrin	*Pyrethoid*	*Insecticide*	*912465-08-6*	*449.9*	$C_{50}H_{19}ClF_3NO_3$	*200*	*0.005 mg/l*	
Cyhexatin	*Organotin*	*Acaricide*	*13121-70-5*	*385.2*	$C_{18}H_{14}OSn$	*Negligible*	*< 1 mg/l*	*WHO III* *EPA III*
Cymoxanil		*Fungicide*	*57966-95-7*	*198.2*	$C_7H_{10}N_4O_3$	*80*	*980 mg/kg*	*WHO III* *EPA III*
Cyromazine		*Insecticide*	*66215-27-8*	*166.2*	$C_6H_{10}N_6$	*4.48 x 10^{-7} Pa*	*13 g/l*	*EPA III*
Deltamethrin	*Pyrethoid*	*Insecticide*	*52918-63-5*	*505.2*	$C_{22}H_{19}Br_2NO_3$	*<1.33 x 10^{-5}Pa*	*<0.2µg/l*	
Fluazifop-P	*2-(4-aryloxyphenoxy) propionic acid*	*Herbicide*	*83066-8-0*	*327.3*	$C_{15}H_{12}F_3NO_4$	*540*	*1 mg/l*	
Guazatine	*Guanidine*	*Fungicide bird repellent*	*115044-19-4*			*<800 nP*	*>3 kg/l*	*WHO II* *EPA II*
Magnesium Phosphate		*Insecticide*						
Metamidophos	*Organophosphorus*	*Insecticide* *Acaricide*	*102665-92-6*	*141.1*	$C_2H_8NO_2PS$	*4700*	*>200 g/l*	*EPA I*
Methyl parathion	*Organophosphorus*	*Insecticide*	*298-00-0*	*263.23*	$C_8H_{10}NO_5PS$	*0.97 x 10^{-5} mmHg*	*50-60 ppm*	*WHO I* *EPA I*
Paraquat	*Quaternary Nitrogen compound*	*Herbicide*	*1910-42-5*	*257.2*	$C_{12}H_{14}C_{l2}N_2$		*700 000*	*WHO II* *EPA II*
Permethrin	*Pyrethroid*	*Insecticide*	*52645-53-1*	*391.3*	$C_{21}H_{20}Cl_2O_3$	*45*	*0.2 mg/l*	*WHO II* *EPA II*
Thiophanate-methyl	*Benzimidazole precursor*	*Fungicide* *Wound protectant*	*23564-05-8*	*342.4*	$C_{12}H_{14}N_4O_4S_2$	*9.5*	*Practically insoluble*	*EPA IV*

Appendix II : Ecotoxicology and Environmental fate of pesticides used in PETAR region (Hayer and Laws 1991; Tomlin 1994 and EXTOXNET Extention. http://ace.orst.edu/cgi-bin/mfs/01).

Common Name	LC_{50} Fish (mg/l)	EC_{50} Daphnia (mg/l)	Bioaccumulation	Environmental fate water	Environmental fate soil	K_{oc}
Benomyl	Rainbow 0.17 (96h) Goldfish 4.2 (48h)	0.64 (48h)	No accumulation	Half-life 2 months	Half-life 3-12 months	1900
Carbofuran	Rainbow 22-29 (96h) Bluegill fish 1.75 (96h) Gold orfe 107-245 (96h)	15 (48h)			DT_{50} 50-60 d	22
Captan	Bluegill sunfish 0.072 (96h) Harlequin fish 0.3 (96h) Brook trout 0.034 (96h)				Kd 3-8 DT_{50} 24 h	
Cartap	Carp1.6 (24h) and 1.3 (48h) Trout 0.056 (96h)	7-10	No accumulation	Half life 23-54 h	DT_{50} 3d Half life 1-10 d	
Cartap hydrochloride						
Chlorothalonil	Bluegill sunfish 62 (96h) Channel fish 44 (96h)	79 ppb (48h)			DT_{50} 5-36 d Half life 1-3 months	1600 (sand) 14 000 (silt), low mobility to immobile
Copper oxychoride	Carp 2.2 (48h)	3.5 (24h)			Strongly absorbed in soil	
Cyamide	Bluegill sunfish 44 (96h) Carp 87 (96h) Rainbow trout 90 (96h)	3.2 (48h)			DT_{50} 20 d	
Lambda-cyhalothrin	Bluegill sunfish 210 Rainbow trout 240	360 (48h)			Half life 4-12 weeks	
Cyhexatin	Large-month bass 0.06 (24h) Goldfish 0.55 (24 h)					
Cymoxanil	Rainbow trout 18.7 (96h) Bluegill sunfish 13.5 (96h)	> 30 ppm (48h)			DT_{50} < 20 weeks	
Cyromazine	Bluegill fish > 90 (96h) Carp, catfish, rainbow trout >100 (96h)	>9.1 (48h)			Half life 107-142 d	
Deltamethrin	Rainbow trout (96h) 0.00091 Bluegill sunfish 0.0014 (96h)	0.0035 (48h)			DT_{50} 9 d Half life 1-2 weeks	4.6.-16.3 x 10^5 cm^3/g
Fluazifop-P	Rainbow trout (96h) 1.07	1.07			DT_{50} 3 weeks	

(cont.) Appendix III: Ecotoxicology and Environmental fate of pesticides used in PETAR region

Common Name	*LC_{50} Fish (mg/l)*	*EC_{50} Daphnia (mg/l)*	*Bioaccumulation*	*Environmental fate water*	*Environmental fate soil*	*K_{oc}*
Guazatine	*Rainbow trout (96h) 19*	*0.15 (48h)*				
Guazatine	*Rainbow trout (96h) 19*	*0.15 (48h)*				
Magnesium phosphate						
Methamidophos	*Rainbow trout 25-51 (96h)* *Golden orfe 47.7 (96h)* *Bluegill 34-46 (96h)*	*0.27 (48h)*		*Half life 27 days*	*Half life 1.9-12 d*	
Methyl parathion	*Rainbown trout 2.7 (96h)* *Golden fish 2.7 (96h)* *Golden orfe 6.9 (96h)*	*0.0073 (48h)*		*Half life 8-38 d*	*Half life 1-30 d*	
Paraquat	*Rainbow trout 32 (96h)*			*Half life 13.1 h*	*Half life < 100 d*	
Permethrin	*Rainbow trout 2500 (96h) 5400 (468h)* *Bluegill sunfish 1800 (48h)*	*600 (48h)*		*Half life <2.5 d*	*DT_{50} <30 d* *Half life 30-38 d*	
Triophanate-methyl	*Rainbow trout 7.8 (96h)* *Carp 11 (96h)*	*20.2 (48h)*				

Appendix IV: Number of fishes sampled in November 1998.

Type of stream	Large streams, rocky substrate					Small stream, rocky substrate			Small stream, sandy substrate			
Sample site	*B9*	*B1*	*B10*	*I4*	*P7******	*B4*	*B7*	*B11*	*I2*	*I3*	*P6*	*P5*
Ancistrus *sp*			1	1								
Ascentronicthys *sp*				1	1							
Astyanax *sp*	3		9			8			127	23	4	
Bryconamericus *sp*	3	2	8									
Characidium *sp*	1		37	33	8			8		19		5
Chasmocranus lopezi	7	5		4	1	5						
Corydoras *sp*			18	3	1							
Crenicichla *sp*					2							
Deuterodon *sp*	1		1	12								
Geophagus *sp*											16	
Gymnotus *sp*								3				
Harttia kronei	15	4				1						
Hisotonus *sp*			3	15								
Hollandichthys *sp*												
Hypostomus *sp*							7					**1**
Imparfinis *sp*												
Kronichthys *sp*	12	3	67	18	6		4					
Microglanis *sp*					1							
Mimagoniates *sp*				1								
Neoplecostomus *sp*			2									
Paratocinclus *sp*			7		1							
Pareiorhaphis *sp*	117	39	7	63					17			
Pimelodella transitoria		1		1		9						
Poeciliidae n.i.	2		1									
Rhamdia *sp*			1				7	6			3	
Rhamdiioglanis frenatus	14	6	1	6	2	30						
Rimeloricaria *sp*	1		20	3								
Trichomycterus dawisi	4		3	3								
Trichomycterus *sp1*	1		2									
Trichomycterus *sp2*			1				28					
TOTAL	181	60	189	161	23	53	45	17	144	42	**23**	**6**

(* only one pass during electrofishing)

Appendix V: Number of fishes samples in March 1999.

Type of stream	Large streams, rocky substrate					Small stream, rocky substrate					Small stream, sandy substrate		
Sample site	B9	B1	B10	I4	P9	B4	B7*****	B11	I5	P8	I2	I3	P5
Ancistrus *sp*			*3*	*31*	*2*				*44*				
Ascentronicthys *sp*									*1*				
Astyanax *sp*			*21*		*6*	*3*			*10*	*57*	*2*	*234*	*5*
Bryconamericus *sp*	*53*	*12*	*18*	*14*								*1*	
Characidium *sp*	*11*	*5*	*124*	*113*	*70*			*2*	*39*			*36*	*24*
Chasmocranus lopezi	*14*	*29*	*2*	*3*	*5*	*2*			*1*				
Corydoras *sp*			*57*	*5*					*2*				
Crenicichla *sp*					*1*								
Deuterodon *sp*			*8*	*13*					*6*				
Geophagus *sp*					*1*			*2*		*2*			
Gymnotus *sp*									*1*				
Harttia kronei	*4*	*25*	*1*		*4*								
Hisotonus *sp*			*6*	*3*									
Hollandichthys *sp*										*1*			
Hypostomus *sp*				*1*			*10*		*2*				
Imparfinis *sp*									*1*				
Kronichthys *sp*	*7*	*5*	*85*	*25*	*14*		*1*		*16*				
Microglanis *sp*				*1*									
Mimagoniates *sp*				*4*					*1*				
Neoplecostomus *sp*	*1*	*2*	*2*										
Paratocinclus *sp*			*6*		*2*								
Pareiorhaphis *sp*	*31*	*328*	*44*	*38*		*1*	*1*				*64*		*1*
Pimelodella transitoria	*1*	*1*	*2*	*14*	*1*	*7*			*1*				
Poeciliidae n.i.	*1*	*2*	*2*									*13*	
Rhamdia *sp*			*2*			*1*	*1*		*1*	*7*			
Rhamdiioglanis frenatus	*30*	*16*	*2*	*22*	*6*	*23*	*1*	*11*	*10*				
Rimeloricaria *sp*	*1*	*2*	*30*	*19*	*2*				*14*				
Trichomycterus dawisi	*26*	*20*	*11*	*3*			*18*		*13*				
Trichomycterus *sp1*	*7*	*1*	*1*	*2*	*1*								
Trichomycterus *sp2*		*1*	*6*										
TOTAL	*187*	*449*	*433*	*311*	*116*	*37*	*32*	*15*	*163*	*67*	*66*	*284*	*30*

(* only two passes during electrofishing)

Appendix VI: Abundance, number of species, diversity, richness and biomass of fish communities samples in PETAR streams during November 98 and March 99.

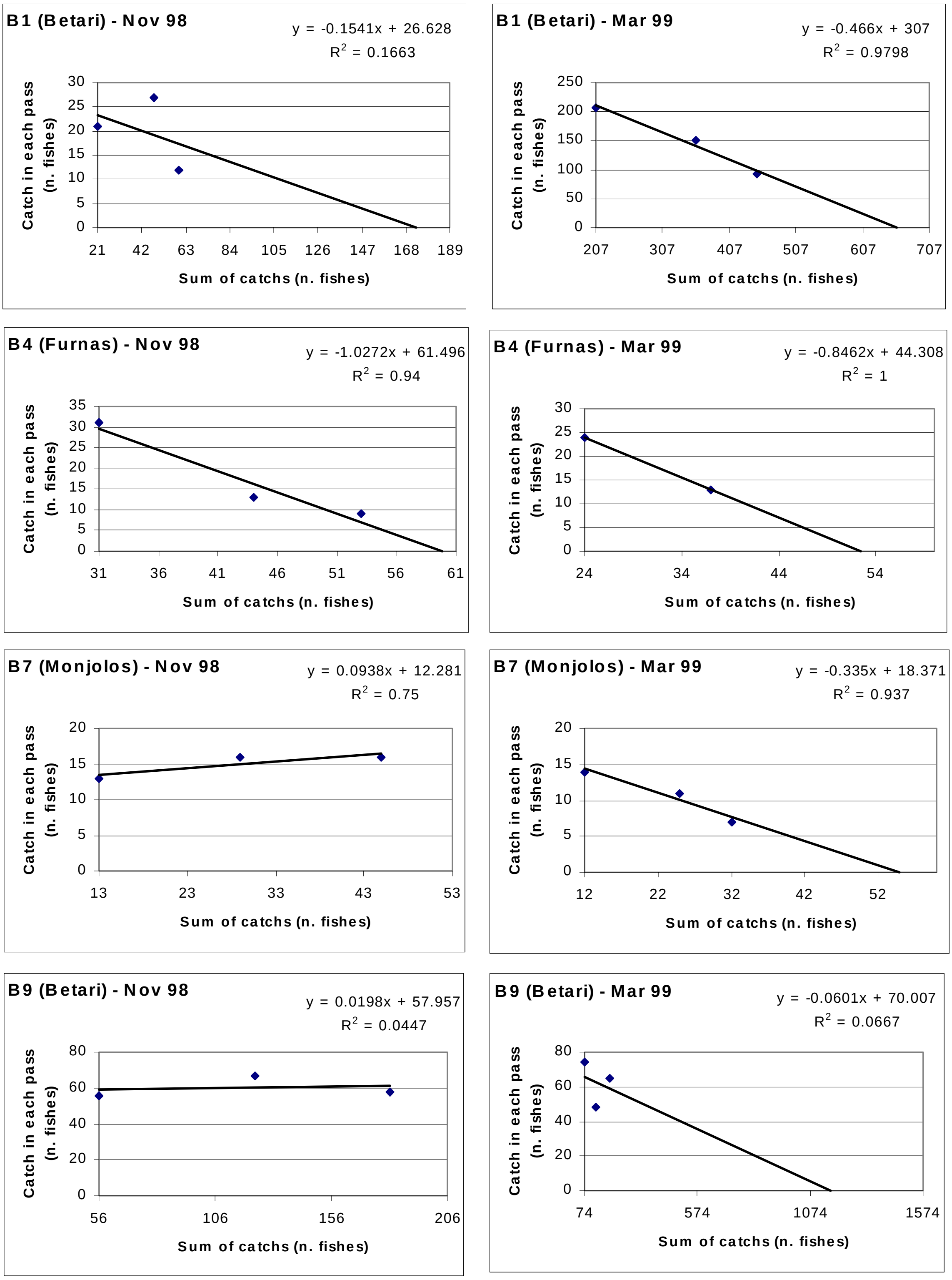
		Number of sampled individuals		Number of sampled individuals per area (ind./m2)		Number of sampled species		Richness index (D)		Shannon Diversity Index(H')		Diversity (c´)		Evenness Index (e)		Total sampled fish biomass (in g)		Total estimated fish biomass (in g)	
	Site	Nov-98	Mar-99	Nov-98	Mar-99	Nov-98	Mar-99	Nov-98	Mar-99	Nov-98	Mar-99	Nov-98	Mar-99	Nov-98	Mar-99	Nov-98	Mar-99	Nov-98	Mar-99
large streams, rocky bed	B9	255	307	1.0	1.0	13	13	2.31	2.29	1.99	1.64	0.6	0.5	1.78	1.47	613.6	718.5	863.1	1178.1
	B1	84	659	0.3	2.2	7	13	1.47	1.96	1.77	2.92	0.6	0.8	2.10	2.62	262.6	1617.1	369.4	2373.4
	B10	269	551	1.4	3.3	18	21	3.24	3.29	2.98	3.17	0.8	0.8	2.37	2.40	536.8	1208.4	762.8	1537.7
	I4	232	510	0.5	1.5	13	17	2.36	2.79	2.66	3.11	0.8	0.8	2.38	2.52	567.9	993.8	817.2	1629.5
	P9		184		1.0		14		2.73		2.21		0.6		1.93		656.6		761.0
small streams, rocky bed	P8		83		0.4		4		0.71		0.78		0.3		1.30		614.3		761.0
	B4	60	52	0.5	0.5	5	6	1.01	1.38	1.74	1.68	0.6	0.6	2.49	2.16	787.2	507.2	889.2	717.8
	B7	63	55	0.6	0.6	4	6	0.79	1.44	1.57	1.62	0.6	0.6	2.61	2.08	226.2	206.9	318.2	354.6
	B11	24	25	0.2	0.2	3	3	0.71	0.74	1.24	1.10	0.6	0.4	2.61	2.31	89.8	124.5	126.3	204.1
	I5		266		2.3		17		3.14		3.07		0.8		2.49		939.2		1532.7
small streams, sandy bed	I2	144	105	0.6	0.5	2	2	0.20	0.24	0.52	0.20	0.2	0.1	1.74	0.65	404.8	32.4	404.8	51.7
	I3	63	305	0.7	4.1	2	4	0.27	0.53	0.99	0.84	0.5	0.3	3.30	1.40	53.9	91.7	80.8	98.6
	P5	6	102	0.1	1.0	2	3	0.56	0.59	0.65	0.85	0.3	0.3	2.16	1.79	8.1	37.5	8.6	127.6
	P6	53		0.2		3		0.64		1.19		0.5		2.49		175.9		404.8	

Appendix VII: Fish community composition on surveyed sites in terms of percentage of individuals of each Family.

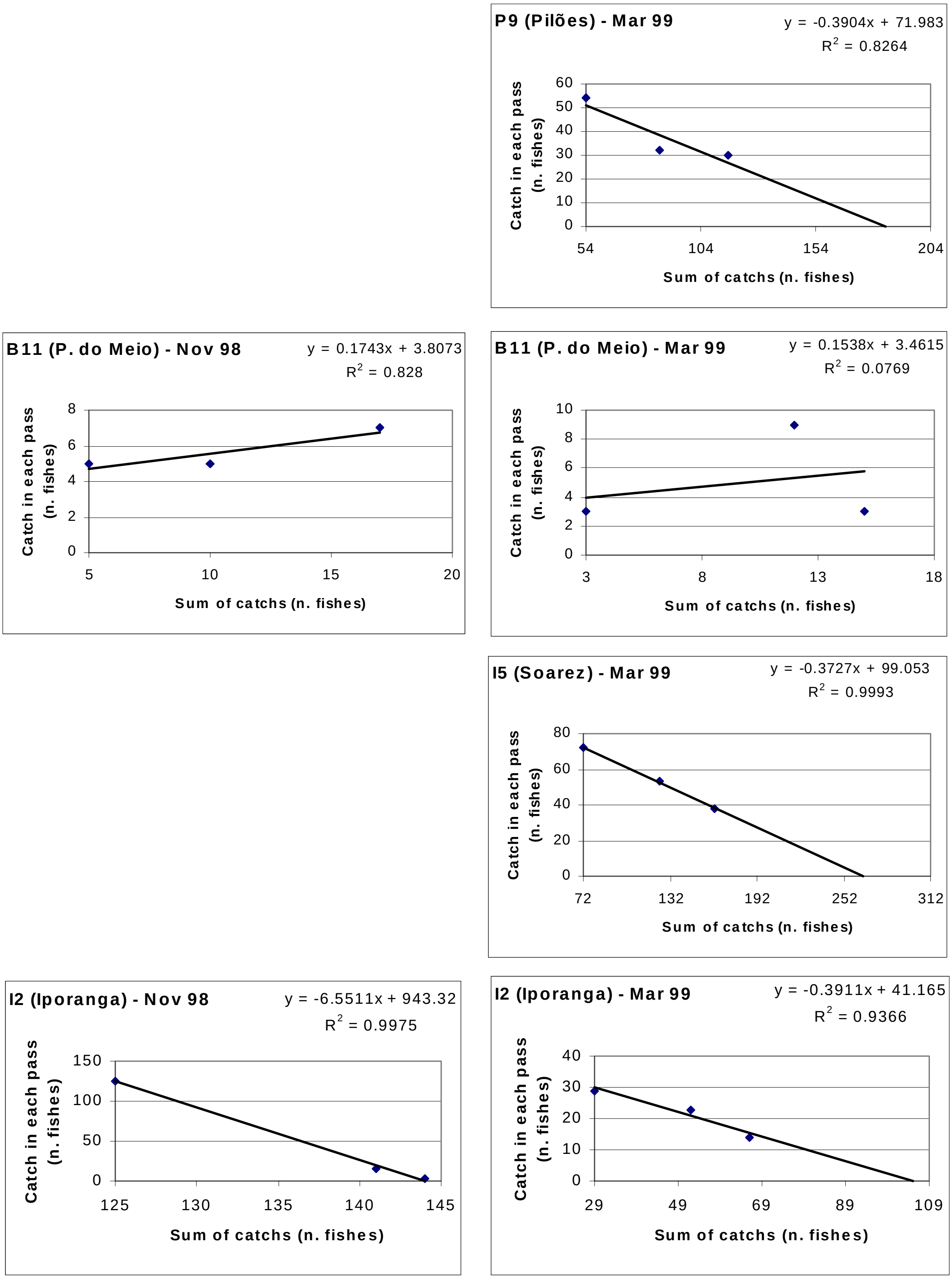
Sampling site	*Sampling period*	*Fish Familly (% of total fish caught)*							
		Loricariidae	*Pimelodidae*	*Characidea*	*Trichomycteridae*	*Poecilidae*	*Callichthyidae*	*Cichlidae*	*Gymnotidae*
B9	*Nov*	*78.9*	*12.6*	*4.6*	*2.9*	*1.1*			
	Mar	*23.5*	*24.1*	*34.2*	*17.6*	*0.5*			
B1	*Nov*	*73.8*	*23.0*	*3.3*					
	Mar	*80.8*	*10.0*	*3.8*	*4.9*	*0.4*			
B10	*Nov*	*56.6*	*1.1*	*28.6*	*3.2*	*0.5*	*9.5*		
	Mar	*34.2*	*8.8*	*39.5*	*4.2*	*0.5*	*12.9*		
I4	*Nov*	*62.1*	*14.9*	*21.1*			*1.9*		
	Mar	*37.6*	*12.5*	*46.3*	*1.6*				
P9	*Nov*								
	Mar	*20.7*	*10.3*	*65.5*	*1.7*			*1.7*	
B4	*Nov*	*1.9*	*82.7*	*15.4*					
	Mar	*2.7*	*89.2*	*8.1*					
B7	*Nov*	*8.9*	*31.1*		*62.2*				
	Mar	*37.5*	*6.3*		*56.3*				
B11	*Nov*		*38.9*	*44.4*					*16.7*
	Mar		*73.3*	*13.3*					*13.3*
I5	*Nov*								
	Mar	*47.6*	*8.3*	*34.5*	*7.7*		*1.2*		*0.0*
P8	*Nov*								
	Mar		*10.4*	*86.6*				*3.0*	
I2	*Nov*	*11.3*		*88.7*					
	Mar	*3.3*		*96.7*					
I3	*Nov*			*100.0*					
	Mar			*95.0*		*5.0*			
P5	*Nov*	*16.7*		*83.3*					
	Mar								
P6	*Nov*		*13.0*	*17.4*				*69.6*	
	Mar								

Appendix VIII: Estimation of fish populations size based on the graphic method (Li and Li 1996). (*) only two passes. Values for slop higher than zero and for R^2 lower than 0.5 are presented in bold.

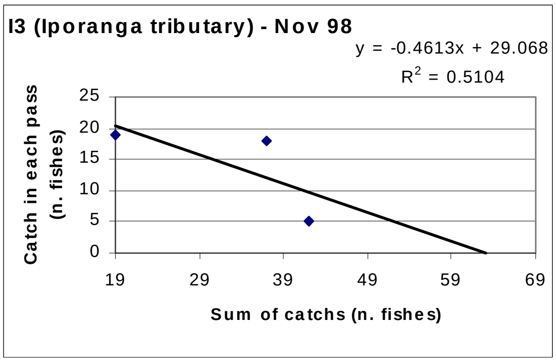
		Nov-98		Mar-99		Nov-98				Mar-99			
Site	Pass	Accumulated sum	each pass	Accumulated sum	each pass	slope	intercept	R^2	Estimated fish population	slope	intercept	R^2	Estimated fish population
B1	1st	21	21	207	207	-0.154	26.628	**0.166**	172.797	-0.466	307.000	0.980	658.798
	2nd	48	27	357	150								
	3rd.	60	12	449	92								
B4	1st	31	31	24	24	-1.027	61.496	0.940	59.868	-0.846	44.308	1 (*)	52.361
	2nd	44	13	37	13								
	3rd.	60		52									
B7	1st	13	13	12	14	**0.094**	12.281	0.750		-0.335	18.371	0.937	54.839
	2nd	29	16	25	11								
	3rd.	45	16	32	7								
B9	1st	56	56	74	74	**0.020**	57.957	**0.045**		-0.060	70.007	**0.067**	1164.842
	2nd	123	67	122	48								
	3rd.			187	65								
B10	1st	94	94	220	220	-0.496	133.320	0.771	268.574	-0.681	375.300	0.962	550.859
	2nd	142	48	364	144								
	3rd.	189	47	433	69								
P9	1st			54	54					-0.390	71.983	0.826	184.383
	2nd			86	32								
	3rd.			116	30								
B11	1st	5	5	3	3	0.174	3.807	0.828		**0.154**	3.462	**0.077**	
	2nd	10	5	12	9								
	3rd.	17	7	15	3								
I5	1st			72	72					-0.373	99.053	0.999	265.771
	2nd			125	53								
	3rd.			163	38								
I2	1st	125	125	29	29	-6.551	943.320	0.937	143.994	-0.391	41.165	0.937	105.254
	2nd	141	16	52	23								
	3rd.	144	3	66	14								
I3	1st	19	19	180	181	-0.461	29.068	0.510	63.013	-1.315	401.380	0.834	305.348
	2nd	37	18	236	56								
	3rd.	42	5	284	47								
I4	1st	77	77	113	113	-0.483	111.990	0.956	231.671	-0.037	111.460	**0.133**	3004.313
	2nd	124	47	206	93								
	3rd.	161	37	311	105								
P5	1st	4	4	14	11	-1.500	9.500	0.750	6.333	-0.124	12.694	**0.995**	102.042
	2nd	5	1	21	10								
	3rd.	6	1	30	9								
P6	1st	9	9			-0.210	11.088	0.928	52.926				
	2nd	17	8										
	3rd.	23	6										
P8	1st			35	35					-0.755	62.611	0.917	82.907
	2nd			58	23								
	3rd.			67	9								

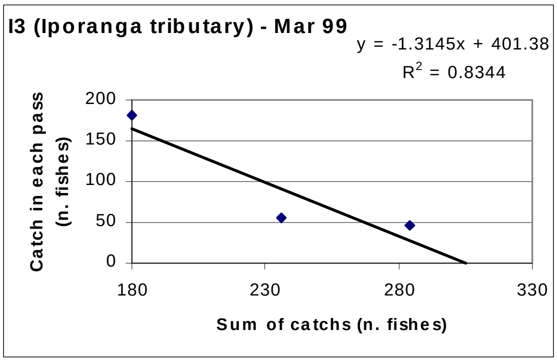


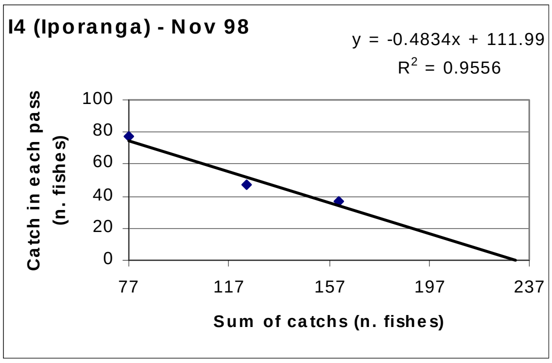
Appendix IX: Estimation of fish populations size at B1, B4, B7 and B9.

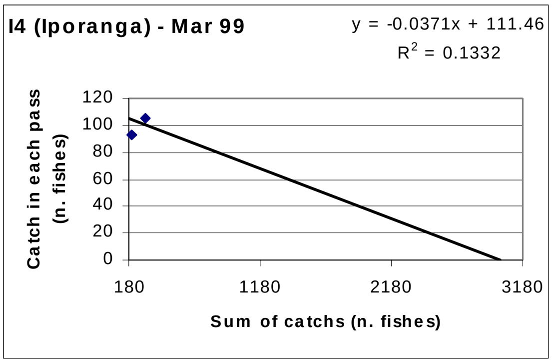


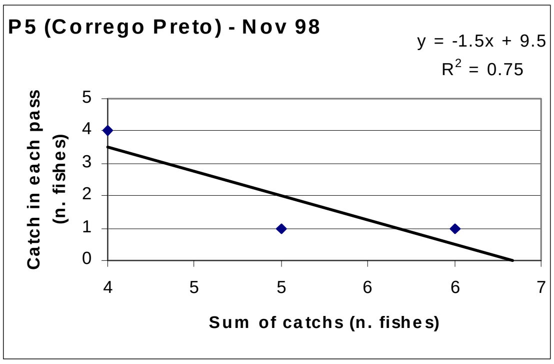
Appendix X: Estimation of fish population sizes at P9, B11, I5 and I2.

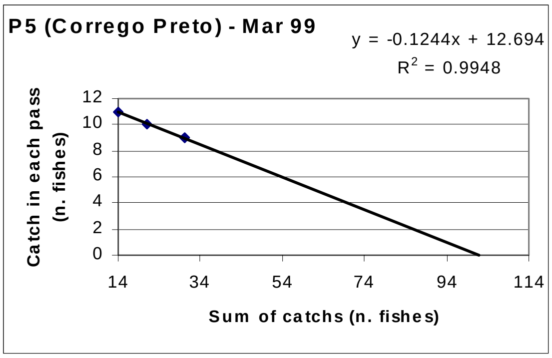


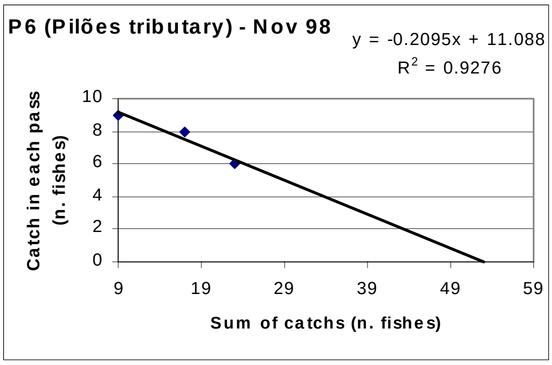


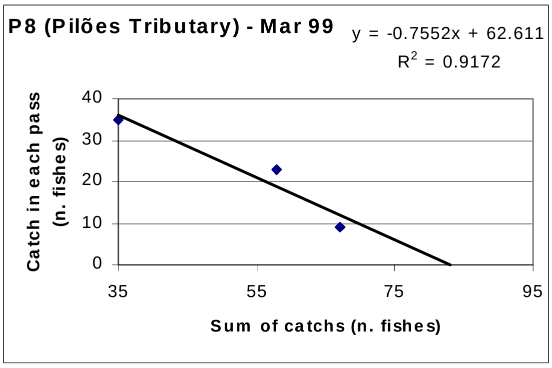












Appendix XI: Estimation of fish population sizes at I3, I4, P5 and P6.