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Environmental Impact Assessment of the Alto Yuna Multipurpose Project

Topical Report on Water Quality, Aquatic Life and Fish in the affected Water Bodies

Norwegian Institute for Water Research **REPORT**

Main Office	Regional Office, Sørlandet	Regional Office, Østlandet	Regional Office, Vestlandet	Akvaplan-NIVA A/S
P.O. Box 173, Kjelsås	Televeien 3	Sandvikaveien 41	Nordnesboder 5	
N-0411 Oslo	N-4879 Grimstad	N-2312 Ottestad	N-5008 Bergen	N-9005 Tromsø
Norway	Norway	Norway	Norway	Norway
Phone (47) 22 18 51 00	Phone (47) 37 29 50 55	Phone (47) 62 57 64 00	Phone (47) 55 30 22 50	Phone (47) 77 68 52 80
Telefax (47) 22 18 52 00	Telefax (47) 37 04 45 13	Telefax (47) 62 57 66 53	Telefax (47) 55 30 22 51	Telefax (47) 77 68 05 09
Internet: www.niva.no				

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Abstract

The report gives a description of the baseline status of the water quality, aquatic life, and fish in the water bodies that will be affected by the planned river regulation scheme. It analyses the impacts on these water items both during the construction phase and in the following operation phase. At the end the report gives recommendations for abatement measures to minimise the negative impacts on the aquatic environment from the project, again both in the construction phase and in the following operation phase.

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Dag Berge
Project manager

Dag Berge
Research manager

Nils Roar Sælthun
Head of research department

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Norwegian Institute for Water Research
Oslo

Instituto Superior de Agricultura
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Topical Report on Water Quality, Aquatic Life and Fish in the affected Water bodies

Oslo, Norway, November 2003

Project leader	Dag Berge	*Norwegian Institute for Water Research*
Co-workers	Luis Almanzar	*Instituto Superior de Agricultura*
	Milton Garcia	“
	Gerson Valdez	“
	Torleif Bækken	*Norwegian Institute for Water Research*
	Randi Romstad	“

PREFACE

This report sums up the findings and recommendations from the part project dealing with the impacts on "Water Quality, Aquatic Life, Fish and Fisheries" in the Alto Yuna EIA. The project is commissioned by Instituto Nacional de Recursos Hidraulicos (INDRHI). The work is conducted as a co-operation between Norwegian Institute for Water Research (NIVA) and the Instituto Superior de Agricultura (ISA).

The study is based on review of existing data, as well as on data from field work performed in the period October 2002 – March 2003. Dag Berge (NIVA) has been the project leader for this part project. The field work is performed by Dag Berge, Luis Almanzar, Milton Garcia, and Gerson Valdez. The chemical analyses are performed partly at the laboratory of INDRHI and partly at the laboratory of NIVA. The bacteriological analyses are performed by INDRHI. The fish species are identified by Luis Almanzar (ISA), the phytoplankton species by Pål Brettum (NIVA), the periphyton by Randi Romstad (NIVA), and the bottom animals by Torleif Bækken (NIVA).

The report is written by Dag Berge and Luis Almanzar with contributions from Torleif Bækken and Randi Romstad.

The report has been given the same quality assurance that is normal for Hydropower Development EIAs in Norway.

The co-operation with the team from the Dominican Republic has been very good in all phases of the project. Particularly the field work was enjoyable and I was impressed by the dedication and eagerness that Luis and his team members showed during the long working days in the field. Likewise I was impressed by the environmental awareness that the Dominican team possessed.

I thank the client INDRHI and the Dominican study team from ISA for a very interesting, instructive, and enjoyable project in a beautiful and exotic country.

Oslo, 1 November 2003

Dag Berge
(Project leader)

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1 SUMMARY AND CONCLUSIONS

1.1 Background and aims

The Alto Yuna regulation will imply diversion of most of the water from Rio Yuna (upstream Los Quemados) to Rio Jima (Caño Piedra). Rio Masipedro will also be taken into the diversion tunnel. The water will be used for hydropower production (Rio Jima and Rincon), drinking water supply (San Francisco de Macarice), and irrigation water (downstream of Rincon).

In downstream Rio Yuna and Rio Masipedro the water flow will be considerably reduced, whereas in Rio Jima, the water flow will increase.

This part project of the EIA aims at elucidating how this regulation impacts the water quality, aquatic life, fish and fisheries in the affected water bodies. The baseline situation is mapped by water quality sampling, review existing monitoring data, sampling of bottom animals, periphyton, and phytoplankton, test fishing, interview of fishermen and employees at the municipalities.

1.2 The water bodies included in the study and the sampling stations

The water bodies included in the study are

- Rio Yuna from Boca de Blanco to Los Quemados
- Rio Yuna between Bonao City and Lake Hatillo
- Lake Hatillo
- Rio Yuna downstream of Lake Hatillo
- Arroyo Margajita and Arroyo Mejita draining the mining fields east of Lake Hatillo
- Rio Masipedro
- Rio Jima from the planned tailrace entrance from the power station, and down to Lake Rincon
- Lake Rincon
- Rio Jima downstream of Rincon reservoir

Altogether it was established 15 stations where samples for water chemistry, water bacteriology, aquatic life and fish have been collected.

1.3 Water quality and pollution

1.3.1 Erosion material

Upstream areas of Rio Yuna were little impacted by pollution. Upstream Boca de Blanco Rio Yuna was of the clear water river type all the year around. Rio Blanco transported, however in periods, considerable amounts of erosion material, and downstream of Boca de Blanco Rio Yuna was grey to reddish by soil particles. Downstream of Bonao and down to Hatillo Rio Yuna was in wet periods highly impacted by erosion material. A heavy rain shower coloured the river reddish grey in half an hour. One day afterwards, the water could have cleared up again.

Rio Masipedro and Rio Jima at Caño Piedra were of the clear water type all the year around.

From Auto Pista Duarte and down to Rincon Rio Jima was impacted by erosion material from the agricultural areas.

The other water bodies were little impacted by erosion material.

1.3.2 Coliform bacteria and hygienic pollution

Upstream of Los Quemados the Yuna River was little impacted by hygienic pollution. Downstream of Bonao, however, the Yuna River was in periods heavily impacted by coliform bacteria which indicate that hygienic pollution from the Bonao sewage enters the river. The contamination was in periods so massive that it can be a health hazard to bath in the river. At the station downstream of Cotui (La Mata) the Yuna River was also impacted by coliform bacteria.

Rio Jima at Canjo Piedra and Rio Masipedro at the balneario (start of Masipedro canal) had only minor content of coliform bacteria. At the entrance of Rincon Rio Jima contained lots of coliform bacteria, likely discharges from the village of Cañabon.

Hatillo Reservoir and Rincon Reservoir had low concentration of coliform bacteria.

1.3.3 Nutrients

Rio Yuna from Bonao and down to Hatillo, and Rio Jima at the confluence with Rincon, had high concentrations of nutrients. In the first locality this is due to discharges from Bonao, in the other it is due to discharges from Cañabon and runoff from agricultural land.

For phosphorus it could be very high concentrations during high flow periods. This was due to P-content in the soil particles which enter the river by erosion in rainy periods.

The other localities had relatively low concentrations of nutrients. The nutrient concentrations indicated that Lake Hatillo was oligotrophic, whereas Lake Rincon was mesotrophic. The algal concentrations, however, indicated that both the lakes were mesotrophic.

1.3.4 Oxygen

During the low flow season all the river stations had high concentrations of oxygen. An exception was the Rio Jima just downstream of Rincon Power station, which was fed by low oxygen containing deep water from Lake Rincon. In both reservoirs there were pronounced thermal stratification. In Rincon reservoir the oxygen was more or less totally depleted in the deep water (from 10m and down), whereas the oxygen situation in Hatillo was much better. Also here there was a marked drop in the concentration with increasing depth, but it was far from depletion as was the case in Rincon reservoir.

It should be mentioned that the oxygen values derived in the sampling in the wet season gave lower oxygen values in the rivers. It is believed that this in an artefact due to use of a complete new electrode on the measuring instrument, which was difficult to adjust to stable readings. The oxygen readings from the wet seasons are most likely too low.

1.4 Aquatic life

1.4.1 Bottom dwelling animals

The bottom animals consisted mainly of insects larvae, worms (Oligochaeta), snails (Gastropoda), and with less density of crabs (*Epilobocera haytensis*), and molluscs (*Anodonta* *sp*). In a few places there were found crayfish and shrimps, but their density were not so great that they were caught by the applied sampling technique.

Insect larvae were by far the most dominating type of organism in the bottom fauna. Of these the order Ephemeroptera (May-flies), and Trichoptera (Caddies flies) and Chironomida (midges), and odonata (nymphs) were dominating in numbers and biomass. Plecoptera (stoneflies) were not found at any stations, neither in October nor in March. It is likely that this group of insects is not present on the Hispaniola Island. It is common in the US-mainland, but they are poor fliers, and are known to be absent in some islands.

In October, when all the stations were sampled, the lowest density of bottom animals was found at the uppermost station in Rio Yuna (St.1), whereas the highest densities were found at Station 7, i.e. the station that is downstream both Bonao City and Falconbridge. The high amount of animals is due to discharges of nutrients and organic material from the Bonao City, and the agricultural activity in the area. The discharges from Falconbridge could not be seen to make any impact on the community of bottom dwelling animals.

Downstream of Hatillo the density of bottom animals was low. Most likely this is due to out-sedimentation of edible organic material in the reservoir.

1.4.2 Periphyton in the rivers

It was relatively small amounts of periphyton in the rivers. Most of the periphyton consisted of a thin layer of diatoms on the surface of the stones. Only small amounts of filamentous green algae could be seen. The species composition was dominated by species that thrive in electrolyte rich water, and water with relatively rich content of nutrients. There was not made any observation of aquatic mosses in any of the rivers. Nor was it observed any heterotrophic growth of fungi or bacteria. This last finding indicates that none of the rivers are loaded to any extent by organic material.

In Rio Yuna downstream of Bonao City in the dry season there were observed considerably more periphyton than during the rainy season. This is due to more effects from nutrient discharges from Bonao, and more quiet, and stable, current conditions. The periphyton growth was not of the intensity that could cause any ecological problems for the river, but it was so prominent that it gave the river a somewhat unpleasant look, for example in relation to be an attractive bathing place.

In the other rivers the periphyton growth during the dry season was of normal intensity, it indicated often nutrient rich waters, but did not show much sign of pollution.

Aquatic macrophytes were not a problem in the studied rivers to day. However, downstream of Bonao, there were observed scattered stands of the aggressive, and nuisance water weed, *Hydrilla sp*. Under more quiet current conditions this plant can make large, dense stands which can cause problems for a series of water use interest.

1.4.3 Phytoplankton in the rivers

The upstream part of Rio Yuna, Rio Masipedro and Rio Jima were sampled for phytoplankton analysis. In the free water masses of the rivers there were very little algae. Most of the species were periphyton species that were torn loos from the bottom due to the strong currents in these fast flowing rivers. The algal society indicated no, or very little, pollution in the upstream part of the rivers.

1.4.4 Phytoplankton in the reservoirs

The amount of phytoplankton in Lake Rincon showed mesotrophic values both during the sampling in October 2002 and during the sampling in March 2003. In Lake Hatillo, only the sample in March 2003 had mesotrophic algal amounts, whereas the sampling in October had oligotrophic values. Diatoms were the dominating group in both lakes. Lake Rincon had a small content of blue green algae, indicating a somewhat greater fertilisation impact by human discharges than in Lake Hatillo.

1.5 Fish and fisheries

The species diversity in the fish fauna was relatively poor, only 8 species of fishes were found. According to local fishermen, this was also the total number. In addition there were crabs and crayfish which also were included in the fishermen's catch. In the upper part of Rio Yuna the catches contained biajaca (*Cichlasoma haytensis*) and crabs (*Epilobocera haytensis*). In addition 3 species of small fish were also found (*Poecilids*). In the lower part of Rio Yuna there were also found Nile tilapia (*Tilapia niloticus*) and Mozambique tilapia (*Tilapia mozambiqua*). In the reservoirs there were in addition to the above mentioned species, largemouth bass (*Micropterus salmoides*) locally called trucha, and common carp (*Cyprinius carpio*). Upstream the project area, in the Rio Blanco Reservoir, there was a fish which the locals called Chinese carp. Most likely this was mirror carp – which is a subspecies of the common carp. When Rio Blanco Power Station performed spillway flow release from the reservoir, dead specimen of this carp came drifting down into Rio Yuna. There they were included in the catches if they still were fresh. There was yet no viable population of this carp type in Rio Yuna elsewhere. In Rio Masipedro there was also a good stock of the American "Red swamp crayfish" *Procambarus clarkii.*

Of the above mentioned species, only the poecilids, the biajaca, and the crab are native. All the other species are introduced. Before the construction of Hatillo dam and the Rincon dam, three other migratory fish species were told to live in the rivers; the eel (Anguilla sp), and two other species with local name dajao and guabinas. These species are no extinct in the project area.

In all the rivers and reservoirs there were performed some kind of fishing. In Alto Yuna they caught biajacas and crabs, and collected dead mirror carps drifting down from Rio Blanco reservoir. In lower part of Rio Yuna, i.e. downstream of Bonao City, tilapias constituted most of the catches. In Rio Masipedro they caught mainly crabs in the upper part, and crayfish in the lower part. Also some biajacas were caught here. In Rio Jima they caught biajacas, crabs and tilapias. In the reservoirs they caught tilapias, largemouth bass (trucha) and carps.

In the rivers fishing was mostly performed for leisure. Particularly popular was the leisure fishery for crabs. The rivers in the area were known for their rich stocks of crabs and we met crab fishermen all the way from Santa Domingo, and other places far from the project area. In Rio Yuna and in Rio Jima, as well as in the reservoir, people did also some fishing for food supply. This was important for poor people.

In the area where Rio Jima entered Rincon Reservoir, there was a rich fishery, and in the village Cañabon, people had fish for dinner several times a week (2-4 times). In the reservoirs there were also professional fishermen. In the Cañabon area of Rincon, there were 14 registered commercial fishermen. All the villages around the reservoirs had commercial fishermen. Most of the fish were delivered to buyers that brought the fish to the nearby cities for sale in food stores, or in special fish stores. Some of the fish was also sold along the highway (Auto Pista Duarte). Crabs were also sold in the stores and along the highway.

In Lake Hatillo there were similar fishery activities as in Lake Rincon, i.e. both commercial and leisure fishery. They had a better bass fishery than in Rincon. In Maimon they had initiated ecotourism based on fishing and recreation in the Lake Hatillo. They had established cabin village for renting, and they had a fashionable "Bass Club" with members from a wide catchment. Also in the southern part of the lake (the Cotui area) there were plans for developing ecotourism based on the use of Lake Hatillo.

1.6 Impacts during the construction phase

In this phase the water flow will be approximately as it was before. During the construction phase, the following pollutants will affect the water quality:

- Erosion due to road building,
- Erosion due to construction work in the dam area
- Erosion on machine park area, construction workers living area, spoil rock deposit area
- Erosion from soil deposits
- Erosion from the timber clearance area
- Runoff from crushed and ground rock material from the drilling, blasting and stone crushing plant (quarry)
- Sanitary effluents from the construction worker's camp
- Oil and chemical spills
- Leaching of ammonia and nitrogen from the tunnel blasting and spoil rock deposit
- Temporarily increase in the turbidity of Lake Rincon and Lake Hatillo
- Temperature effects is not expected

The affected water bodies will be Rio Yuna from Boca de Blanco and down to Bonao, Rio Masipedro downstream of the planned intake, and Rio Jima upstream of Lake Rincon. The impacts will be most pronounced close to where the construction works take place. The impacts in Rincon Reservoir and Hatillo Reservoir will be moderate during the construction phase.

1.7 Impacts during the operation phase

The flow in Rio Yuna will be reduced considerably, and the renewal of water in Lake Hatillo will decrease, and the water residence time will increase. Thus, only little, if any, water will be back in Rio Masipedro. The flow in Rio Jima will increase and the water residence time in Lake Rincon will be reduced.

This will cause negative consequences for water quality and aquatic life in the Rio Yuna watercourse, included Lake Hatillo. This will also be the case for Rio Masipedro. In the Rio Jima watercourse, however, there will be both positive and negative impacts.

1.7.1 Rio Yuna upstream of Bonao

The Alto Yuna dam will create a migratory barrier for migratory species of the river biota. There is, however, no migratory fish species left in the river. Neither among the other organism groups there is known any migratory species. The barrier effect will not be great problem for river biota in this project.

In the first 10 years after the regulation it will take place shoreline erosion in the steep reservoir sides due to water level fluctuations. Most of this will settle out in the reservoir, but in the first years it is likely that the turbidity will increase in Rio Yuna downstream of the dam, creating problems for the drinking water intake for Bonao.

Downstream of the abstraction of drinking water for Bonao City, and irrigation water for the Yuna - Cañabon canal and upstream the entrance of Rio Yaboa, there will be very little water left in Rio Yuna. Here it needs to be established a minimum flow of approximately 1,5 m^3/s.

1.7.2 Rio Yuna downstream of Bonao

If the discharges from Bonao City will enter this smaller river, the hygienic conditions will be very bad and will make it hazardous to use the river for bathing, and irrigation, etc. in the stretch downstream of Bonao. Also for aquatic life the pollution can give problems.

The discharges from Falconbridge are under control to day, and no ecological impacts were observed in Rio Yuna during this study. If the discharges are given the same treatment as to day, or improved, these discharges will not cause problems in the future smaller Rio Yuna either.

1.7.3 Hatillo Lake

The wish of supplying irrigation water in the Yuna canal as to day, and the wish to produce the same amount of electricity as before, can easily increase the range and frequency of water level fluctuation in Lake Hatillo. This will have negative impacts on the biological life in the littoral zone, included fish production and reproduction. Particularly the trucha and carp will be impacted negatively by increased water level variation.

As it is the diluting, high mountain water that is diverted, while the pollution inputs still are the same, Lake Hatillo will be more eutrophic (nutrient rich). If the water level is kept as high as possible, and close to full supply level, the eutrophication can be reduced somewhat. If the average water level will be lower than to day, and nothing is done with the discharges from the Bonao City area, the eutrophication of Lake Hatillo can be problematic after the regulation.

The pollution from the mining area draining to Arroyo Margajita can also be a problem in the future, particularly if the average water level in Hatillo will be kept lower than to day. The reduced water renewal in Hatillo will by itself result in that the mining pollution entering via Arroyo Margajita can be a problem. The pollution from Arroyo Margajita should be controlled.

1.7.4 Rio Yuna downstream of Hatillo

Downstream of Hatillo and downstream of the abstraction of irrigation water to Yuna Canal, the water flow will be very small compared with the flow to day. The average flow will be reduced by almost 50%.

The reduction in water flow will result in that the concentration of coliform bacteria will increase considerably during periods of low flow. It may be hazardous to use the river for bathing, and washing, if nothing is done with the existing discharges from the Cotui area.

The smaller river will support less aquatic life than before. If there is not established a minimum flow, the impact on aquatic life can be detrimental. Particularly the larger fish and crabs may face problems without a minimum flow.

1.7.5 Rio Masipedro

Rio Masipedro will be more or less without water after the regulation. This will have detrimental impacts on the aquatic life and fish, included the crab. If all the water is taken, there will only be small temporary pools of standing water (without fish) back. This will create conditions for mosquito production. The bathing places will also be destroyed if all the water is removed and no action is taken to give them alternative water supply.

1.7.6 Rio Jima between Caño Piedra and Rincon Lake

Here the water flow will increase from an average to day of 3-4 m^3/s to approximately 18 m^3/s. This increase will result in great erosion problems. There has to be built riverbed- and riverbank enforcement. The rapid water flow fluctuations between start and stop of the power station will easily result in flush away and stranding of fish and other organisms.

1.7.7 Lake Rincon

For Lake Rincon the increased water renewal will be an advantage. It will lead to an oligotrophication with less algal growth and less oxygen deficiency in the deep water. Likewise it will be easier to keep the water level in Lake Rincon at a higher and more constant level, which may increase the population of carp and largemouth bass through improved spawning conditions.

1.7.8 Rio Jima downstream of Lake Rincon

Downstream of Lake Rincon the increased flow will also mainly have positive effects. The pollution will decline due to dilution, and the higher water level will be positive for the river biota.

1.8 Mitigating measures during the construction phase

1.8.1 Road construction

- The inner road sides and outer road fill should be sowed by convenient grass as soon as possible after construction to prevent erosion.
- The road ditches should be lined with stones in erosion prone areas.
- The road ditches should preferentially be discharged to existing brooks/water ways. If they have to be released at new sites, these should be enforced to prevent erosion.
- Permanent roads should be paved as soon as possible after the construction.
- Road construction should mostly take place in the dry season.
- The same measures should be considered when constructing other areas like parking lots, camp areas, etc.

1.8.2 Spoil rock deposits and soil deposits

- Soil deposits and spoil rock deposits should be placed in flat areas or moderate inclined areas where the erosion can be minimised / controlled.
- The heaps should be drained properly so that incoming storm flow water will not erode.
- It should be established sedimentation/monitoring basins downstream of the deposits.
- Runoff water should be monitored for at least ammonia, ammonium, pH, and suspended particles.
- If high pH and free ammonia is discovered, the runoff should be neutralised before discharge.

1.8.3 Sanitary discharges from workers camp and adm. area

As most of the construction work takes place upstream the point in Rio Yuna where Bonao City abstract drinking water, sanitary effluents from the workers camp and from the project administration area can be a problem.

- Most likely normal pit latrines will not be satisfactory due to steep terrain and lack of infiltration soils.
- Toilet water (black water) should be collected and transported out of the area, to the sewage treatment plant in the city or infiltrated at safe areas.
- Alternatively portable toilets that can be emptied every second day, can be used.
- Grey water (washing water) can most likely be infiltrated locally.

1.8.4 Oil and chemical spills

The large construction activities will require large amounts of machineries like, tractors, trucks, bulldozers, excavators, cars, etc. Their use will require a lot of chemicals like fuels, motor oil, lubrication oil, hydraulic oil, cooling liquid, battery acids, etc.

- Chemicals should be prevented from reaching the river.
- Fuel tanking area should be paved and drained to a collecting tank.
- Workshop floors should be drained to collecting tanks.
- Parking lots for machinery should either be drained to an oil cleaning device, or consist of soils with good infiltration capacity.
- The drivers and workshop personnel should be given an environmental course.

1.9 Mitigating measures during the operation phase

1.9.1 Rio Yuna upstream of Hatillo Lake

1. Here it should be established a minimum release over the Alto Yuna dam that takes care of

    - Drinking water for Bonao and the surroundings
    - Irrigation water to Yuna – Cañabon canal, and other need for irrigation
    - Dilution water for the pollution discharges from the Bonao area
    - Water to support life for fish and other aquatic organisms

    The minimum flow in Rio Yuna just upstream the confluence with Rio Yaboa should not be less than 1.5 m^3/s. The necessary discharge over the dam should be calculated according to the above mentioned needs.

2. The sewage system from Bonao City should be modernised. This comprises both the collection and treatment of the sewage.

1.9.2 Lake Hatillo

The reduction in water renewal in Lake Hatillo will lead to problems confined with:

- Reduced recipient capacity for nutrients - Eutrophication
- Reduced recipient capacity for mining runoff - Heavy metal pollution
- Destroyed aquatic life – due to water level fluctuations

The proposed measures are:

- All these 3 impacts can be reduced somewhat by keeping the water level in the lake as high as possible, and reduce the water level fluctuation as much as possible. It should be worked out water level manoeuvring rules (regulations) for the lake.
- The water pollution from the mining fields affecting Arroyo Margajita should be studied better, and there should be elaborated a cost effective pollution abatement plan for the river.
- It should be made an analysis about the necessity for a fish stocking programme (trucha and carp) of the reservoir. This is particularly relevant if there is not possible to keep the water level relatively high, and within narrow fluctuation limits.

1.9.3 Rio Yuna downstream of Hatillo

The problems here are to secure the river enough water to have the necessary recipient capacity for pollutants, and to support aquatic life.

Only one abatement measure is proposed:

- Establish a minimum flow of approximately 10% of average annual flow, i.e. 3 m^3/s.

1.9.4 Rio Masipedro

The aims of the measures here are confined with having some water flow left that can prevent the fish from disappearing, and to give enough water to feed some bathing places with water.

Three measures are proposed:

- Establish a minimum release of 300 l/s
- Divert any sewage effluent from the river
- Bathing places must be upgraded/constructed and supplied by alternative water if necessary

1.9.5 Rio Jima between Caño Piedra and Cañabon

The problems here are mainly confined with erosion and stranding/flushing-away of organisms due to fierce and rapid changing water flow.

Two measures are proposed:

- Strengthening of the river banks at certain points
- Elaborate manoeuvring rules/procedures for a smooth start and stop of the power station.

1.9.6 Lake Rincon

In Lake Rincon there will be mainly positive impacts. These can be optimised by keeping the water level as high as possible.

Only one measure is proposed:

- Elaborate water level regulation with the aim of keeping the water level as high and constant as possible.

1.9.7 Rio Jima downstream of Rincon

Here the impacts will in most cases be positive. However, there can be increased problems with erosion during periods of high flows.

Only one measure is proposed:

- Perform a study to evaluate if there is a need for some flood protective works and some riverbank strengthening at certain points.

2 INTRODUCTION

2.1 Background and aims

The Alto Yuna regulation will imply diversion of most of the water from Rio Yuna (upstream Los Quemados) to Rio Jima (Caño Piedra). Rio Masipedro will also be taken into the diversion tunnel. The water will be used for hydropower production (Rio Jima and Rincon), drinking water supply (San Francisco de Macarice), and irrigation water (downstream of Rincon).

In downstream Rio Yuna and Rio Masipedro the water flow will be considerably reduced, whereas in Rio Jima, the water flow will be increased.

This part project aims at elucidating how this regulation impacts the water quality, aquatic life, fish and fisheries in the affected water bodies. The baseline situation is mapped by water quality sampling, review existing monitoring data, sampling of bottom animals, periphyton, and phytoplankton, test fishing, interview of fishermen, and interview of key employees at the municipalities.

2.2 Study area and sampling stations

In the original programme it was agreed upon that it would be necessary to gather information and do sampling for water quality, aquatic life and fish from the following stations:

1. Rio Yuna at the confluence with Rio Blanco (all parameters in Rio Yuna, only water chemistry in Rio Blanco)
2. Rio Yuna downstream of the planned Dam Site
3. Rio Masipedro just upstream of the bathing resort
4. Rio Jima at the tailrace entrance from the planned power station
5. Rio Jima at the inlet to Rincon
6. Rio Yuna downstream of the sewage discharge from Bonao City
7. Rio Yuna downstream of discharges from Falconbridge

During the field work in October it became clear that there were great concern among people from Cotui that the project would have significant negative impact on Lake Hatillo and the water and aquatic life downstream of the lake. There was also addressed concern about the possible impact from the gold mining areas on the Eastern side of Lake Hatillo. In Rincon they also wanted to get elucidated any impact that the project would have on Lake Rincon and on the water quality downstream.

Therefore several new sampling stations were added.

8. Shoreline station in Lake Rincon close to the dam.
9. Shoreline station in Lake Hatillo close to the dam
10. Rio Yuna downstream of Cotui (at the road crossing, La Mata).
11. Lake Hatillo over the deepest point
12. Arroyo Margajita
13. Lake Rincon over the deepest point
14. Rio Jima downstream of Lago Rincon
15. Arroyo Mejita

The location of the stations is shown on the map-illustration in Figure 2.1.

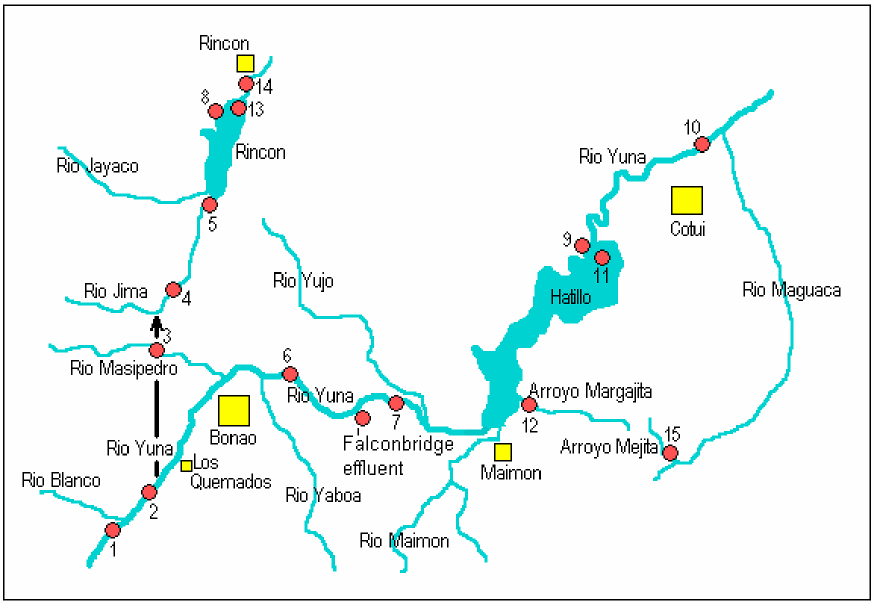

Figure 2.1 The sampling stations in the study (red circles). Yellow squares show towns and cities. The black arrow indicates the planned diversion of water from Rio Alto Yuna and Rio Masipedro to Rio Jima.

2.3 Methodology

2.3.1 Water quality

Existing data were collected from the monitoring programmes run by INDRI and Falconbridge. In addition new samples were taken by the study team. These new samples were partly analysed at the laboratory at INDRI in Santa Domingo and partly at NIVA in Oslo according to standard methods.

Oxygen and temperature were measured in the field using an instrument from YSI (Yellow Spring Instruments). The instrument used in the first field trip was difficult to calibrate to stable readings due to quite new electrode, and these results must therefore be regarded as relatively insecure. The instrument used in the second field trip was calibrated at the Instrument Central at NIVA just prior to the field trip. This instrument showed reliable values.

2.3.2 Phytoplankton

Phytoplankton was sampled by the study team on 100 ml glass vials and preserved by addition of 100 ml of Lugols solution. The samples were analysed in an inverse microscope at NIVA in Oslo, where the species were identified and their respective biomass calculated according to Uthermøhls sedimentation techniques.

2.3.3 Periphyton

Periphyton was collected by the study team. The visible cover-percentage of diatom-cover on stones, filamentous algae, mosses, and heterotrophic growth, were evaluated in the field.

Samples were taken of these elements, conserved with formalin, and analysed at NIVA in Oslo. Here the species composition was identified and the relative abundance assessed.

2.3.4 Bottom animals

Bottom animals were collected by the study team after the "stirring of sediments method". Here stirring of sediments is performed by the boots of a wading person. Just downstream the same person holds a fine meshed hand net (mesh size 250 µm). This operation is performed 3 x 1 minute. The material collected in the hand net is conserved in alcohol or formalin and analysed for species composition and relative abundance of bottom dwelling animals.

2.3.5 Fish and fishery

In the fish study the following methods were used for gathering information

- Test fishing with electric fishing gear
- Fishing by local fishermen by use of throw net and gill net
- Interviewing local fishermen and inspecting their catch
- Interviewing fish sellers

Most of the fish material were analysed and identified in the field. The small fishes, the Poecilids, were conserved in formalin and brought to Santa Domingo for identification.

3 Description of the sampling stations

Station/date	**1: Rio Yuna at the confluence with Rio Blanco 9/10-02**
Site description:	Rapids with bottom consisting of stones and gravel with the particle size varying from coarse sand to stones 25 cm in diameter. The water of Yuna was clear, whereas the water of Blanco was turbid. The stones were clean with a visible green look on the downstream side. Only a few small patches of filamentous green algae, with abundance typically < 1% coverage. On the sunny side of the river the filamentous algae had a greater coverage, up to 5%. No mosses could be seen. Small fishes of 2-3 cm could be seen in shallow water.
Samples for:	In Yuna: Water chemistry, bacteriology, phytoplankton, periphyton, bottom animals, and fish. In Blanco: Water chemistry
Position:	N: 18^o 52' 08.6" W: 70^o 28' 53.6"
Temperature:	26.4 ^oC
O_2-saturation:	73% saturation


Figure 3.1 Station 1; Rio Yuna (the clear water river from the left) at the confluence with Rio Blanco. In the dry season, Rio Blanco was of the clear water type (right panel).

Station/date	**2: Rio Yuna at dam site 9/10-02**
Site description	Rapids with bottom consisting of stones and gravel (course sand to stones 25 cm in diameter). The water was turbid. The stones were covered by a thin layer of silt. A few patches of filamentous green algae had about 5% coverage. No mosses could be seen. Forest vegetation all the way down to the river.
Samples for:	Water chemistry, bacteriology, phytoplankton, periphyton, bottom animals, and fish.
Position:	N: 18° 53' 00.7" W: 70° 28' 06.9"
Temperature	25 °C
O_2-saturation	96% saturation

Figure 3.2 Station 2; Rio Yuna at the planned dam site

Station/date	**3: Rio Masipedro just upstream the Balneario 9/10-02 (50 m upstream of the inlet to the Masipedro irrigation canal)**
Site description	Rapids with bottom consisting of stones and gravel (course sand to stones 25 cm in diameter). The water was clear. The stones were clean with a green colour on the downstream side. No mosses could be seen, neither any filamentous algae. Forest vegetation all the way down to the river. The river had little incoming light due to being situated in a narrow valley with overhanging jungle all the way down to the river. Decaying leaves could be seen as part of the river bed substrate. Small fast shrimps could be seen in the shallow water in the shoreline. Also a few small fishes could be seen. 35 people were bathing at the time when the samples were taken.
Samples for:	Water chemistry, bacteriology, phytoplankton, periphyton, bottom animals, and fish.
Position:	N: 18^o 58' 33.9" W: 70^o 27' 04.1"
Temperature	23 ^oC
O_2-saturation	68.3% saturation

Figure 3.3 Station 3; Rio Masipedro just upstream the bathing place at the start of Masipedro canal

Station/date	**4: Rio Jima at tailrace entrance (the bathing place) 9/10-02**
Site description	Rapids with bottom consisting of stones and gravel (course sand to stones 35 cm in diameter). The water was clear. The stones were clean. No mosses could be seen, neither any filamentous algae. The river had little incoming light due to overhanging big trees. Decaying leaves could be seen as part of the river bed substrate. Bathing place. Approximately 15 persons were bathing at the time where the samples were taken (ca 1600 hrs).
Samples for:	Water chemistry, bacteriology, phytoplankton, periphyton, bottom animals, and fish.
Position:	N: 18^o 59' 59.5" W: 70^o 26' 52.4"
Temperature	23.4 ^oC
O_2-saturation	43.6 % saturation, most likely too low due to electrode problems

Figure 3.4 Station 5; Rio Jima at the planned entrance of the tailrace canal from the power station (at bathing place of Caño Piedra).

Station/date	**5: Rio Jima at the inlet to Rincon Reservoir 10/10-02 (1600 hr)**
Site description	Rapids with bottom consisting of stones, sand and also some mud. The water was very turbid due to heavy rain the night before. The station was situated at a wading place in an open pasture landscape with no trees bordering the river. The lower part of Jima (downstream of the Auto Pista) had erosion prone soil materials in the river sides. The water was so turbid that it was impossible to do an evaluation of the periphyton coverage. However, no mosses, neither any filamentous algae could be seen in the sample of bottom dwelling animals, which indicate only minor occurrence of such type of vegetation in the river bed.
Samples for:	Water chemistry, bacteriology, periphyton, bottom animals, and fish.
Position:	N: 19^{o} 03' 09.7" W: 70^{o} 25' 0.2"
Temperature	26.9 ^{o}C
O_2-saturation	31 % saturation

Figure 3.5 Station 5; Rio Jima at the entrance into Rincon Reservoir close to the village of Cañabon. The right panel shows the same station after flooding.

Station/date	**6: Rio Yuna downstream of Bonao City effluents, but upstream of discharges from Falconbridge 10/10-02 (1730 hr)**
Site description	Rapids with bottom consisting of stones, sand and also some soil. The water was very turbid due to heavy rain the night before. The riverbed was approximately 200 m wide at this station, and it was water in half of this at the time of sampling. The river had erosion prone soil materials in the river sides. The water was so turbid that it was impossible to do an evaluation of the periphyton coverage. However, no mosses, neither any filamentous algae could be seen in the sample of bottom dwelling animals, which indicate only minor occurrence of such type of vegetation in the river bed.
Samples for:	Water chemistry, bacteriology, periphyton, phytoplankton, and fish.

Position:	N: 18° 57' 48.0"
	W: 70° 22' 47.2"
Temperature	26.1 °C
O_2-saturation	54.1 % saturation

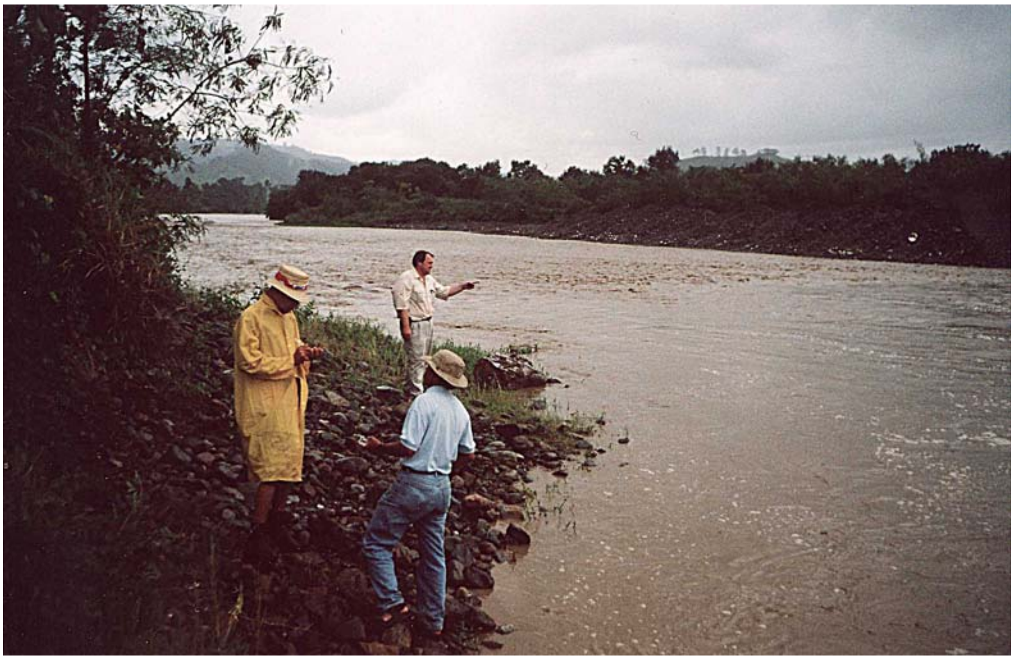

Figure 3.6 Station 6; Rio Yuna downstream of Bonao City (at the road crosses the river on the way to Falconbridge)

Station/date	**7: Rio Yuna 200 m downstream of Falconbridge canal outlet 10/10-02 (1300 hr)**
Site description	Rapids with bottom consisting of stones, sand and also some soil. The water was very turbid due to heavy rain the night before. The riverbed was approximately 200 m wide at this station, and it was water in half of this at the time of sampling. The river had erosion prone soil materials in the river sides. The water was so turbid that it was impossible to do an evaluation of the periphyton coverage. However, no mosses, neither any filamentous algae could be seen in the sample of bottom dwelling animals, which indicate only minor occurrence of such type of vegetation in the river bed.
Samples for:	Water chemistry, bacteriology, periphyton, phytoplankton, bottom animals.
Position:	N: 18° 57' 03.7"
	W: 70° 19' 45.5"
Temperature	25.9 °C
O_2-saturation	53.1 % saturation

Figure 3.7 Station 7; Rio Yuna downstream the discharges from Falconbridge (entrance of Falconbridge canal)

Station/date	**Station 9 and station 11: Hatillo reservoir close to the dam**
Site description	Station 9 is a shoreline station sampled in October 2002, whereas station 11 was out on the lake over the deepest point at the dam foot, sampled in March 2003. Samples were taken for water chemistry and phytoplankton in the reservoir at the dam site. Oxygen and temperature was measured at several depths to reveal the stratification of the water masses in the reservoir. The water quality seemed good with relatively clear water. The water had a light green appearance. Secchi depth transparency was judged (not measured) to be between 2.5 and 3m.
Samples for:	Water chemistry, phytoplankton and bacteriology.
Position:	
Temperature	
O_2-saturation	

Figure 3.8 Station 9 and station 11; Hatillo reservoir close to the dam. Station 9 is a shoreline sampling station whereas station 11 is out on the lake over the deepest point.

Station/date	**Station 8 and station 13: Rincon reservoir close to the dam**
Site description	Station 8 is a shoreline station sampled in October 2002, whereas station 13 was out on the lake over the deepest point, sampled in March 2003. Samples were taken for water chemistry and phytoplankton in the reservoir at the dam site. Oxygen and temperature were measured at several depths to reveal the stratification of the water masses in the reservoir. The water quality seemed good with relatively clear water. The water had a light green appearance. Secchi depth transparency was judged (not measured) to be around 2.5 m.
Samples for:	Water chemistry, phytoplankton and bacteriology.
Position:	
Temperature	
O_2-saturation	

Figure 3.9 Station 8 and 13; Rincon reservoir close to the dam. Station 8 is a shoreline station sampled in October 2002, whereas station 13 is out on the lake over the deepest point.

Station/date	**Station 10: Rio Yuna downstream of Hatillo, at the road crossing La Mata.**
Site description	The station is located at the road crossing La Mata. The river was fast flowing, and the bottom consisted of gravels and stones. The area was used for bathing, washing (also car washing), and fetching household water. The river was wide and shallow at this point.
Samples for:	Water chemistry, bacteriology, bottom animals
Position:	
Temperature	26 ^{o}C
O_2-saturation	94%

No picture is available from the station.

Station/date	**Station 12: Arroyo Margajita just upstream the entrance into Hatillo reservoir.**
Site description	The station is located at the road crossing upstream the entrance in Hatillo. The river was slow flowing, and the bottom consisted of soft mining polluted mud. The water colour was red, most likely due to high content of iron. The river seemed dead due to mining pollution. No living creatures were observed. The locals knew that the river were toxic. It contained "pure poison", they said.
Samples for:	Water chemistry, and heavy metals
Position:	
Temperature	
O_2-saturation	

Figure 3.10 Station 12; The mining polluted Arroyo Margajita just upstream where it enters Hatillo. The red colour is due to extremely high content of iron.

Station/date	**Station 14: Rio Jima downstream of Rincon reservoir**
Site description	The station is located 200 m downstream of the outlet from Rincon power station. The river was fast flowing, and the bottom consisted of stones and boulders. The water was clear and pleasant look. There was no odour despite the withdrawal was almost oxygen free deep water in Rincon reservoir.
Samples for:	Water chemistry, and bacteriology.
Position:	
Temperature	
O_2-saturation	49%

There is no picture available from the station

Station/date	**Station 15: Arroyo Mejita**
Site description	The station is located just upstream the entrance in Rio Maguaca. The stream is coming from another part of the same mining area as arroyo Margajita. The water was clear. The stream seemed to have relatively intact aquatic life.
Samples for:	Water chemistry, and heavy metals.
Position:	
Temperature	
O_2-saturation	

There is no picture available from the station.

4 WATER QUALITY

4.1 Temperature in the rivers

The water temperature was measured on each station both in October 2002 and in March 2003. The results are given in Figure 4.1.

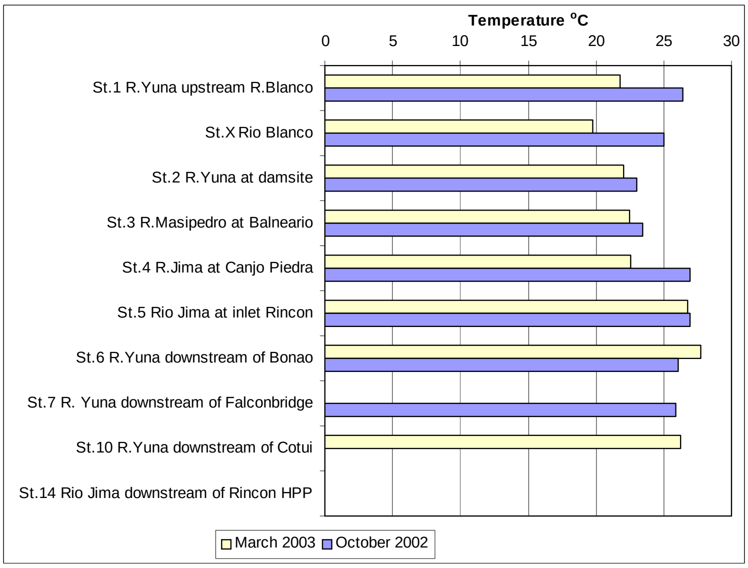

Figure 4.1 Water temperature at the different sampling stations in the rivers

The temperature varied between 20 and 28 °C, and there were only small differences in the temperature between the wet season (October) and dry season (March). In the upper reaches the rivers were slightly colder in winter, where as in October the differences in altitude did not seem to impact the water temperature significantly.

4.2 Oxygen in the rivers

Oxygen was measured at both the field trips by using an oxygen meter. In October it was applied a quite new apparatus of the brand YSI (Yellow Spring Instruments) belonging to the Aquarium in Santa Domingo. We had problems with the calibration of this instrument, and therefore the measurements from the October field work should be regarded as relatively insecure. In the second field trip we applied an oxygen meter belonging to Norwegian Institute for Water Research, which was checked at the Instrument Lab just before use, which include test against oxygen titration. This instrument gave reliable measurements.
From Figure 4.2 it can be seen that the oxygen saturation at most stations were much lower in October than in March. There is no rational explanation for such a difference. If it was due to pollution it should have been the other way around. Then the rivers should have lowest oxygen in the low flow season, whereas in fact the opposite was observed. We therefore believe that the measurements from October are wrong.

In the measurements from the low flow season the oxygen saturation was around 100% at most river stations. At some stations the saturation was more than 100%, which is a result of the oxygen production from the photosynthesis in the river plants. The oxygen conditions in these rivers were good, and no oxygen problems are likely to occur in near future.

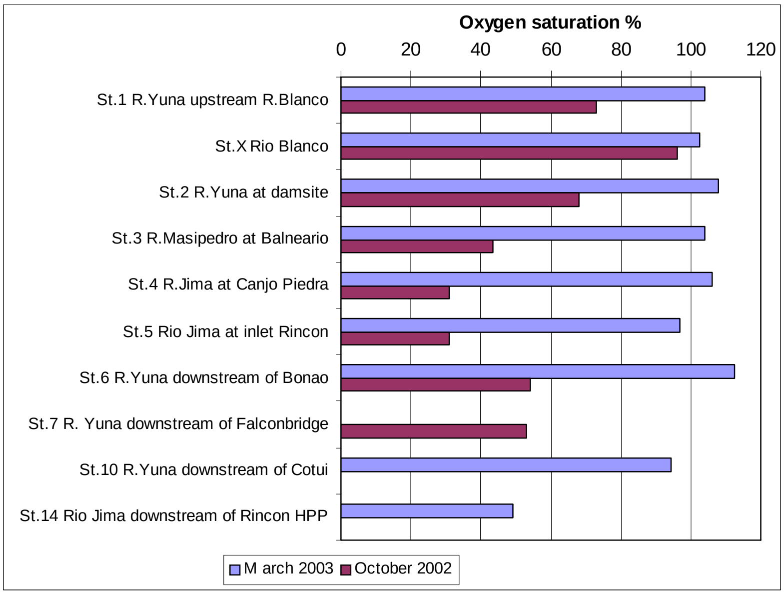

Figure 4.2 Oxygen saturation in the rivers March 2003 (The measurements in October are most likely incorrectly too low, se text.)

The low oxygen concentration downstream of the Rincon Hydropower Plant is due to the deep water intake from the Rincon Reservoir. The deep water of Rincon had very low oxygen, see chapter 4.3. If long periods of anoxic waters are prevailing in the reservoir, it may smell sulphide from the water coming out of the HPP. There was not observed any smell in this case, and people from the area could not remember to have experienced such smell downstream of Rincon HPP.

4.3 Temperature and Oxygen in Hatillo Reservoir and Rincon Reservoir

Measurements of temperature and oxygen in Hatillo and Rincon Reservoir are given in Figure 4.3.

In both lakes the water masses are stratified with a light top layer of thickness 10-15 m which is lying on above a heavier colder bottom layer of about the same thickness. The bottom layer is prevented from coming in contact with the atmosphere most of the year. Only in periods of cold weather combined with storms the whole water column will circulate recharging the deep water with new oxygen. The dead algae sink through the thermocline and decompose in the deep water consuming the oxygen there, and giving poor conditions for fish and bottom animals. Nutrient discharges enhance the algal growth, which again results in increased sedimentation of dead algae and increased oxygen consumption in the deep water.

In both lakes there is a marked decrease in the oxygen concentration with increasing depth. In Lake Rincon the situation is bad, with total disappearance of oxygen below 15 m depth. Lake Rincon has a eutrophication problem. In Lake Hatillo the situation is somewhat better, but even there the decline in oxygen is significant, which shows that the lake is susceptible to increased nutrient load. A reduction in the water renewal (e.g. by the planned regulation) of the lake gives the same response as an increase in the nutrient load.

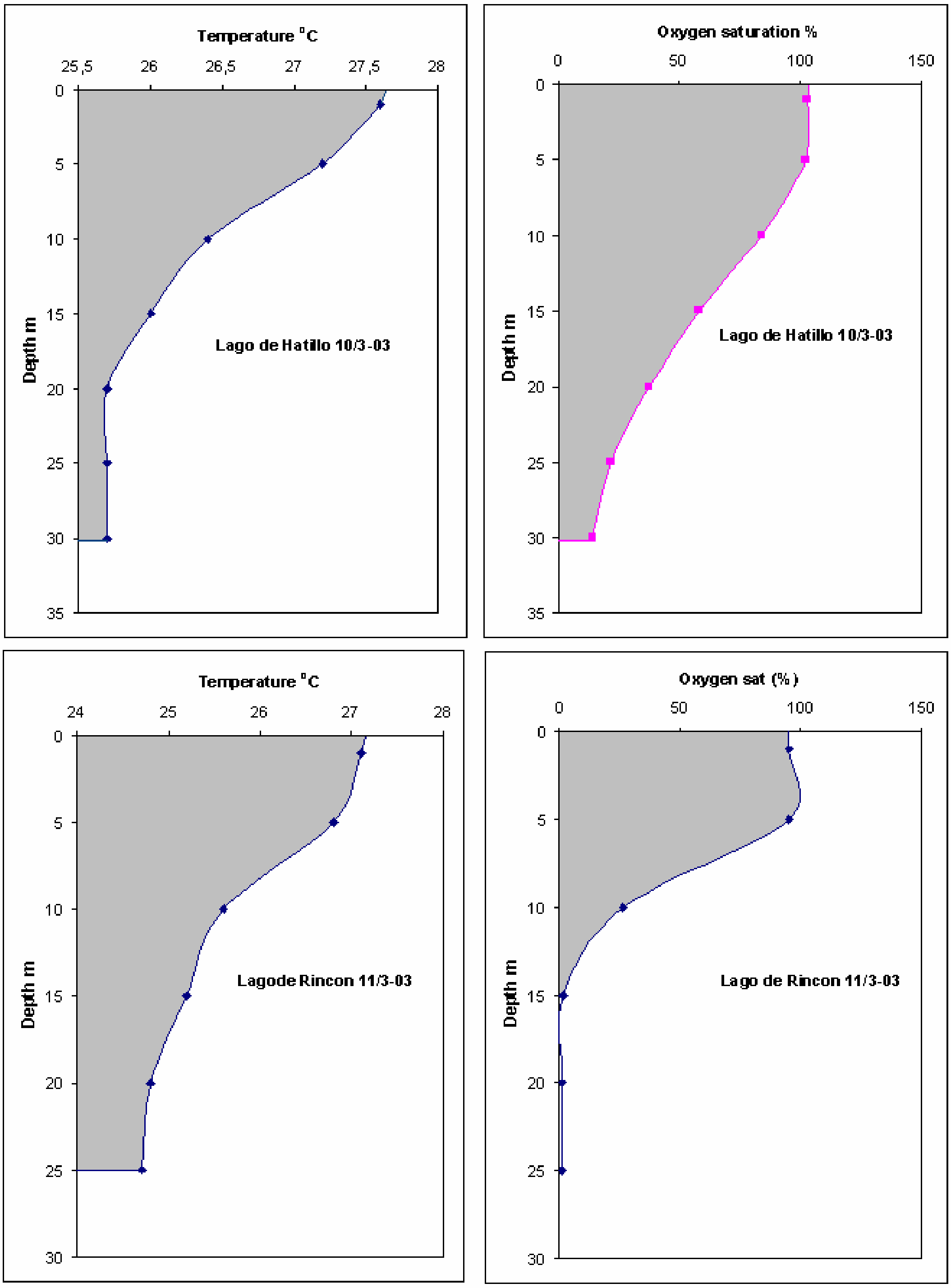

Figure 4.3 Measures of temperature and oxygen in the reservoirs Lago de Hatillo and Lago de Rincon.

4.4 Main chemical constituents (major ions)

The main chemical constituents, or the major ions, of freshwater is Ca^{++}, Mg^{++}, Na^{+}, K^{+}, $HCO3^{-}$, Cl^{-}, and $SO4^{--}$. These are the dissolved compounds that normally are found in mg/l in the water. All other compounds are found in µg/l or ng/l, or less. Table 4.1 shows the main ions together with conductivity and pH. All rivers except for Margajita, are of the bicarbonate type of water with high calcium and magnesium and with bicarbonate as dominating anion.

The pH is slightly alkaline. The waters are well buffered and can tolerate acid rain very well. Arroyo Margajita is highly polluted from mining runoff and differ therefore highly from the other. Sulphide from the metal ore is oxidised to sulphate which react with water to give sulphuric acid. The sulphate content was as high as 3301 mg/l. This is more than 200 times higher value than what it would have if it was not affected by mining. The pH value is only 2.2 which is very acidic water. No animals are able to live in such environment. The acidic water dissolves heavy metals from the ground giving the water even more toxic.

Table 4.1 Main chemical constituents in the examined rivers. Average of 5 samplings.

Station	Date	Cond. µS/cm	pH	Ca mg/l	Mg mg/l	Na mg/l	HCO3 mg/l	Cl mg/l	SO4 mg/l
St.1 R.Yuna upstream R.Blanco	Average	211	7,94	26	4,9	9,2	98	8,9	10,3
St.2 R.Yuna at damsite	Average	224	7,94	26	4,4	13,0	98	11,3	14,8
St.3 R.Masipedro at Balneario	Average	138	7,68	12	5,6	7,1	60	7,1	11,1
St.4 R.Jima at Canjo Piedra	Average	119	7,46	10	4,8	6,1	48	8,7	9,9
St.5 Rio Jima at inlet Rincon	Average	174	7,26	13	8,3	8,8	78	9,6	10,4
St.6 R.Yuna downstream of Bonao	Average	285	7,6	31	9,1	11,8	135	12,1	12,3
St.7 R. Yuna downstream of Falconbridge	Average	291	8,02	32	9,5	11,8	128	12,4	13,3
Hatillo Reservoir, surface water at the dam	Average	269	7,46	26	8,8	14,3	82	11,6	41,4
Rincon Reservoir, surface water at the dam	Average	165	7,56	12	8,3	8,5	74	9,9	9,4
St.14 Rio Jima downstream of Rincon HPP	11.03.03	168	6,9	13	7,3	9,7	85	6,7	7,6
St.10 R.Yuna downstream of Cotui	11.03.03	266	7,1	26	8,1	14,7	85	16,0	46,0
Margajita	11.03.03	4210	2,2						3301,0

4.5 Nutrients and support parameters

Table 4.2. shows the content of the plant nutrients phosphorus and nitrogen, turbidity, and water colour. P and N are also shown in Figure 4.4 and Figure 4.5 and the results are commented under these. The colour of the water is from 5-15 mgPt/l which shows that it contain very little humic material. The turbidity, varies very much which shows that the rivers are easily fed by erosion material during rainy weather.

Table 4.2 Nutrient concentrations, turbidity and water colour in the affected water bodies.

Station	Date	Tot P µgP/l	Orto-P µgP/l	Tot-N µgN/l	Turb FNU	Coulor mgPt/l
St.1 R.Yuna upstream R.Blanco	Oct. 02	4	2	205	2,20	5,8
	11.03.03	3		170	1,20	2,7
Rio Blanco	Oct. 02	49	21	535	14,00	5
St.2 R.Yuna at damsite	Oct 02	34	19	440	18,00	5,4
	11.03.03	11		185	2,08	3,1
St.3 R.Masipedro at Balneario	Oct 02	8	6	190	1,10	2,7
	11.03.03	4		119	1,28	3,5
St.4 R.Jima at Canjo Piedra	Oct 02	5	2	220	2,10	2,7
	11.03.03	8		245	3,40	2,7
St.5 Rio Jima at inlet Rincon	Oct 02	97	9	705	98,00	15,1
	11.03.03					
St.6 R.Yuna downstream of Bonao	Oct 02	3996	119	4720	3232,00	13,5
	11.03.03	24		980	6,15	3,9
St.7 R. Yuna downstream of Falconbridge	Oct 02	547	144	8580	326,00	17
Hatillo Reservoir, surface water at the dam	Oct 02	4			2,70	1
	11.03.03	5		295	1,21	3,1
Rincon Reservoir, surface water at the dam	Oct 02	9		2070	2,10	5
	11.03.03	10		300	2,60	5
St.14 Rio Jima downstream of Rincon HPP	11.03.03	15		320	6,15	7
St.10 R.Yuna downstream of Cotui	11.03.03	4		290	0,23	2,3
Falconbridge canal	oct 02	305	201		58,00	9,7

4.5.1 Total phosphorus

Figure 4.4 shows the concentration of total phosphorus at the different sampling stations in the different water bodies of the study, results from the October visit and March visit respectively. The results are compared with the water quality guidelines for the Dominican Republic. For total P the guidelines merge class A and B.

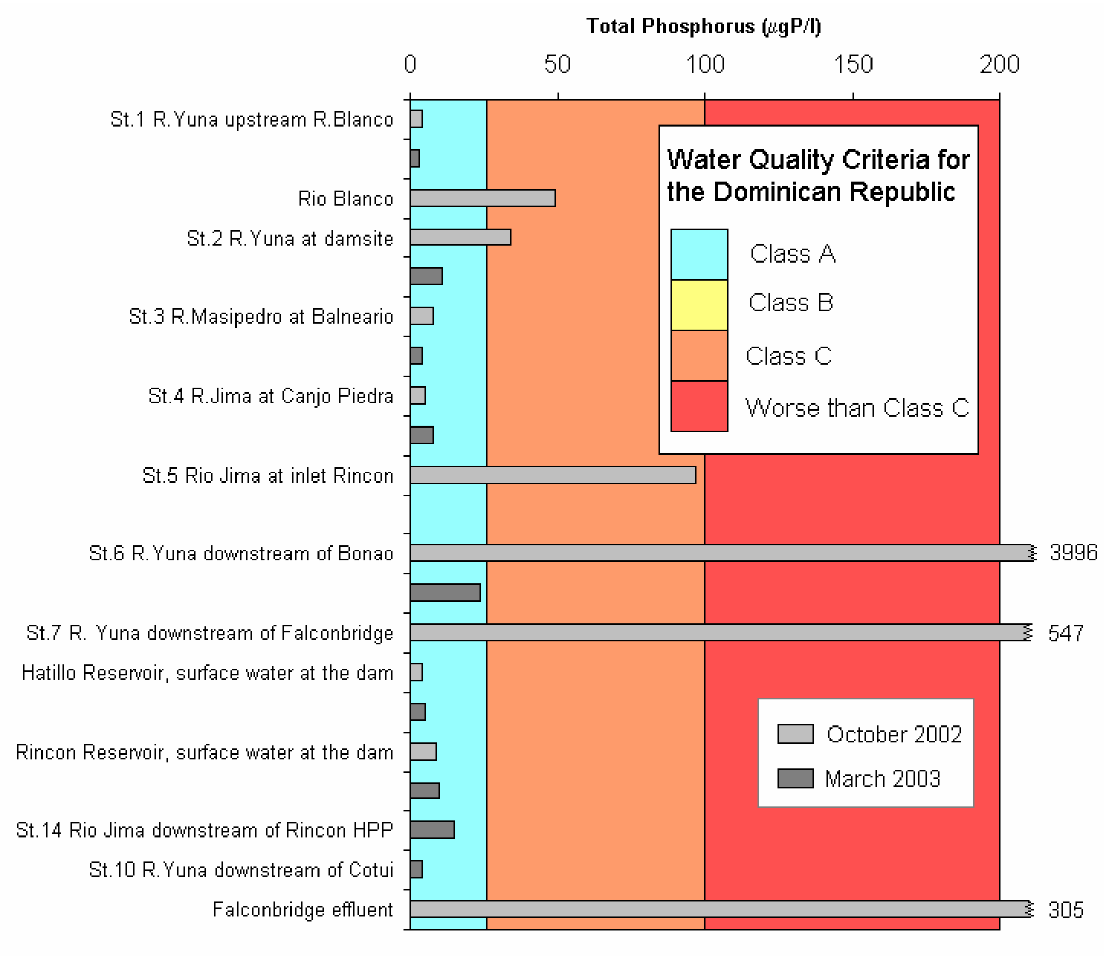

Figure 4.4 Concentration of total phosphorus in the different water bodies. (analysis from NIVA).

Most of the stations have P concentration that lies inside the best water quality class, both in the wet season (October) and in the dry season. At some of the stations, however, the water quality is susceptible to erosion, and these stations show high P-concentration in the wet season. This applies to Rio Blanco, Rio Jima from Cano Piedra to Rincon inlet, and most of all, Rio Yuna from Los Quemados and downwards. Downstream of Bonao the P-concentration was as high as 3,9 mg P/l, which is a very high value for freshwater. The sample was taken during a heavy rain shower, and during such showers the river receives both erosion material as well as pollution from Bonao City. During the same shower the turbidity increased to above 3000 FNU indicating large amounts of erosion material. The concentration of faecal coliform bacteria increased also considerably during such periods, which indicates overflow in the sewer systems.

The reservoirs, Lake Hatillo and Lake Rincon had both low levels of total phosphorus in the surface waters, being in the oligotrophic to mesotrophic level. Rincon seem to be slightly more nutrient rich than Lake Hatillo.

The Dominican Republic has not yet developed water quality guidelines for total nitrogen, and Figure 4.5 is therefore given without coloured background. The nitrogen concentrations were high downstream of Bonao and the Falconbridge area. Nitrogen has no geological sources, and does not increase due to erosion as is the case for phosphorus. Therefore the observed high values are discharges from human sanitary systems or runoff from agricultural land.

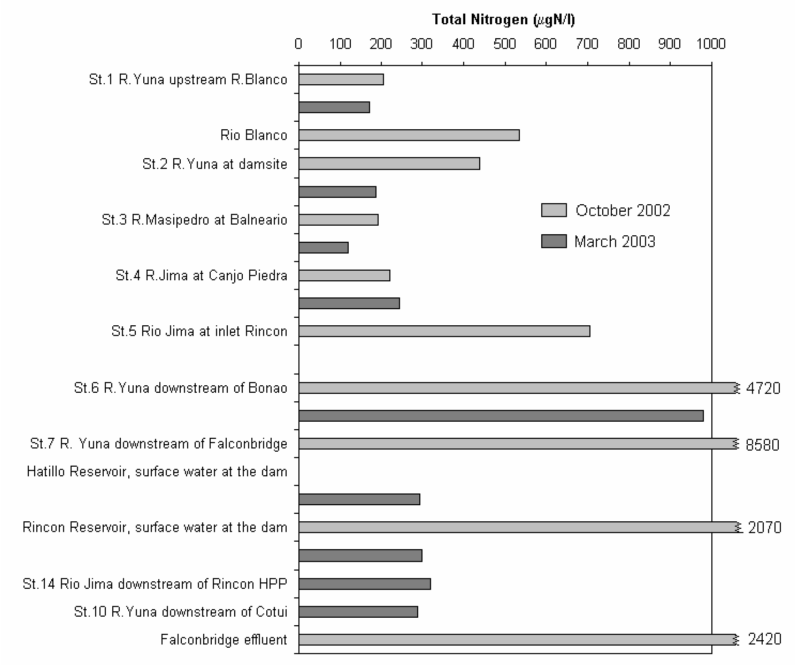

Figure 4.5 Concentration of total nitrogen in the different water bodies affected by the project

4.6 Heavy metals

The results from the analyses of heavy metals are given in Table 4.3.

Table 4.3 Analyses of the concentration of some heavy metals in the water from the different localities.

Station	Date	F µg/l	As µg/l	Cd µg/l	Co µg/l	Cr µg/l	Cu µg/l	Fe µg/l	Mn µg/l	Ni µg/l	Pb µg/l	Zn µg/l	Hg ng/l
St.1 R.Yuna upstream R.Blanco	Oct. 02	62	0,26	<0,005	0,02	1,4	0,87	36	1	0,05	0,03	0,37	
St.6 R.Yuna downstream of Bonao	Oct 02	125	0,39	0,603	48,30	81,5	140	46900	2150	59,5	13,6	167	
St.7 R. Yuna downstream of Falconbridge	Oct 02	87	0,1	0,071	6,35	13,6	18,7	4460	286	24,7	1,37	18,4	
Falconbridge effluent	oct 02	210	0,33	1,83	21,70	17,8	3,26	1300	332	782	0,19	36,1	
Rio Margajita	11.03.03		1390	410	1360	59,6	6250	437000	6300	179	8,5	92100	58
Rio Mejita	11.03.03		13	0,1	116		6,17		1650		0,07		7,5

Class A
Class B
Class C
Worse than Class C

The mining affected (gold-iron) Rio Margajita had very high concentrations of nearly all the analysed metals. The river is extremely polluted. In addition to high concentrations of heavy metals, the water was to acidic to support any natural life (pH of 2), and the concentration of sulphate was 3,3 grams per litre. The water from Rio Margajita impacts the Hatillo reservoir to day, particularly with respect to increase in sulphate. This impact will increase in the future as the through flow of water in Hatillo will be reduced. Rio Margajita is also a threat to children's playing in and with water, household animals (and wild animals) drinking from the water, as well as use of the water for irrigation. It should have been prepared a pollution abatement plan for Rio Margajita.

Rio Yuna receives also a considerable amount of heavy metals (Cr, Fe, Mn, Zn) when it passes Bonao City. This is particularly seen in the wet season when the storm flow City canals carry all kind of pollutants into Rio Yaboa, which enters into Rio Yuna a short distance downstream. The impact of the pollution from Bonao City will be even more pronounced when most of the water is diverted to Rio Jima. The mitigation plan for the regulation project should include building a system for collection and treatment of the effluents in Bonao City.

Further down in Rio Yuna (downstream of Falconbridge) the conditions improves somewhat. In the main effluent stream from the wastewater treatment system of the processing plant of Falconbridge, the water had low values for all heavy metals except for iron and nickel. When this effluent stream is mixed into the Falconbridge canal and subsequently into the Rio Yuna mainstream, the concentrations of these two compounds drop to non-problematic levels. Our findings fit well with the results from the monitoring performed by Falconbridge, which states that Falconbridge with the measures taken, does not give rise to any significant water pollution anymore.

4.7 Hygienic conditions at the river stations

Five times during December - January there were collected water samples for bacteriological analysis at the river stations 1-8 (Figure 2.1 for location of the stations). The results are given in Figure 4.6.

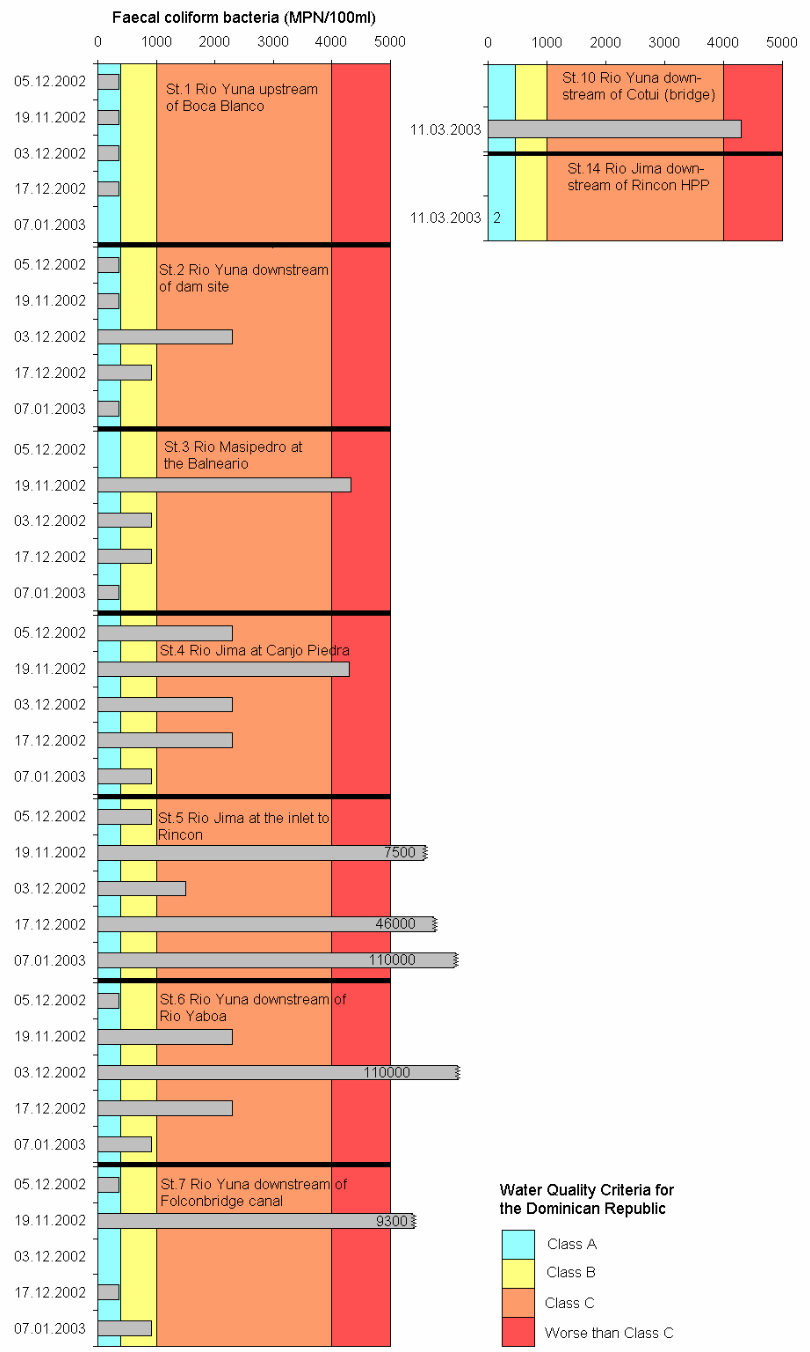

Figure 4.6 Concentration of faecal coliform bacteria (MPN/100 ml) at the river stations compared with the water quality criteria for The Dominican Republic, see text for further explanation.

In the Water Quality Guidelines (WQG) for the Dominican Republic the water quality of surface water is divided into three classes A, B and C. A short resume is given below.

Class A. Water that can be used as drinking water after simplified water treatment (filtration and disinfection). This water can also be used for swimming and used for irrigation of fruit and vegetables that are eaten raw without boiling (salads, strawberries, etc).

Class B. Water that has a quality good enough to preserve aquatic ecology, that can be used for drinking water after fully treatment (flocculation, filtration and disinfection), that can be used for irrigation of crops that are not eaten without boiling/frying, that can be used for water sports without direct contact (e.g. boat sports), etc.

Class C. Water that can be used for transportation and with limited interactions with areas of any environmentally value.

With respect to bacteria class A water should be kept below 400 MPN/100ml of faecal coliform bacteria. At all stations the river is used for bathing. It is, however, only at Boca de Blanco (St.1) that the water quality satisfies the requirement for this activity according the WQG at all times. In Rio Jima at Canjabon and in Rio Yuna downstream of the discharges from Bonao, the hygienic contamination is at times so large that it may be a health risk to bath and swim here.

The samples are taken at the end of the wet and one sample in the dry season. The potential for dilution is less during the dry season. However, for Bonao's septic tank based sewerage system the overflow to urban drainage may be more frequent during the wet season. It is therefore not necessarily likely that the hygienic contamination is much greater during the dry season. Reduction of the water flow in Rio Yuna will increase the hygienic contamination considerably. This should not be done without previous improvement of the sewerage network and the sewage treatment in Bonao, if the river should satisfy the quality requirement for bathing and other Class A use categories. In Rio Jima at Canjabon it is not recommended to swim, and at Canjo Piedra the water quality is also questionable for bathing and children's playing in the water.

In Masipedro and in the upper part of Yuna the water quality are more satisfactory. In the lower parts of Rio Yuna, the water quality improves again, due to dilution from incoming streams and die-off of the coliform bacteria in these warm waters.

4.8 Hygienic conditions in the reservoirs Hatillo and Rincon

The results are given in Figure 4.7 and show that the surface water quality in these lakes are in most instances in class A. The long water residence time, and exposure to UV-sun radiation of the surface water are the two main factors purifying the lake water for bacteria.

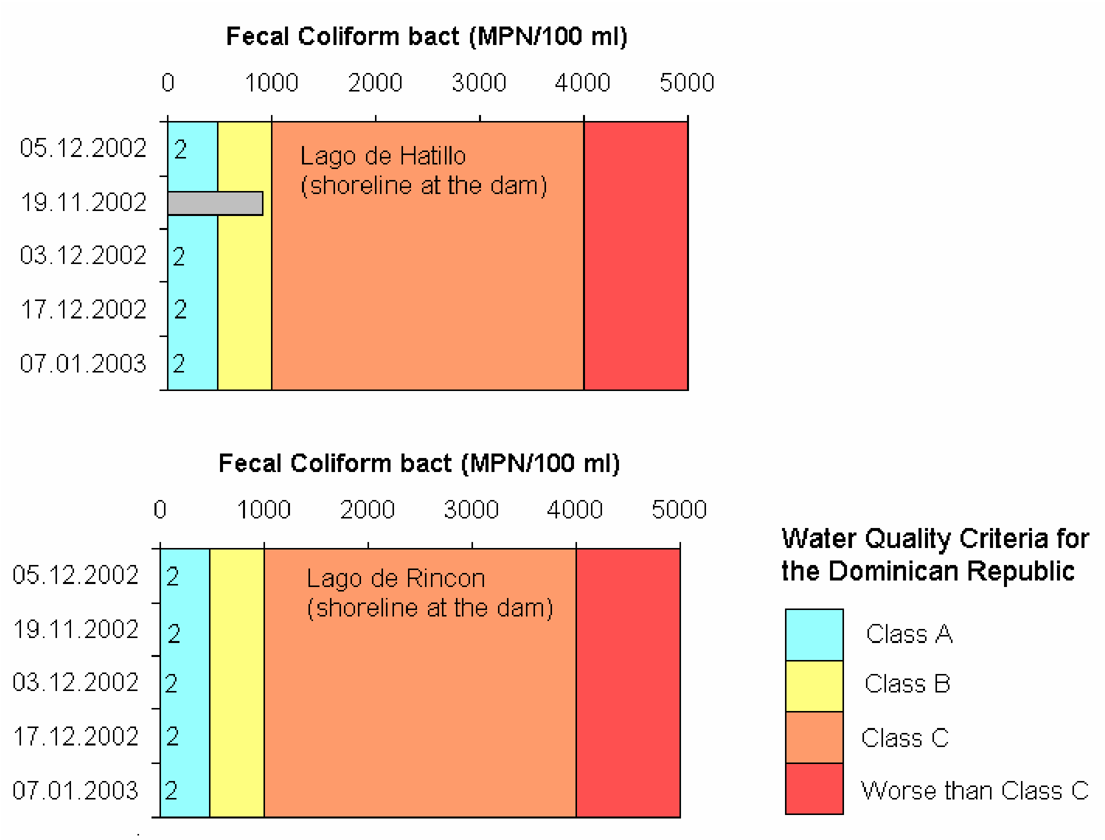

Figure 4.7 Coliforme bacteria (44 ^{o}C) in the surface water of the reservoirs Hatillo and Rincon.

5 HEAVY METAL IN THE FISH OF LAKE HATILLO

As the highly heavy metal contaminated river, Rio Margajita, enters into Lake Hatillo which is a lake that supplies considerable amount of fish for human consumption, it was of interest to analyse the metal content in some big specimen of a carnivorous fish. We bought the biggest specimen we could find of the “trucha” (*Micropterus salmoides*, in English Largemouth bass) from fish sellers in Maimon, a town in the northern end of Hatillo. This type of fish is the top predator in the lake, and if accumulation of heavy metals in fish is a problem in Lake Hatillo, it should be seen in the trucha. The size of the fish was 0,75 kg, and 35 cm long. It is not common to catch truchas above one kg in Hatillo, and the specimen analysed here is among the largest normally consumed. The results of the analyses are given in Table 5.1.

Iron mining in sulphide containing rocks often results in pollution runoff by several heavy metals. When the sulphides come in contact with air and water, sulphuric acid is formed, which dissolves the heavy metals in the ore containing rock material. It has also been mining for gold in the Rio Margajita/Mejita catchments, which includes often the use of mercury. Mercury exerts the greatest problem with respect to accumulation of dangerous concentrations in fish flesh. The higher up in the nutrient chain the fish belongs, and the bigger the fish, the higher the mercury content will be.

The concentration of mercury in the trucha-filet from Hatillo was 0,58 ppm. The limit for consumption depends on how often this fish is eaten. WHO has set as a guideline that if you eat fish once a week, it should not contain more than 0,5 ppm Hg. For pregnant women the concentration limit is half of this, i.e. 0,25 ppm. If you eat fish more seldom, you can accept higher concentrations, i.e. bigger fish.

The concentration of the other metals is below problematic levels.

As it is rare to catch truchas bigger than one kg in Lake Hatillo, it does not seem to be a problem with respect to metals in fish flesh. Other fish species like tilapia and carps will have lower levels of metals in the meat, as they are belonging to lower levels in the food chain.

Table 5.1 Analyses of the filet of a large specimen of “trucha” (*Micropterus salmoides*) from Lake Hatillo.

Metal species	Spec.	mg/kg ww
Arsen	As	0,132
Cadmium	Cd	0,0002
Cobolt	Co	0,00551
Cromium	Cr	0,284
Copper	Cu	0,158
Mercury	Hg	0,58
Nickel	Ni	0,0048
Lead	Pb	0,004
Selen	Se	1,09
Tin	Sn	0,027
Zinc	Zn	6,04

6 AQUATIC LIFE

6.1 Life in general in fast flowing rivers

Rapids with moderate slope are often the most productive stretches of rivers. There are several reasons for this. The substrate is varied, large stones, smaller stones, gravel, some mud in between, some dead tree-trunks, etc. This diversified bottom offers shelter and homes for many types of organisms. With respect to bottom living organisms the biodiversity of such reaches are much higher than on the uniform mud surface of a slow flowing river. In steep rapids with fierce flow the rough physical environment may restrict the biodiversity and the biological production, but it is astonishing how rough environment the river biota can handle.

The rapids are shallow and the whole bottom surface receives the life-giving sunlight. On all substrates, stones etc., there are tiny layers of algae. These are the “pastures” of the river bottom, and are the most important starting point of the river food chain. Another important source of nutrients to a river is the falling of leaves and other debris from the riparian vegetation. Overhanging big trees are very important in this respect. A third group of energy input is what is called “drift”. These are edible organic particles coming with the current. The drift may come from the river itself, from the catchment, or from upstream lakes. Figure 6.1 gives a general picture of the life in rapid flowing rivers.

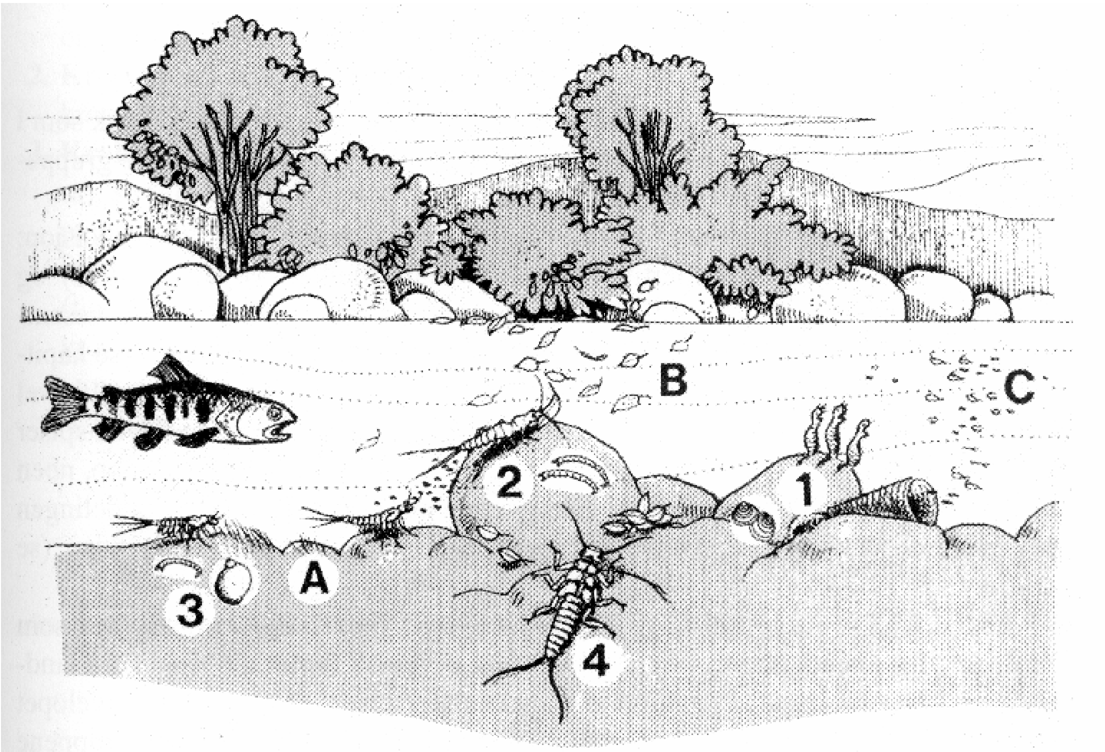

Figure 6.1 The life of rapids in rivers. A=periphyton which is tiny plants growing on stones etc. B is leaves and debris falling in from the riparian vegetation. C is drift, i.e. edible organic particles (both living and dead) coming with the current. 3 are organisms eating periphyton, 2-and 4 are organisms eating dead leaves and terrestrial debris, and 1 is filter-feeding organisms. The fish is mainly feeding on bottom animals in these reaches. (From Lillehammer et al 1980).

In the Alto Yuna Impact Study the following components are included:

1. Periphyton
2. Phytoplankton
3. Bottom dwelling animals
4. Fish

For sampling techniques see the chapter on methodology. The species compositions of the 3 first groups were analysed at NIVA in Norway, whereas the fish species were identified in the Dominican Republic.

6.2 Periphyton

The organism groups, which here are called periphyton, consist of "attached growth" on the river bottom (on stones, tree-logs, mud surface) of algae, mosses, heterotrophic bacteria, and fungi. On all fixed substrates in shallow rivers, there is a thin layer of this attached growth, which serves as food for the bottom dwelling animals. This thin layer of algae is the main primary producer in Alto Yuna, and thus is the most important sources of food for the river. Another important source of food input in rivers is leaves and debris falling from the riparian vegetation. In the smaller rivers like Rio Masipedro and Rio Jima this is more important than in the larger Rio Yuna.

In the tables in this section the abundance of the different periphyton species is given after a tripartite scale where

x = present (but in low numbers)
xx = common (medium numbers)
xxx = dense growth (large numbers)

6.2.1 Station 1: Rio Yuna just upstream the confluence with Rio Blanco.

At this station the Rio Yuna is a clear water river with rapids. The bottom consisting of stones and gravel from the size of course sand to stones 25 cm in diameter. The water of Rio Yuna was clear, whereas the water of Rio Blanco was turbid. The stones were clean with a visible green look on the downstream side. Only a very few small cloths of filamentous green algae coverage (< 1%) could be found. On the sunny side of the river the filamentous algae had a greater coverage, up to 2-3%. No mosses could be seen. The species found are given in the Table 6.1 below.

Table 6.1 Station 1. Rio Yuna upstream confluence with Rio Blanco. Observed species in the periphyton community.

Cyanphycea:	
Unidentified coccale blue-green algaes	x
Green algaes (Chlorophyceae):	
Cladophora cf. *glomerata*	x
Penium sp.	x

<u>Bacillariophyceae:</u>	
Achnanthes cf. *minutissima*	xx
Cocconeis placentula	xx
Gomphonema spp.	xx
Gomphonema truncatum	x
Fragilaria ulna	x
Fragilaria spp.	x
Cymbella tumida	x
Cymbella spp.	x
Denticula sp.	x
Melosira lineata	x
Unidentified diatom species	xx

The periphyton society was sparsely developed. The only visible elements consisted of small green dots of the chlorophyceaen species *Cladophora cf. glomerata*. This species is normally found in waters rich in electrolytes with a pH value of 7.5-8.5. The diatom (Bacillario-phyceae) society was dominated by species that prefer high conductivity waters of neutral to alkaline reaction. It was not found decomposers (heterotrophic bacteria and fungi) in the samples of attached growth. This indicates that the waters are little impacted by human discharges.

6.2.2 Station 2: Rio Yuna just downstream of the planned dam-site.

The results are given in Table 6.2. The periphyton was sparsely developed and was dominated by species that thrive in natural water qualities with high content of electrolytes and good nutrient conditions. The periphyton society consisted mainly of the clorophycean species *Cladophora cf glomerata* and a diverse list of diatoms. The first mentioned species made a visible green colour on some stones. It was not observed any decomposer organisms in the periphyton samples.

Table 6.2 Observed species in the periphyton society in Rio Yuna at station 2, just downstream of the planned dam-site.

<u>Cyanophyceae:</u>	
Phormidium sp. 7,5µ bred	x
Small unidentified blue-green algae	x
<u>Chlorophyceae:</u>	
Cladophora cf. *glomerata*	1%
<u>Bacillariophyceae (Diatoms):</u>	
Cocconeis placentula	x
Gyrosigma sp.	x
Cymbella tumida	x
Cymbella spp.	*x*
Gomphonema spp.	x
Fragilaria ulna	x
Fragilaria spp.	x
Navicula spp.	xx
Denticula sp.	x
Melosira lineata	x
Unidentied diatoms	xx

6.2.3 Station 3: Rio Masipedro just upstream the Balneario

It was no visible growth of periphyton on this station. The stones had a clean look. Brushing of stones gave the algal species listed below in Table 6.3. The algae society was dominated by different diatoms. *Cymbella tumida* is a cosmopolitan species and grows normally epiphytic, it is common in the tropics and is regarded as alkali-troph. The species is found in mesotrophic to eutrophic waters. The genus *Nitzschia* is most common in water bodies with high content of nutrients, while the species *Fragilaria ulna* is found in all kinds of water qualities. The blue green algae *Oscillatoria limosa,* which was present in the sample in small quantities, is common in nutrient rich waters. It was also observed some small filaments of the green algae genus *Oedogonium* and *Spirogyra*. Decomposers were not observed, which indicate that the river is not impacted by human organic wastes.

Table 6.3 Periphyton ("attached growth") on stones in Rio Masipedro at el Balneario.

<u>Cyanophyceae:</u>	
Merismopedia revoluta	x
Phormidium sp. 7,5µ	x
Oscillatoria limosa	x
<u>Chlorophyceae:</u>	
Oedogonium sp. 12µ	x
Spirogyra sp. 36µ	x
<u>Bacillariophyceae(diatoms):</u>	
Fragilaria ulna	xx
Fragilaria spp.	xx
Cymbella tumida	xx
Cymbella spp.	xx
Nitzschia spp.	xx
Cymatopleura sp.	x
Surirella linearis var. *constricta*	xx
Amphipleura sp.	x
Denticula sp.	x
Gomphonema truncatum	x
Navicula spp.	x
Melosira lineata	x
Unidentified diatoms	xx

6.2.4 Station 4: Rio Jima at the planned tailrace entrance

There was not any visible periphyton ("attached growth") at this station. The stones in the riverbed seemed clean-scoured by the current. However, brushing of stones revealed the presence of the periphyton species listed in Table 6.4. The species composition here was very much the same as at the previous station. However, there was not found any green algae here. Neither was it observed decomposers (bacteria, fungi,).

Table 6.4 The species composition of the periphyton society at station 4; Rio Jima at the entrance site of the planned tailrace canal from the hydropower plant.

<u>Cyanophyceae (blue-green algae):</u>	
Cyanothece sp.	x
Oscillatoria limosa	x
Phormidium sp. 7,5µ	x
<u>Bacillariophyceae (diatoms):</u>	
Fragilaria ulna	xx

Fragilaria spp.	x
Cocconeis placentula	xx
Cymbella tumida	x
Surirella linearis var. *constricta*	x
Nitzschia spp.	x
Gomphonema truncatum	x
Melosira lineata	x
Amphipleura sp.	x
Denticula sp.	x
Gyrosigma sp.	x
Unidentified diatoms	xx

6.2.5 Station 5: Rio Jima at the inlet to Rincon Reservoir

The stones on the river bottom at this station were covered by a layer of inorganic silt due to periodically high sediment load. The periphyton society was sparsely developed, and was composed of species that thrives in waters rich in electrolytes. The sediment cover of the surface of the bottom structures, stones, etc., gives problems for several of the algal species, as well as it makes the species identification more difficult. The composition seems, however, to indicate more nutrient rich conditions here than at the previous stations, see Table 6.5. It was not found decomposers in the sample, which indicate that organic human waste is not a problem.

Table 6.5 Periphyton at station 5; Rio Jima at the entrance to Rincon Reservoir.

Cyanophycea (blue-green algae):	
Phormidium sp. 7,5µ	x
Chlorophyceae (green algae):	
Cosmarium sp.	x
Penium sp.	x
Bacillariophyceae (diatoms):	
Cocconeis placentula	x
Cymbella tumida	x
Cymbella spp.	x
Fragilaria ulna	x
Fragilaria spp.	x
Navicula spp.	xx
Gyrosigma sp.	x
Nitzschia tryblionella	x
Nitzschia spp.	x
Amphora sp.	x
Melosira lineata	x
Unidentified diatoms	xx

6.2.6 Station 6. Rio Yuna downstream of Rio Yabua entrance (discharges from Bonao City) Oct. 2002

The sample contained much inorganic mud, due to high sediment load in the river at this site. Thus it was not possible to get a visible impression of the periphyton growth in the field. The brushing of stones gave the species listed in Table 6.6.

Table 6.6 Periphyton at station 6; Rio Yuna downstream of Rio Yabua entrance (discharges from Bonao City, Oct. 2002)

Cyanophyceae (blue-green algae):	
Phormidium sp. 7,5µ	x
Unidentified filamentous blue-greens	x
Bacillariophyceae (diatoms)	
Cymbella minuta	x
Cymbella sinuata	x
Cymbella tumida	x
Fragilaria ulna	x
Fragilaria spp.	x
Cocconeis placentula	x
Melosira lineata	x
Nitzschia spp.	x
Navicula spp.	x
Gyrosigma sp.	x
Gomphonema spp.	x
Amphora sp.	x
Unidentified diatoms	x

The periphyton was dominated by species that thrives in waters rich in electrolytes. The species composition did also indicate a somewhat more nutrient rich river than at the other stations. However, it was not observed decomposers (bacteria, fungi, etc.) to any extent that indicated that the river was loaded by organic waste effluents to give pollution problems.

6.2.7 Rio Yuna downstream of Bonao City 13.03.03

The periphyton consisted of two main elements. All the stones were covered by a loose, hairy (2 cm long) layer with grey-yellow-green appearance. The element had a cover of about 90% of the stony bottom. This element showed to be consisted of diatoms, of which *Fragilaria ulna* and *Cymbella spp.* were dominating.

Here and there were clots of filamentous dark green algae. This element had a cover of about 5% of the river bottom, and it showed to be consisted of the green algae *Cladophora glomerata.*

On this sampling station it was much more periphyton in this low flow season than in the wet season in October. The periphyton was totally dominated of only two species. This indicates clearly that the river is impacted by nutrient inputs from Bonao City.

Table 6.7 Periphyton at station 6; Rio Yuna downstream of Rio Yabua entrance in March 2003

Cyanophyceae	
Merismopedia tenuissima	*x*
Chlorophyceae	
Cladophora *cf.* glomerata	*1%*
Scenedesmus *spp.*	*x*
Cosmarium spp.	x
Closterium sp.	x
Spirogyra *sp. 36µ*	*x*
Bacillariophyceae	
Fragilaria ulna	*xxx*
Cocconeis placentula	x

Cymbella spp.	xx
Gyrosigma sp.	
Un-identified diatoms	xx

6.2.8 Station 7: Rio Yuna downstream the outlet of the Falconbridge canal.

The river was heavily loaded with suspended sediments and it was impossible to do a visually based evaluation of the periphyton growth at the station. The brush of stones gave the species listed in Table 6.8. The periphyton society was dominated by species that thrives in water rich in electrolytes and rich in nutrients. It was not observed decomposers in the samples, which means that discharges of organic wastes does not influence the river to any extent that gives pollution problems.

Table 6.8 Periphyton species at station 7; Rio Yuna downstream of the outlet of the Falconbridge canal.

<u>Chlorophyceae (green algae):</u>	
Cladophora cf. *glomerata*	x
Cosmarium spp.	x
Oedogonium sp. 39µ	x
Scenedesmus sp.	x
<u>Bacillariophyceae (diatoms):</u>	
Fragilaria ulna	xx
Fragilaria spp.	x
Cocconeis placentula	x
Melosira lineata	x
Achnanthes cf. *minutissima*	x
Achnanthes sp.	x
Cymbella tumida	x
Navicula spp.	x
Nitzschia spp.	x
Pinnularia sp.	x
Gyrosigma sp.	x
Unidentified diatoms	xx

6.2.9 Overview of the periphyton growth on all stations.

Table 6.9 gives an overview of the composition and relative abundance at the different stations. The abundance is given after a tripartite scale where

x = present (but in low numbers)
xx = common (medium numbers)
xxx = dense growth (large numbers)

It is seen that all the three rivers had low concentrations of periphyton. There was observed no dense growth at any of the 7 station studied in the rainy season. This season is characterised by frequent floods, which scour away any large build up of periphyton material. In the dry season the current is more gently, and normally, any problems with intensive periphyton growth is then more easily seen. During the inventory in March 2003, more dense periphyton growth were found at all stations, but not to an extent that indicated ecological problems. Particularly downstream of Bonao it was observed increased periphyton growth.

Table 6.9 Overview of the periphyton species composition at the different stations.

x = present (but in low numbers)
xx = common (medium numbers)
xxx = dense growth (large numbers)

station	st.1	st.2	st.3	st.4	st.5	st.6	st.7	St.7
Organism	Oct. 02	Oct.02	Oct. 02	Oct. 02	Oct. 02	Oct. 02	Oct. 02	March 03
***Cyanophyceae*, Blue-green algae**								
Cyanothece sp.				x				
Merismopedia revoluta			x					x
Oscillatoria limosa			x	x				
Phormidium sp. (7,5µ)		x	x	x	x	x		
Uid. cyacocc.	x							
Uid. cyatri.		x				x		
***Chlorophyceae*, Green algae**								
Cladophora cf. glomerata	1 %	1 %					x	xx
Cosmarium sp.					x		x	x
Oedogonium sp. 12µ			x					
Oedogonium sp. 39µ							x	
Penium sp.	x				x			
Scenedesmus sp.							x	x
Spirogyra sp. 36µ			x					xx
***Bacillariophyceae*, Diatoms**								
Achnanthes cf. minutissima	xx						x	
Amphipleura sp.			x	x				
Amphora sp.					x	x		
Cocconeis placentula	xx	x	xx	xx	x	x	x	x
Cymatopleura sp.			x					
Cymbella minuta						x		
Cymbella sinuata						x		
Cymbella tumida	x	x	xx	x	x	x	x	
Cymbella spp.	x	x			x			
Denticula sp.	x	x	x	x				
Fragilaria ulna	x	x	x	xx	x	x	xx	xxx
Fragilaria spp.	x	x	xx	x	x	x	x	
Gomphonema truncatum	x		x	x				
Gomphonema spp.	xx	x				x	x	
Gyrosigma sp.		x		x	x	x	x	x
Melosira lineata	x	x	x	x	x	x	x	
Navicula spp.		x	x		xx	x	x	
Nitzschia cf. tryblionella					x			
Nitzschia spp.			xx	x	x	x	x	
Pinnularia sp.							x	
Surirella linearis var. constricta			xx	x				
Un-identified diatoms	xx	xx	xx	xx	xx	xx	xx	xxx

6.3 *Phytoplankton*

6.3.1 Phytoplankton in the reservoirs Hatillo and Rincon

Phytoplankton was sampled from the reservoirs Hatillo and Rincon both in October 2002 and in March 2003. The results are given in Figure 6.2.

Lake Rincon has an algal biomass which places the lake in the mesotrophic level with respect to productivity. Lake Hatillo had an algal amount of the eutrophic level in March 2003 whereas the amount in October 2002 was in the oligotrophic level. In both lakes Diatoms and Clorophycea dominated, which often is the case in mesotrophic lakes. Chryssophyceae and Cryptophyceae, which is characteristic for oligotrophic lakes, did not show any significant amounts in any of the lakes. In Lake Rincon there were present a small biomass of blue green algae in both the sampling periods. Both lakes can be regarded as mesotrophic, with Lake Rincon slightly more impacted by fertilisation effects from nutrient inputs than Lake Hatillo.

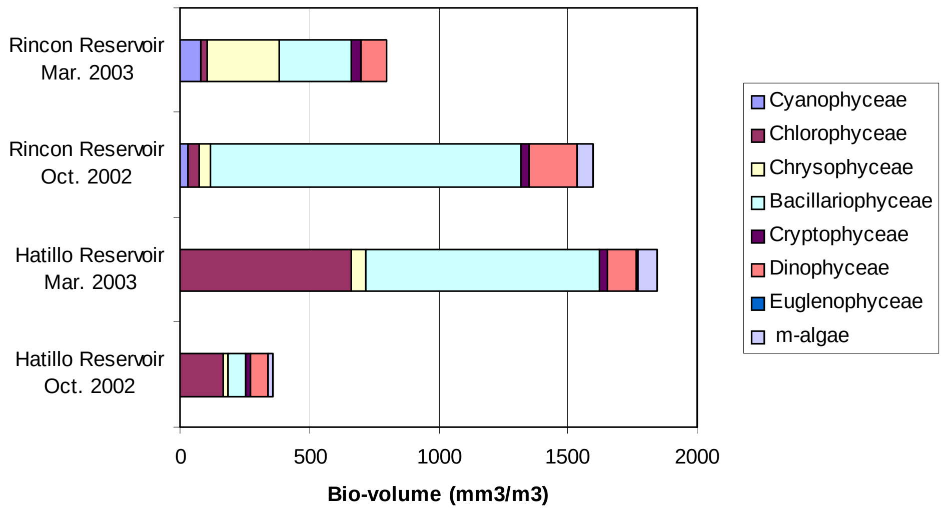

Figure 6.2 Phytoplankton biomass, split into main groups, in the reservoirs Lago de Hatillo and Lago de Rincon.

6.3.2 Phytoplankton in the rivers

Samples are taken from the stations upstream in the three river Rio Yuna, Rio Masipedro and Rio Jima. The results are given in Figure 6.3. The rivers are fast flowing with turbulent waters, which is not a good environment for phytoplankton production. Most of the species found in the free water masses were periphyton species that were loosened by the strong current. Bacillariophyceae (diatoms) were the dominant group.
All the rivers had low bio-volume of phytoplankton which indicates oligotrophic waters at these three upstream stations of R. Yuna, R. Masipedro, and R. Jima.

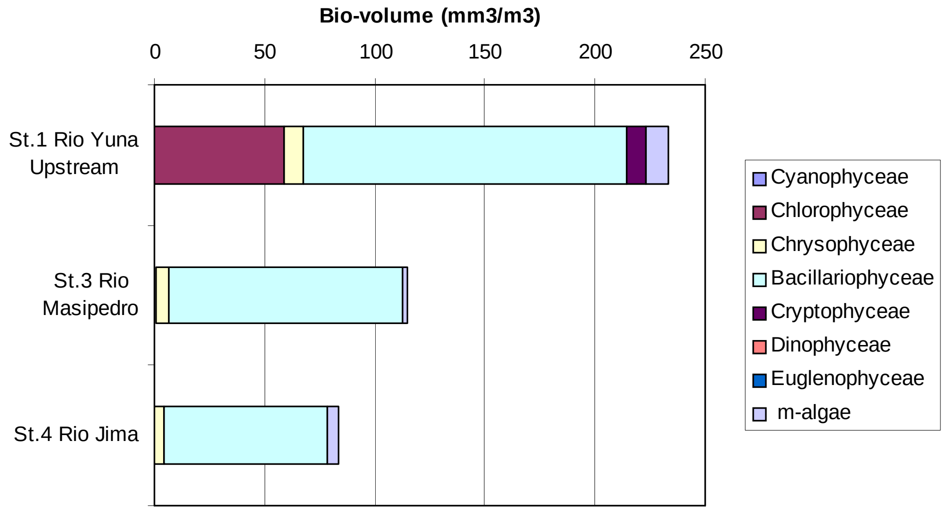

Figure 6.3 Phytoplankton biomass, split into main groups, at the different river stations.

6.4 Bottom fauna

Macro invertebrates at river sites.

Rio Yuna at Boca de Blanco (Sampling Station 1).
Macro invertebrates at station 1 were found in very low numbers in October 2002. The total sum was 18 ind./sample (Figure 6.5). Trichoptera was the most common taxa. The biodiversity, expressed as the number of families observed among Ephemeroptera and Trichoptera, was low. The number of families were 2. It was observed one family in each of these taxa: Leptohyphidae and Glossosomatidae, respectively. In March 2003 this situation had changed considerably. The total sum of individuals was the highest of the resampled sites as was the number of families of Ephemeroptera and Trichoptera. In addition to Glossosomatidae, which was by far the most common Trichopteran family at this site in March 2003, the only individual of the family Philopotamidae was observed at this site in March. Leptohyphidae was the most common Ephemeropteran family (Figure 6.4 and Figure 6.5).

Rio Yuna at the future damsite (St. 2).
Macro invertebrates at station 2 were also found in low numbers. The total sum was 148 ind./sample (Figure 6.5). Chironomidae was the most common taxa. The biodiversity, expressed as the number of families observed among Ephemeroptera and Trichoptera, was higher than at site 1. The number of families was 5. The most common families of the two taxa were Leptohyphidae and Hydroptilidae, respectively (Figure 6.4 and Figure 6.6). The endemic Decapoda species (Crustacea) *Epilobocera haytensis* was observed as one individual in the sample.

Rio Masiperdo (St. 3).
Macro invertebrates at station 3 were also found in moderately high numbers in October 2002. The total sum was 478 ind./sample (Figure 6.5). Ephemeroptera was the most common taxa. The biodiversity, expressed as the number of families observed among Ephemeroptera and Trichoptera, was approximately as observed at station 2. The number of families was 5. The most common families of the two taxa were Leptohyphidae and Glossosomatidae,

respectively. But for some minor changes, the composition of the macro invertebrate fauna in March 2003 was about the same as in October 2002 (Figure 6.4 and Figure 6.6).

Rio Jima at Caño Piedra (St. 4).
Macroinvertebrates at station 4 were also found in moderately high numbers in October 2002. The total sum was 488 ind./sample (Figure 6.5). Ephemeroptera was the most common taxa. The biodiversity, expressed as the number of families observed among Ephemeroptera and Trichoptera, was higher than at all the other stations. The number of families was 7. The most common families of the two taxa were Leptohyphidae and Glossosomatidae, respectively. But for some minor changes in composition and abundance, the macroinvertebrate fauna in March 2003 was about the same as in October 2002 (Figure 6.4 and Figure 6.6).

Rio Jima at Cañabon (St. 5).
Macroinvertebrates at station 5 were found in relatively high numbers. The total sum was 928 ind./sample (Figure 6.5). Simulidae was the most common taxa, however Ephmeroptera was also common. The biodiversity, expressed as the number of families observed among Ephemeroptera and Trichoptera, was lower than at station 4. The number of families was 4. The most common families of the two taxa were Leptohyphidae and Hydropsychidae, respectively (Figure 6.4 and Figure 6.6). The abundance of Hydropsychidae, however, was low.

Rio Yuna downstream of Bonao (St. 6).
Macroinvertebrates at station 6 were found in relatively high numbers. The total sum was 1213 ind./sample (Figure 6.5). Ephemeroptera was the most common taxa, however, Simulidae and Trichoptera were also frequently observed. The biodiversity, expressed as the number of families observed among Ephemeroptera and Trichoptera, was approximately as at site 5. The number of families was 4. The most common families of the two taxa were Leptohyphidae and Hydropsychidae, respectively (Figure 6.4 and Figure 6.6). The endemic Decapoda species (Crustacea) *Epilobocera haytensis* were observed in few numbers.

Rio Yuna downstream of Falconbridge (St. 7).
Macro invertebrates at station 7 were found in high numbers. The total sum was 3167 ind./sample (Figure 6.5). Ephemeroptera was the most common taxa, however, Simulidae, Chironomidae, Lepidoptera and Oligochaeta were also frequently observed. The biodiversity, expressed as the number of families observed among Ephemeroptera and Trichoptera, was as the second highest of all. The number of families was 7. The most common families of the two taxa were Leptohyphidae and Hydropsychidae, respectively (Figure 6.4 and Figure 6.6).

Rio Yuna downstream of Hatillo (st. 10).
Macroinvertebrates at station 10 were only sampled in March 2003, and was found in low numbers. The total sum was 64 ind./sample (Figure 6.5). This station was the only one without Ephemeropteran, included both October and March samples. The biodiversity, expressed as the number of families observed among Ephemeroptera and Trichoptera, was low being just one family (Hydropsychidae)(Figure 6.4 and Figure 6.6).

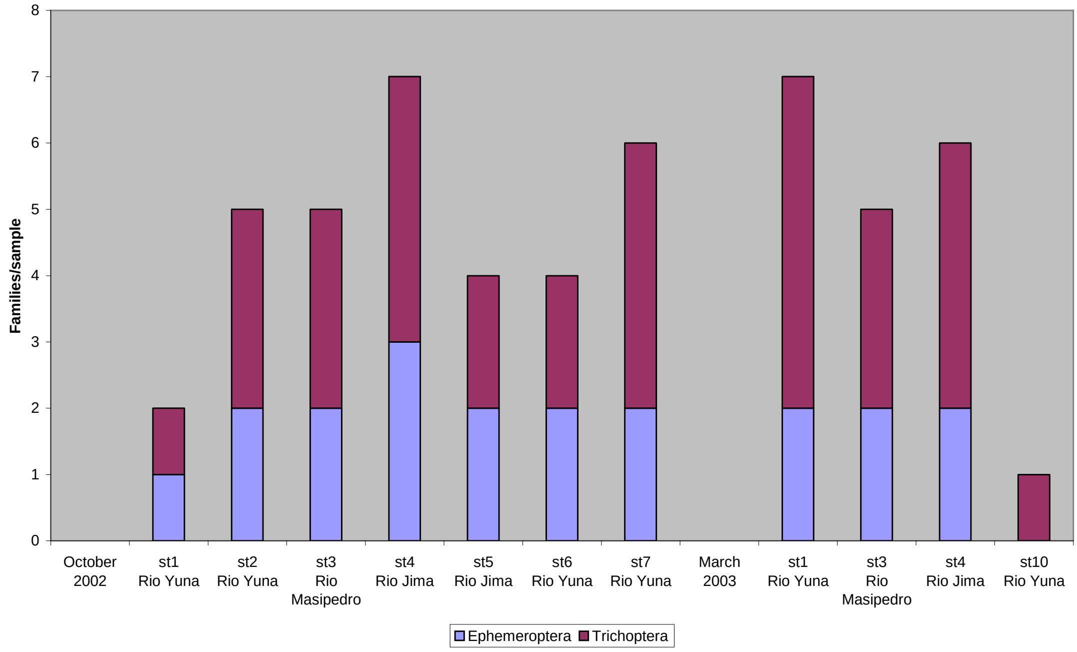

Figure 6.4 The number of families in each sample observed among Ephemeropetera and Trichoptera at river stations on the 09-10.10.2002.

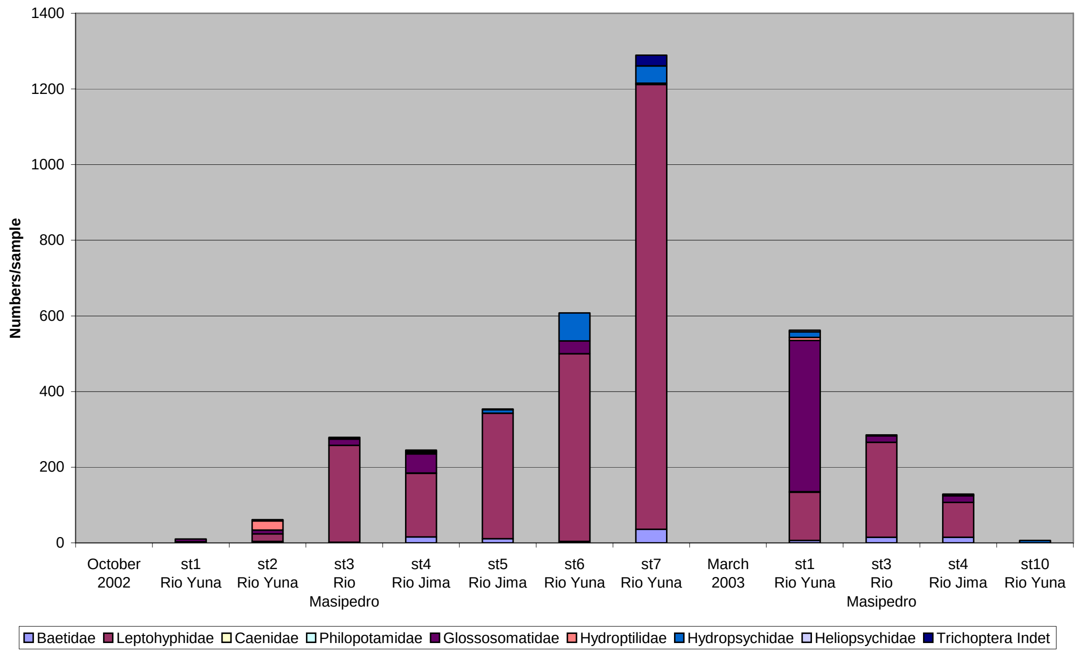

Figure 6.5 The number of individuals per sample for each family observed among Ephemeropetera and Trichoptera at the different river stations on the 09-10.10.2002.

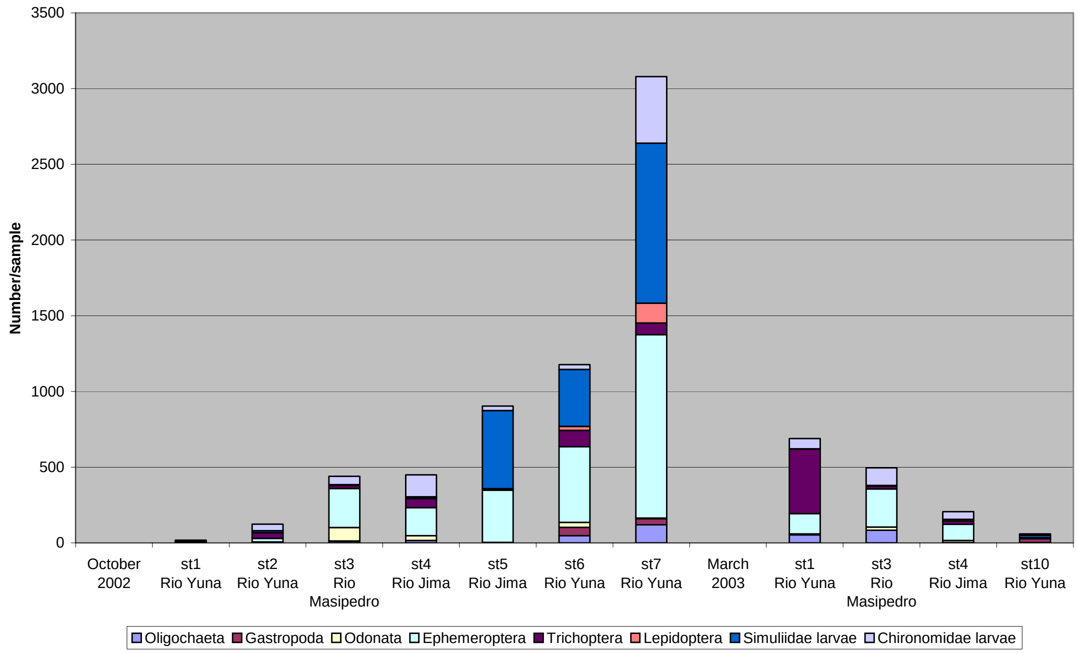

Figure 6.6 The number of individuals per sample observed for each main taxa at the river stations on the 09-10.10.2002.

7 FISH AND FISHERY STUDY

The freshwater fish fauna of Hispaniola is poor in number of species. In the fish and fishery study we found only the following species:

- Largemouth Bass (*Micropterus salmoides*) local name "trucha"
- Biajaca (*Ciclasoma haytensis*)
- Nile Tilapia (*Tilapia niloticus*)
- Mozambique Tilapia (*T. mossambica*),
- Common carp (*Cyprinus carpio*).
- Mirror carp (a race of *Cyprinus carpio*) (dead species drifting from Rio Blanco Reservoir)
- Titiles or Bahitas (Poecilids) *Poecilia elegans, Poecilia dominicensis, Poecilia hispaniolana*.
- The red swamp crayfish (*Procambarus clarkii*)
- Crabs (Jaiba de rio) (*Epilobocera haytensis*)

According to local people three other species existed before. These were migratory species that disappeared after the construction of Rincon and Hatillo dams (Anguila (eel), dajao(local name) and guabinas(local name)).

Before presenting the results from the study it is instructive to give a short description of the ecology of the different species. Mirror carp is a variant of the common carp raised in China, and are in fact the same species (*Cyprinius carpio*). A few dead individuals were found drifting from storm flow release from Rio Blanco reservoir. This species was not found in the project area, and is therefore not dealt further with in the report.

7.1 Ecology of the most important fish and fishery species

7.1.1 Largemouth Bass (Micropterus salmoides)

(Local name: Trucha)

This description is taken from standard textbooks from the US. No literature is found on the bass ecology in the Dominican Republic. However, as the above description applies for Florida, it is likely that it also applies for the Dominican Republic.

Largemouth bass is widespread over North and Central America. Originally it belonged to the Mississippi / Missouri river basin where it was mostly confined to slow flowing sections and adjoining oxbow lakes. Being good-tasting, and a popular game-fish, it has been introduced to ponds and lakes all over the continent. It thrives in lakes, reservoirs, and slow flowing rivers. It hunts by eye, and does not thrive in very turbid waters. Largemouth bass does not thrive in fast flowing rivers.

It is the primary predators in many lakes, ponds and quiet rivers, foraging on fish, crayfish, frogs, aquatic and terrestrial insects. It is also known to eat small mammals and birds which happen to fall in the water. The small sac fry of bass feed upon microscopic crustaceans.

First-food items are supplemented by insects and insect larvae as the fish grows. Largemouth bass usually start foraging on fish when they are 3-6 cm in length.

The maximum size of the bass is 10 kg (US-record). However, it is seldom to catch specimens over 3-4 kg. In Hatillo and Rincon it is normal to get specimens up to one kg, more seldom above. Figure 7.1 shows a picture of the large mouth bass.

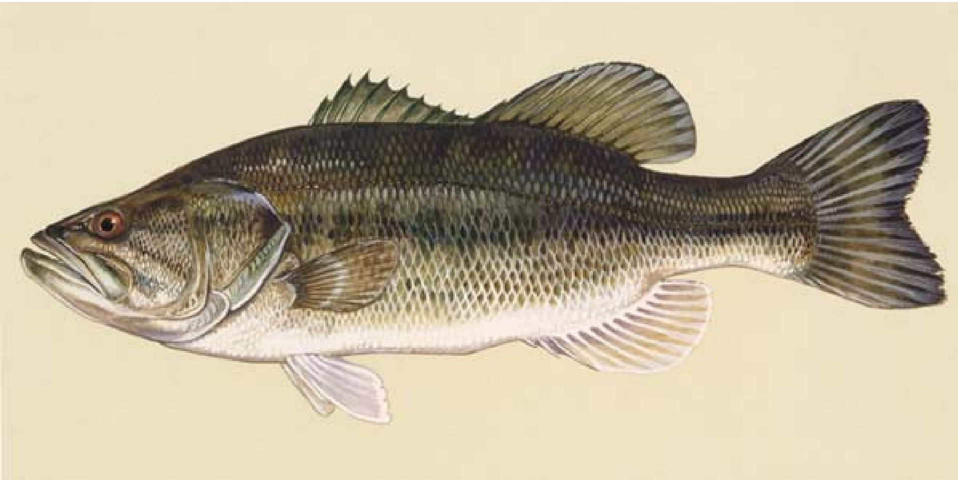

Figure 7.1 Large mouth bass (*Micropterus salmoides*), locally called "Trucha" in the Dominican Republic.

Reproduction characteristics of largemouth bass are quite similar to the other sunfishes. Spawning commences in early May and lasts into June. They deposit their eggs on the roots of submerged plants or grass over rocky or mud bottoms. Male largemouth bass usually construct a nest prior to spawning, by sweeping away debris with its head and tail. However, sometimes they will spawn with very little nest preparation. Water depth over nests ranges from 0,3 m to 4 m, but normally the nest lies between 0,5 and 1 m depth.

The eggs, which may vary from 2000 to 25000 in each nest, hatch in 3-6 days depending upon the water temperature. The male will guard the eggs and fry for about a month. Largemouth bass reach 10-15 cm during the first year of life, but if food is abundant it may reach as much as 25 cm the first year. Both sexes reach sexual maturity in the third year of life.

Both in Rincon and Hatillo there are plenty food for the bass through large population of tilapias and poecilides. Imposing a new water level fluctuation scheme may however, create constraints to the spawning conditions. Successful spawning seems to be depending upon the possibility to spawn in the root zone of aquatic plant (Gregory and Schram 1990). In their study, no nests were found in vegetation free zones. The regulation zone in reservoirs is often denuded for aquatic macrophytes due to periodic dry-out, and shoreline erosion. Keith (1975) has shown that a significant rise in water levels, timed to occur just before, during and for a short time after the bass spawning season, resulted in high spawning success, and high survival of young fishes.

7.1.2 Tilapia

There are two types of tilapia present in the reservoirs and the lower reaches of the rivers. These two are Nile Tilapia (*Tilapia niloticus*) and Mozambique Tilapia (*T. mossambica*), see Figure 7.2. The species are also known under the genus name *Oreochromis*.

Figure 7.2 *Tilapia mossambica* (left panel) and *T. niloticus* (right panel)

Both species are native to Africa, where they are found all over the continent. They are appreciated by fishermen, but are particularly popular in pond aqua-culture, both for single household and in larger scale. Having no intra-muscular bones they give easily bone-free filets. This combined with a tasty meat and easy to cultivate is the reason for the popularity. For cultivation purposes the species have been spread around most of the tropical and subtropical world. *T. niloticus* is the northernmost native tilapia, and this can also survive in the southernmost temperate zone.

These tilapias are introduced to the Dominican Republic and are found in most watercourses in the lowland. They thrive in ponds, lakes and reservoirs, but also in rivers. In the most fast flowing reaches, however, they do not thrive. Its weight can be more than one kilo, but typically catch in Rincon and Hatillo contained sizes from 100-300 grams. In the rivers, Rio Jima and Lower Yuna, the typical size was between 100-200 grams.

The reproduction potential is enormous. They spawn around the year almost in a continuous manner. The males define and defend territories on the bottom, and form a nest by cleaning a circular area 20 to 30 cm wide. In areas with soft bottoms the nest is excavated 5-8 cm deep by digging with the mouth and brushing with the fins. The female is attracted to the nest where she is courted by the male. The female lays her eggs in the nest after they are fertilised by the male. The female picks up the fertilised eggs in her mouth and leaves the nest. The male continues to guard the nest and attracts other females for mating. Courtship and spawning require less than one day. Eggs are incubated for 3-5 days in the female's mouth before they hatch. Young fry stay with their mother for an additional 5 to 7 days. They hide in her mouth when danger threatens. The female does not eat while incubating her eggs or caring for the new fry. The female will be ready to mate again about one week after she stops caring for the fry.

Tilapia is omnivorous, i.e. it can eat everything, from small crustaceans, insect larvae, but also vegetative diet like periphyton and softer parts of aquatic macrophytes.

The tilapia has more or less out-competed the endemic ciclid species biajaca *(Cichlasoma haytensis*) in the reservoirs and the lower reaches of the rivers.

7.1.3 Biajaca (Cichlasoma haytensis)

The biajaca is a Ciclid species endemic to Hispaniola island. It resembles the tilapia both in shape and size. It can be up to 500 grammes, but typical sizes in R.Yuna is from 100-250 grammes. It is a close relative of the tilapias. Like the tilapia it is a mouth brooder, which takes care of their offspring, but obviously it cannot compete well with the tilapia in standing waters and in gentle flowing rivers. In fast flowing rivers it seems to be better fit than the tilapia. In Rio Yuna at Boca de Blanco in a fisherman catch of about 25 fishes, all were biajacas, see Figure 7.3. The further down we got in Rio Yuna, the greater were the portion of tilapia in the catches.

Figure 7.3 Biajaca (*Ciclasoma haytensis*) caught in Rio Yuna just downstream of the confluence with Rio Blanco

The biajaca is the only fish from the ciclid group that is endemic to the Hispanola Island. It achieves a length of approximately 15-20 cm and prefers quiet and shallow waters in rivers and canals, where it lives single or in pairs, sometimes associated with dajaos, poecilids or tilapias. The males differ from the females by having longer dorsal and ventral fins, and when they grew older they form a fatty hump on the rear end of the head. For the spawning they prefer dark placed on muddy bottom covered with vegetation. They eat molluscs, snails, insect larvae, and they also eat soft shoots of vegetation as well as periphyton.

We have not found any detailed descriptions of the reproduction biology of the biajaca, but it is believed to be relatively similar to what is observed for tilapia, see this. Living in fast flowing rivers, it will not have great possibilities to dig nests in the boulder-consisting substrate. It is therefore believed that it finds suitable spawning areas among the stones and protects these during the mating.

7.1.4 Common carp (Cyprinius carpio)

This species has been introduced in both Lake Rincon and Lake Hatillo where it now constitutes viable populations in both lakes. It is an important commercial fish in the reservoirs. It does not form any populations in the rivers.

The common carp is introduced to the North American continent about 150 years ago, and it is spread over the whole continent. It is native to the Euro-Asian continent. In Europe it has been used in aqua-culture since year 1500. When it was introduced to the Hispaniola Island is not known.

The common carp can be large, with the adults weighing up to 20 kilo or more. In Lake Rincon and Lake Hatillo sizes from 1-5 kilo is typical. Body colour is grey to olive dorsally, golden yellow laterally, and yellowish-white ventrally, see Figure 7.4.

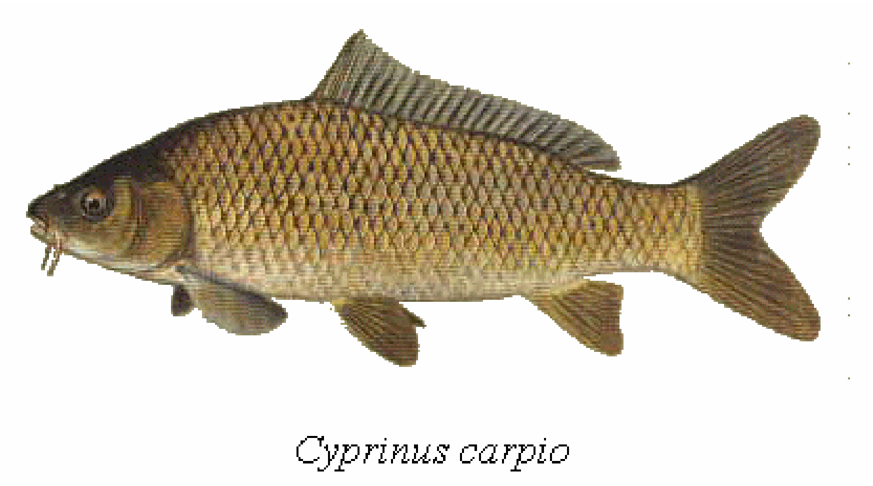

Figure 7.4 Text-book picture of the common carp (*Cyprinus carpio*).

Common carp prefer warm water, either standing or with sluggish flow. They are most abundant in large rivers and natural lakes with soft organic matter on the bottom. Common carp adapt better than most fish species to pollution caused by sewage or agricultural runoff. They are very tolerant of turbid waters.

It is an omnivorous feeder, taking both vegetable and animal matter in their diet. Aquatic insects, crustaceans, and small molluscs make up the bulk of their forage. They are particularly fond of tender roots and shoots of young aquatic plants and often “root-up” large quantities of vegetation in their food search. Thus, they are a nuisance in shallow, weedy habitat where their activity creates high turbidity in otherwise clear water.

Spawning occurs from mid-April through June when the adhesive eggs are scattered in the shallow water over vegetation, debris, logs or rocks. Splashing carps, with their backs out of the water may be seen in shallow waters during the spring. Females can spawn more than 500 000 eggs over a period of several days.

Carps are able to dominate over other fish species. This is both due to competition but also by its ability to change the habitat and make the water more turbid. Thus, after the introduction to the US, several native species were eradicated where the carp was introduced, for example the Eastern trout. For this reason it is now not legal to set out carp even in ponds in the US in areas where it is not present in receiving waters. Several eradication projects have been launched, but more or less all has failed. Now, in the US the trend is a recognition that the carp is “nationalised” and the attention is toward utilisation of the carp through commercial harvest and increased awareness of sport and food potential of the species.

7.1.5 Titiles or Bahitas (Poecilids)

This family is represented by about 300 species of freshwater and brackish water fish found from eastern United States to South America and in Africa. These fishes are normally small from 3-10 cm, and many are used as aquarium fishes (guippy, molly, Swardtail, among others). The poecilidae family is widely distributed in the Caribbean. In the rivers included in this study, there were found three species, *Poecilia elegans, Poecilia dominicensis, Poecilia hispaniolana*.

The poecilids are small fishes (3-10 cm) living in shallow waters of all kind of waterbodies, ponds, lakes and rivers, see Figure 7.5.

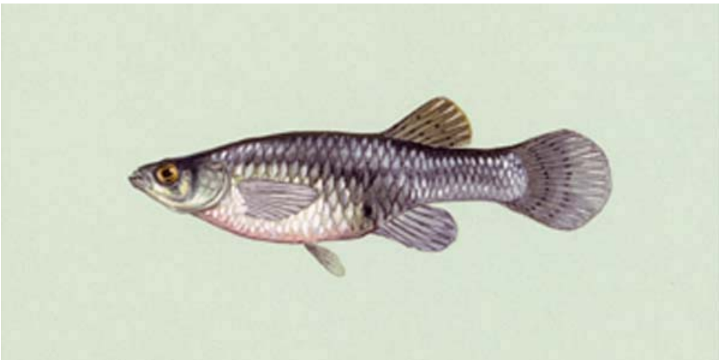

Figure 7.5 Representative for the fish family Poecilidae, of which we found three species in the water bodies included in this study.

There are several species of the family Poecilida in Republica Dominicana, for the major part belonging to the genus Poecilia and Limia. These species are called “titiles” in the northern region of the island, and “bahitas” in the southern part. The name “titile” derives from the indian word “titiri”. The titiles are live-bearing, that is the females give birth to living fry. The males differ from the females by having the “gonopodio” or sexual organ formed by the first spine of the anal fin. They are distributed from the mountainous- to the coastal regions. They can tolerate many environmental conditions like for example brackish waters. The Biajaca and the titiles tell part of the geological history of Hispaniola, in that their presence shows that the country has been connected to Yucatan and the Central America.

The genus Poecilia comprises about 25 species. The genus is represented in the South East US and in Central America, Hispaniola, and the Atlantic coast of South America down to Rio de la Plata. *Poecilia dominicensis* has many similarities to *P. hispaniola* with respect to distribution and ecology. Both species are most common in rivers and streams in the interior and in elevated areas of the island. *P.hispaniola* is able to live in higher mountain streams than *P. dominicensis*. This last species prefers quiet waters with substrate of sand and mud. The size of the two species is similar. The males can be up to 27 mm long whereas the female can be up to 52 mm. In average the males have about half the size as the females.

Their main diet is insects, insect larvae and small crustaceans. In standing waters they can be seen patrolling the shoreline and capture stinging mosquitoes hanging in the surface, which is one of their favourite diets. For this reason they have been thought to have a large potential to reduce the mosquito plague, and in particular to control malaria. One of the Poecilid species, *Gambusia affinis,* is called “mosquito fish” and has been introduced over most tropical America with the aim of reducing the mosquito plague. However, the introduction of this species has in many cases destroyed the population of endemic poecilids and has not shown to give any better control of mosquito populations than the native fish species.

Most members of the poecilidae family produce live young throughout the summer months and thus are quite prolific (live-bearing). Males are smaller than the females (1.5-2") and have a specialized anal fin known as a gonopodium. Females are larger (up to 2.5") and have a small, rounded anal fin.

The poecilids found in this study, could most typically be seen patrolling the shoreline area in quiet reaches. But they were also found in fast flowing areas where they were hiding behind stones. In the studied rivers there are no carnivorous fish, so it is not likely that the poecilids, to a significant extent, serve as food for other species of the river ecosystem. In the lakes however (Hatillo and Rincon), they are most likely a food item for the largemouth bass. For the humans they are important in reducing the number of mosquito larvae.

7.1.6 The Red Swamp Crayfish (*Procambarus clarkii*)

The *Procambarus clarkii* is a crayfish native to the southern states of the United States, see Figure 7.6. They were introduced in Europe at the end of the 19th century, and with-it came the crayfish plague, a disease that has killed most of the original European crayfish (*Astacus astacus*). It has been introduced to the Dominican Republic by accident following rice plants in pots with water-containing soils.

The size of the animal is typical 10 cm from the nose to the tail.

Figure 7.6 The red swamp crayfish (*Procambarus clarkii*)

The red swamp crayfish is carnivorous eating insect larvae, tadpoles, and snails. When traditional food is scarce, the crayfish eat the remains of dead animals, fish and worms.

The red swamp crayfish mates in late autumn. Sexes are separate, but the location of gonads are similar in both males and females -just anterior to the heart. Testes are usually white, while ovaries are usually orange. The sperm cells (crayfish sperm lack tails and are sometimes referred to as spermatophores) are released from the body of the male crayfish through a pore at the base of the fifth pair of walking legs. Fertilization is internal. Sperm enters the female at the base of the third pair of walking legs, where the eggs are fertilized and released. The female crayfish then lies on her back and curls her abdomen forward. By beating her pleopods, or swimmerets, the female creates a water current, which drives the fertilized eggs into the swimmerets where they will remain for approximately 6 weeks. By spring, the eggs will become larvae, and remain on the mother until sexually mature. The red swamp crayfish reaches maturity in as little as three months, and in warm climates can reproduce two generations per year. Large healthy females typically produce over 600 viable young (Barnes 1974; Vodopich and Moore 1999; Safra, et al 1999).

As the common name implies, red swamp crayfish are found mainly in swamps, sloughs, and ditches. In this study it was found mainly in the lower reaches of Rio Masipedro. This species avoids streams and areas with strong current. During periods of drought or cold, the red swamp crayfish burrows itself for survival (McDonald 1996).

Because of the success of commercial aquaculture in its native southern USA, the red swamp crayfish has been introduced to many other areas. Most of these introductions have had negative consequences. Many of these areas have sophisticated irrigation systems in which the crayfish have burrowed. The burrowing activity has damaged the levees, dams, and water control structures. In addition, *Procambarus clarkii* is an intermediate host for many parasitic helminths of vertebrates, which may create new health problems in areas where the species is successfully established. Because of such adverse effects, many areas introduced to the red swamp crayfish are now trying to eradicate them (Jarmon 1999).

We observed a few fishermen catching crayfish in Rio Masipedro with the aim of selling them in Bonao. The crayfish was not very popular for leisure fishing, as for example was the fishing after river crabs (jaiba de rio).

7.1.7 Jaiba de rio (*Epilobocera haytensis*)

This species belong to the *Pseudothelphusidae* family. The crab-species of the genus *Epilobocera* have a great scientific value through being endemic to the Large Antillas. It is probably the most primitive genus of the Pseudothelphusidae family of the Antilles.

The species *E. haytensis* is the only freshwater decapoda endemic to Hispaniola. It is widespread in more or less all the river basins in Republica Dominicana. The crab is able to complete its total life cycle in freshwater, and does not need to migrate to the sea to reproduce as do most other crabs.

The picture in Figure 7.7 is of its relative *Epilobocera sinuatifrons,* the river crab from Puorto Rico. There is however differences between their ecology. While *E. sinuatifrons* can walk out of the water and do hunting also in terrestrial shoreline areas during night time, Jaiba de rio (*E. haytensis*) lives in the water all the time.

Figure 7.7 ***Epilobocera sinuatifrons*** **from Puerto Rico. A close relative to jaiba de rio.**

The crabs construct homes underneath stones or tree-trunks in the riverbed, or dig holes in the river bank. Here they stay in day time. They are active hunting during night time. They eat mainly bottom dwelling animals, like insect larvae, worms, molluscs, and other not too fast moving water dwellers. Living fish is normally to fast swimmers for the crabs to be able to catch. The crabs eat however, dead fish.

The copulation takes place in the morning or late evening and last for 20-35 minutes. The fertilisation is internal. The female places the fertilised eggs underneath her abdomen. Here the eggs develop and hatch. This crab species has eliminated the larval stages in the development, and when the eggs hatch the small crabs that come out is very similar to adult crabs. The small crabs are then released to manage life on their own. Most of this period, when carrying offspring, the female is inactive sitting in her "home" and makes only very small tours outside. This period of reproduction is mainly from March to mid of May.

7.2 Fish study October 2003

7.2.1 Rio Yuna Boca de Blanco – planned Damsite

The study was performed Friday October 11 2002.
Information was obtained by interviewing fishermen, and in addition there was carried out supplementary catch of small fish species by use of electro fishing device. Interview of a group of fishermen practising throw-net fishing in Alto Yuna between Aroya Vispa and Rio Blanco, gave the following information:

1. Number of fishermen: 5
2. Fish species caught: 2 species of fish and one species of crab
3. Duration of the fishing: 2 hours
4. Frequency of fishing: 2 times a month
5. Yield of 2 hours of fishing: 20 crabs and 15-20 fishes
6. Method of fishing: throw-net

Additional information:

The interviewed fishermen informed that the dam of Rio Blanco was opened the day before (storm flow release due to heavy rain), and because of that they have found some dead Chinese carps that were killed because of the pressure in the released water. These carps were not scientifically identified, but they looked like “Mirror carp” which is a variant of Common carp (*Cyprinuis carpio*). Generally this group of five fishermen went fishing together with other fishermen (approximately eight) during the weekends. The catch normally includes individuals of the fish "Biajaca" (*Cichlasoma haytensis*) and crabs "Jaibas".

Figure 7.8 Upper panel: Dead specimen of Chinese carps (mirror carps) coming from storm flow release from the Rio Blanco reservoir. Lower panel: One specimen of biajaca and a freshwater crab caught by the fishermen group.

Interview with mr Chicho, a local inhabitant that has been living here all his life gave the additional information:
The dam in Rio Blanco was created in the late 1980's. The dam did only last for 5-6 years before it was filled in with sediments. After the dam was full with sediments, the transport of sediments to Rio Yuna from Rio Blanco increased considerably. The reduction in flow in Yuna during the filling of Rio Blanco dam considerably reduced the number of fishes and crabs in Rio Yuna.

In earlier years in this stretch of Yuna River, as in Rio Jima, it was found eels (*Anguila sp*.), and fishes like Dejaos and Guabinas. Due to effects from the construction of the dams Hatillo and Rio Blanco Dam these species have disappeared from R.Yuna. The same happened in R. Jima due to the construction of Rincon dam.

Electro fishing
20 min of electro fishing gave some 30 small fishes (Poecilids) that were brought to Santa Domingo for identification. It was also caught one big specimen of the freshwater crab (*Epilobocera haytensis)*.

7.2.2 Rio Masipedro (14/10-02)

Interview with local fishermen in lower Masipedro
In lower Masipedro River there are now a considerable population of an American crayfish (*Procambarus clarkii)* species which was introduced by accident (likely transferred together with new rice species). This species has now more or less out competed a native species of shrimps from the river. A fisherman we met on the road had got some 90-100 specimens which he was going to sell in Bonao.

Interview of fishermen at the Balneario zone (Bathing place where the Masipedro canal starts)
In the area of the bathing place (Balneario) there were only a few of this crayfish species. There was not much fish here of edible size. Only some Biajaca (*Cichlasoma haytensis*) and crabs (Jaiba de rio). The crab was the most important species that people used. Around the balneario the crab population was overexploited, but further up in the river, there was a good abundance of crabs. The fishing was for leisure. Commonly groups of 3-6 personas went fishing. The catch was often boiled or fried in the field, or brought back to their home to be processed there. It is not common that people sell fish form Masipedro River. Only sometimes they sell crabs and crayfish.

Electro fishing
20 minutes of elecrofishing gave about 50 small fishes (Poecilids of 3-6cm), and one crab. It was very many small fishes here. The riverbed had stones of many sizes resulting in a great variety of habitats. The rich riparian tree vegetation gives both shadow and food (falling leaves etc) to the river inhabitants. The small fishes were brought to experts in Santa Domingo for identification.

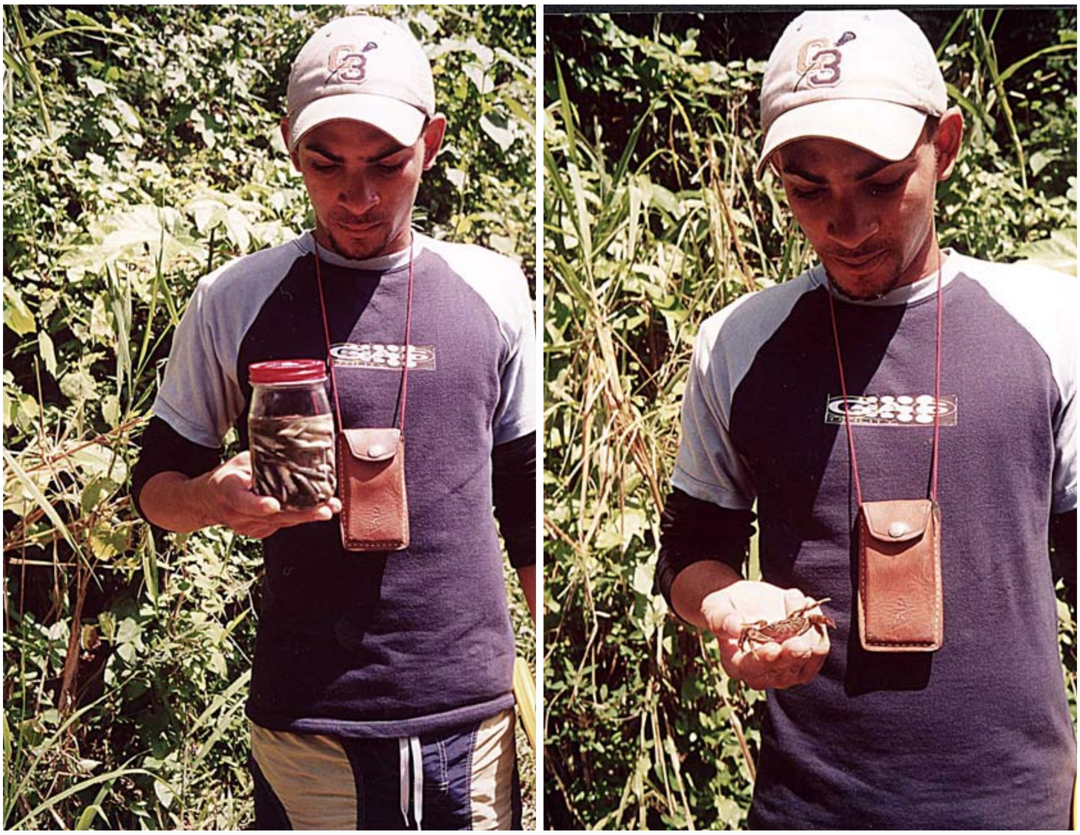

Figure 7.9 Small fish (*Poecilids*) and crab (*Epilobocera haytensis*) caught in the electro fishing in Rio Masipedro just upstream the starting point of Masipedro Canal.

7.2.3 Rio Jima at the planned outlet of the tailrace canal (14/10-02) Caño Piedra.

Interviewing a group of boys that were fishing with rod and earth worms as bate. They had caught about 15 fishes of the size 10-20 cm. Most of them were of the species Biajaca (*Cichlasoma haytensis*), but they had also caught 2 Tilapias. They belong to the two species (*T. nilotica and T. mosambiqua*). The Tilapias comes up from Rincon were they were introduced after the construction of the dam. The specimen of fish they could get in this part of the river seldom became greater than 200 grams.

Fishing was for leisure and private consumption. The catch was brought home for processing, or fried at the shore and eaten there.

The most important fishery here was the crab catch. The population of crabs was good, and a group of fishermen (3-5 persons) got about 10-20 per fishing tour (2-3 hrs). It was only a few times a month (2-3) that the local inhabitants had fish from the river for lunch or dinner.

Electro fishing
The performance of the electro fishing was more difficult here than in Masipedro due to stronger current. Within 20 min of electro fishing we caught 2 biajacas and approximately 30 small fishes Poecilids), and a crab. The small fishes were conserved in formalin and brought to Santa Domingo for identification.

7.2.4 Rio Jima at the entrance into Rincon Reservoir (14/10-02)

The water level of the reservoir was approximately 1,5 m higher than before the weekend. This is partly due to heavy rain and less discharge from Rincon. The river mouth of Rio Jima was flooded. In such periods, fishes from Rincon migrate into the river mouth area, which creates good conditions for fishing. 10 groups of fishermen were fishing in the river mouth area at the day of test-fishing. 3 groups used throw-net form land, 6 groups used boat and traditional nets, and 1 group used rod (partly with earthworm-bate and partly with artificial lures). All groups did good catches (estimated to 2-15 kg in 2-4 hrs of fishing depending on the method). Figure 7.10 shows a catch from 2 hours fishing with throw-net operated from land, mostly tilapias.

Figure 7.10 Catch during two hours fishing with throw-net in the river mouth area where Rio Jima enters Rincon reservoir. The dark fish is Mozambique-tilapia and the light coloured is Nile-tilapia.

Most of the fish was sold to buyers coming from Bonao, but also a significant part was used for food in the village of Cañabon close to the river mouth. A more thorough interview with one of the fishermen revealed that most families in this area had fish in their daily diet, or at least had fish several times a week.

The fish species they caught here were first of all *Tilapia nilotica* and *T. mosambiqua*, but also a good catch of biajaca. In Rincon there were also Common carp (*Cyprinius carpio*) and largemouth bass (*Micrpoterus salmoides*, locally called trucha). The carp could attain large sizes, more than 5 kg. These two last species were more frequently caught further out in the reservoir.

Electro fishing

Electro fishing did not work well in this station, most likely due to too high conductivity in the water. "The fish ran away instead of being paralysed".

7.2.5 Interview with fish-sellers along the Auto pista along Rincon

The sellers had bought the fish in Sabana del Puerto a village on the other side of Rincon reservoir. They sell mainly three types of fish, tilapias, truchas and carps. In addition they sold crabs.

Figure 7.11 Fish selling stand along Auto Pista Duarte, alongside Rincon Reservoir.

7.2.6 Rio Yuna downstream of Bonao (16/10-02)

The river stretch that was visited was 500 m upstream of the bridge to Falconbridge and 100 m downstream of the bridge.

4 groups of fishermen were seen. Most commonly used equipment here was fishing with rod with 3-4 hooks on one line, bated with earth worms. The catches were good.

A father and his son had got 5 kg fish within 3-4 hrs. Also women took part in the fishing here. One of the fishing groups consisted mainly of women with their children. Fishing was mostly practised for leisure. The fish was brought home and used as food. For poor families the fish was important part of the food. It was not common to sell fish here.

The species caught were biajaca, and tilapia (both *Tilapia nilotica*, and *T. mosambica*).

Electro fishing
Electro fishing was easy to perform here and gave several specimen both of biajaca, and the two species of Tilapias. In addition it was caught about 35 small fishes. The small fishes (Poecilids) were brought to experts in Santa Domingo for identification. It was also caught a couple of small crabs in the electro-fishing.

7.2.7 Fish and Fishery in Hatillo

In Lake Hatillo there are going on fishery activities very similar to what takes place in Lake Rincon. There are both commercial fishing for sale as well as fishing for leisure and for private consumption. The species are the same as in Rincon. I.e. the most important species are common carp, Nile-tilapia and Mozambique-tilapia, and largemouth bass. In addition, there are small catches of biajacas and also some crab fishing in the incoming rivers. In Hatillo most fishing is performed by boat.

The fish from the commercial fishing are delivered to buyers or directly to fish-selling stores in Maimon town or Cotui town.

I Hatillo there is also established an eco-tourism business, which is partly based on fishing in Lake Hatillo. In Maimon there is an active “Bass-club” with members from the surrounding area as well as from places like Santa Domingo and Bonao. They have a nice club-house at the lakeside. In Maimon the lake-tourists can stay in rented cabins. In Coutui there are also recently started with eco-tourism business based on fishing and boating in Lake Hatillo. Close to the dam there are a floating restaurant where one can buy tickets for boat trips on the lake, and rent boats for fishing.

8 ANTICIPATED IMPACTS ON WATER QUALITY AND AQUATIC LIFE DURING THE CONSTRUCTION PHASE

In this phase the water flow will be approximately as it was before. During the construction phase, the following pollutants will affect the water quality:

- Erosion due to road building,
- Erosion due to construction work in the dam area
- Erosion from the machine park area, construction workers living area, spoil rock deposit area
- Erosion from soil deposits
- Erosion from the timber clearance area
- Run off from crushed and ground rock material from the drilling, blasting and stone crushing plant (quarry)
- Sanitary effluents from the construction worker's camp
- Oil and chemical spills
- Leaching of ammonia and nitrogen from the tunnel blasting and spoil rock deposits
- Temporarily increase in the turbidity of Lake Rincon and Lake Hatillo
- Temperature effects is not expected

The affected water bodies will be Rio Yuna from Boca de Blanco and down to Bonao, Rio Masipedro downstream of the planned intake, and Rio Jima upstream of Rincon. The impacts will be most pronounced close to where the construction works take place.

8.1 Erosion products from natural soils

The flora and fauna of the Rio Yuna are adapted to large variations in concentration of particles. Whereas pure clear water type of rivers are very susceptible towards large inputs of erosion material from construction work, the Yuna type of river can tolerate considerable amounts. However, heavy rainfalls during the construction phase will give very high concentrations of suspended sediments in the river, and much higher than what is the case to day. This will undoubtedly disturb aquatic life through a number of impact mechanisms, as e.g. siltation of the bottom making problems for organisms that live in the sand and gravel (oxygen and water renewal problems), problems for periphyton and other organisms that live fixed to the bottom substrate like stones, etc. The submerged vegetation will get reduced light condition. Several of the human use categories will also face problems from this intensive erosion, like drinking water, washing cloths, bathing, fish-farming, fishing, eco-tourism, etc. Therefore, appropriate actions should be taken to try to reduce fierce erosion from recently denuded soil-areas, like roads and parking places, camp sites, etc.

8.2 Erosion products from blasting, drilling and stone crushing

The natural erosion products are coming from erosion in natural soils. This consists of particles that have been weathered for thousands of years. The particles have got rounded edges. The newly formed erosion particles from rock drilling, blasting and crushing have often sharp edges. Thus, in addition to the damage created by turbidity and sedimentation, these particles can make direct damage to gill tissue of fish and other aquatic organisms.

8.3 Leaching of ammonia and nitrogen from blasting and spoil rock deposits

Modern blasting techniques include use of ammonium-nitrate containing explosives. The spoil rock, particularly from tunnel blasting, can contain large amounts of ammonium and free ammonia. If spray-concrete is used in the same time for tunnel tightening, the high pH in the runoff may convert the ammonium into free ammonia, which is very toxic to fish and other river living animals. This can lead to significant damage in small rivers.

The use of full profile tunnel drilling is not creating this kind of free ammonia fauna kill.

8.4 Sanitary runoff from construction workers camp

Hydropower projects often gather several thousands workers which normally live in temporary camps near the river in barracks colonies. If the sanitary discharge enters the river, it may be a health problem for the people living downstream. Construction workers are often coming from other districts, and bringing in new waterborne diseases. Untreated sanitary effluents should not be discharged to the river.

8.5 Oil and chemical spills

Construction of hydropower plants, including dam, spillway, diversion tunnels, headrace tunnels, tailrace tunnels, as well as the underground powerhouse, include the use of a large number of machines of different kinds, like drilling- and boring machines, dumpers, tractors, trucks, shovel dozers, bulldozers, excavators, cars, etc. All these need repair and maintenance, which will include a fairly busy workshop, and machine parking area. This will imply the use of large amount of fuel, motor oil, lubrication oil, cooling liquids (glycols), battery acids and other chemicals.

Necessary actions should be taken to prevent oil and other chemicals to reach the river.

8.6 Impacts in the existing reservoirs Lake Rincon and Lake Hatillo

Both Lake Rincon and Lake Hatillo will receive more turbid waters during the construction period. This will have an effect on the phytoplankton, which will receive less light for the primary production. The pelagic bio-production will therefore be somewhat reduced during the construction period.

Of the fish species present in the reservoirs it is only the large mouth bass (trucha) that will be impacted negatively during the construction period. This fish is depending on the eyes to see the prey. It is therefore expected reduced year-classes of trucha, particularly in Lake Rincon, the first years after the construction period.

The other fish species in the reservoirs will be only little impacted during the construction phase of the project.

8.7 Temperature effects

There is not expected any temperature effects during the construction phase.

9 IMPACT ON WATER QUALITY AND AQUATIC LIFE DURING THE OPERATION PHASE

9.1 Short description of the hydrological impacts

The average flow in Rio Yuna at Los Quemados to day is approximately 18 m^3/s, while at the inlet to Lake Hatillo the mean flow is 33 m^3/s, see Figure 9.1. According to the preliminary plans 14-15 m^3/s are going to be transferred to Rio Jima with an underground hydropower plant in the Masipedro area. In addition, the Rio Masipedro is planned to be taken almost entirely into the diversion tunnel (3-4 m^3/s) and contribute to the hydropower production. The flow in Rio Yuna will be reduced considerably, and the renewal of water in Lake Hatillo will decrease, and the water residence time will increase. Very little, if any, water will be back in Rio Masipedro. The flow in Rio Jima will increase, the water residence time in Lake Rincon be reduced.

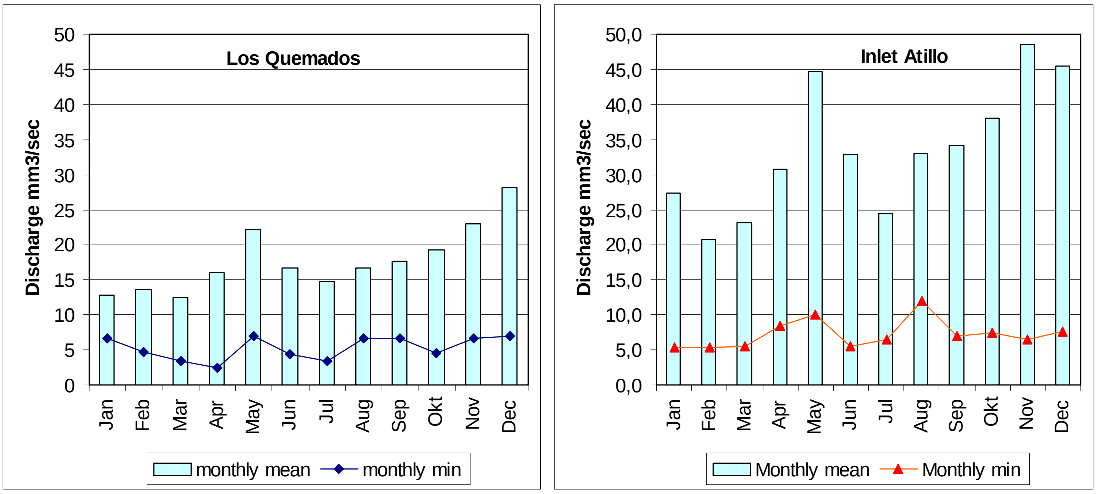

Figure 9.1 Water discharge in Rio Yuna at Los Quemados and at the inlet to Lago de Hatillo.

This will cause negative consequences for water quality and aquatic life in the Rio Yuna watercourse, included Hatillo Reservoir. This will also be the case for Rio Masipedro. In the Rio Jima watercourse, however, there will be both positive and negative impacts.

9.2 Alto Yuna Reservoir

The dam of the Alto Yuna Reservoir will create a migration barrier for fish and all other aquatic organisms in the river. However, the migratory fish that were present there before, dajao, anguilla, and guabina are already disappeared after the construction of the Lake Hatillo dam and the Lake Rincon dam. We were not able to find any long distance migratory fish species in this study. The dam should therefore not impact upstream fish or fishery.

In addition to the fish fauna present in the Rio Yuna today (biajaca and poecilids) the Alto Yuna Reservoir will be stocked relatively quickly from the fish species present in the Rio Blanco Reservoir. There has not been performed any fish study there, but the reservoir had a carp which the locals called Chinese carp, which seemed to be a variant of the common carp called mirror carp (*Cyprinius carpio var*.) However, the species has not been scientifically identified in this study, as Rio Blanco Reservoir was outside the study area.

The Alto Yuna Reservoir is fed with water from Rio Yuna and Rio Blanco. The water up here is relatively clean with little pollution from human discharges. However, in the Rio Blanco catchment, significant erosion is taking place, giving this river high turbidity during periods of rain. In the first period of the Alto Yuna Reservoir there will take place considerable erosion in the sides of the reservoir. Most of this erosion material will settle out within the reservoir, but it is likely that during the first 10 years after the damming, the water downstream will also be turbid in periods. After this initial period with reservoir side erosion the reservoir will act as a net sink of particles and the water downstream of the reservoir will be clearer than the water coming in. The reservoir will also be a sink for bacteria. The reservoir will serve as a settling basin, which will be an advantage for the water quality at the intake to Bonao City. However, in the first period after damming with in-reservoir erosion, there will be less such effect.

9.3 Rio Yuna

The water flow in Rio Yuna will be reduced considerably downstream of the dam. Downstream of the drinking water intake to Bonao, and the intake to the irrigation canals (Yuna-Cañabon), the water flow will be further decreased. In dry periods only the minimum release will be left as the river passes Bonao City. This low flow stretch will be very susceptible for pollutants, which will create problems for the use of the river for drinking water supply, bathing, washing, and irrigation.

The temperature of the river will decrease slightly due to deep water withdrawal from the Alto Yuna Reservoir, but it is not believed that this will be to such an extent that this alone will cause problems for the river biology.

The discharges from Bonao will however be much more pronounced than they are to day. As was seen in chapter 1.3.2 the bacteria content of the water was already too high to serve the human use interests, like drinking, bathing, irrigation of salad, berries and some fruits, i.e. products that are eaten without being boiled (heat treated). If nothing is done with respect to reduce the discharges from the city, the pollution will increase to a three-fold level. Bathing in the river will then be a health hazard. Drinking water for private household is normally not taken from Rio Yuna to day, and to do this in the future will be dangerous. Actions should be taken to reduce the discharges from Bonao.

For the river biology, the river will be smaller, in fact reduced to at least one third to one fourth of the original size. A small river can not produce the same amount of fish and other creatures as before. The fish production will therefore be strongly reduced. We believe that the species present to day, also will be present in the future, but it is likely that the endemic fish biajaca, will partly be replaced by the introduced tilapia. This tilapia has a very big reproduction potential, and is better adapted to tackle pollution. The crabs will most likely face problems as the number of refuges, or hiding places ("homes") will be strongly reduced in the shallow river. It will also be more prone to predators. The decrease in temperature will also possibly make it more susceptible to diseases. It is therefore believed that there will be a significant decline in the biomass of the crab (jaiba de rio).

The heavy metal contamination from Falconbridge will get increased effect. The discharges from Falconbridge are, however, under good control, the impacts on the river are very small to day, and it does not seem that they will be any great threat to the river pollution and biology in the future.

Further downstream of Bonao more tributaries are entering Rio Yuna (Rio Yaboa and Rio Yujo) and the impacts are reduced. At the inlet of Hatillo the Rio Yuna is about half the former size.

9.4 Lake Hatillo

For Lake Hatillo the water renewal will be strongly reduced. The input of water to the reservoir will be reduced by approximately 50%. The input of pollutants will still be approximately as before. It is quite clear that this will have a negative impact on the lake water quality.

The need for irrigation downstream (Yuna canal) will be the same as before, and the electricity production from Hatillo will be sought kept as high as possible. To achieve as little loss in available irrigation water as possible, and as little loss in energy production as possible, will result in higher water level fluctuation in the reservoir and/or lower water flow in Rio Yuna downstream the Hatillo dam.

9.4.1 Impacts on fish and aquatic life in Lake Hatillo

Great increase in water level fluctuation gives problems for the biological life in the littoral zone of a lake. This zone is very important for fish life, as most fishes spawn in the rooted vegetation of this zone, and most fish food items are produced here. The periodically water level fluctuation will lead to wash out of the fine organic material converting the zone into a desert consisting of inorganic sand and stones. The periodically dry-out is another damaging stress for the aquatic organisms. Large water level fluctuations result in that the macrophytes and most zoo-benthos disappear. When the water level fluctuation over the year is more than 10 m, this zone is more or less completely destroyed. When the rooted water vegetation is gone, the shelter and habitat diversity is reduced, and the biodiversity of the lake is reduced. This comes in addition to the reduced biological production.

In Lake Hatillo the maximum water level (full supply level) is 86 m.a.s.l., and the minimum operation level is 62,2 m a.s.l. giving a water level fluctuation range of 24 m. In the historical readings from Hatillo reservoir the water level variation within a year (max-min) has ranged from 2,7 m in the year with lowest variation to 17,5 m in the year with the highest water level variation. In average the water level variation range within a year is approximately 10 m. This means that in most years the life in the littoral zone is highly stressed, and the conditions for water macrophytes to establish permanent stands along the shores in lake Hatillo are poor. In most years the spawning conditions for carp (*Cyprinius carpio*) and trucha (*Micropterus salmoides*) are difficult. With large water level fluctuations the fish fauna will be dominated by small tilapias.

The water level variation range is to day of a size that hampers the function of a healthy lake ecosystem. If the water level variation range will increase considerably after the regulation of Alto Yuna, this will have detrimental impacts on the lake ecosystem. Particularly, the production and biomass of trucha and carp will decline.

The preliminary water balance simulations indicates that there are regulation alternatives where the water level fluctuations in Hatillo reservoir can be kept almost as before.

9.4.2 Impact on water quality and eutrophication in Lake Hatillo.

It is the unpolluted and nutrient poor high mountain water that is diverted to Rio Jima, i.e. it is the diluting water that is taken away from Lake Hatillo. The discharges from Bonao, Maimon and the more densely populated areas will still end up in Lake Hatillo. This will lead to increased concentration of nutrients and algal growth in the lake. More algal material will sink to the bottom and consume deep-water oxygen. The lake is already facing a significant oxygen decline in the hypolimnion. The process of nutrient increase and the associated processes are called eutrophication, and is one of the main world wide ecological problems in lakes.

The anticipated effect of the project with respect to eutrophication can be estimated using the Vollenweider (1976) model. The estimates will not be very precise as we have limited baseline data; only two observations of the total phosphorus concentration, algal biomass, and one observation of oxygen distribution in the deep water.

The analysis of phytoplankton (mean algal bio volume of 1100 mm^3/m^3) and oxygen regime (significant decline of oxygen in the hypolimnion) indicated that lake Hatillo is in the mesotrophic level with respect to the impact of fertilization by discharges of nutrients. However, the concentration of total phosphorus indicated that it was in the oligotrophic level by the observations of 5 µg P/l both in October 2002 and in March 2003. The effect parameters, algal bio-volume and oxygen concentration, both showed that the lake is impacted by eutrophication, and there is likely that the observed total-P value is too low.

Normally, baseline condition should be given as average annual mean values for phosphorus and algal concentrations. Here we have only two observations. Even though the description of the baseline situation is uncertain, the model prediction will show the relative worsening of the eutrofication impact.

Model assumptions

We assume that the nutrient concentration in the diverted high mountain water is 1/3 of the concentration of the low-land input sources to Lake Hatillo. We use the found baseline total Phosphorus concentration as starting point. In simulation one (I) we assume that the water level of the reservoir is kept close to full supply level (86 m a.s.l.), and in simulation (II) we assume an average water level of 75 m a.s.l.

Model results

As it is the internationally recognised and frequently used Vollenweider (1976) model that is used, the different steps in the model calculation are not shown here.

If the lake is kept close to full supply level (Simulation I) both the concentration of algae and total phosphorus will increase by approximately 30%, and if the water level is kept at approximately 75 m a.s.l. (Simulation II), the increase will be of approximately 50%.

If the real situation with respect to eutrophication is close to the baseline condition described by the P-concentration (i.e. 5 µg P/l - an oligotrophic situation), the regulation will not cause any significant eutrophication problem. However, if the real baseline situation is closer to what was found by the algal bio volume (i.e. 1100 mm^3/m^3 – a mesotrophic situation), the increase of 50% will give rice to marked problems with increased oxygen deficiency in the deep water, and algal blooms.

It will therefore be important to keep the water level as high as possible after the regulation.

9.4.3 Impacts on heavy metal pollution from mining

As has been shown in the results from the samplings, Falconbridge does not give rise to significant pollution, neither to Rio Yuna, nor to Hatillo Lake. The river Margajita is, however, a source of pollution that can cause significant pollution of Hatillo in the future, particularly in the upstream end of the reservoir if the water level is kept much lower than to day. The pollution of Rio Margajita, and the reasons causing it, should be studied more in detail and a cost effective pollution abatement plan should be worked out. The stream is to day so polluted that it is a health hazard for wildlife and people (the river life is dead many years ago).

9.5 Rio Yuna downstream of Lake Hatillo

Downstream of Hatillo (also downstream the intake to the Yuna irrigation canal) the water flow to day is about 30 m^3/s in average. The water balance study indicates that this flow will be roughly reduced by 50%.

The result from the samplings in March 2003 indicated that the river here had high concentration of coliform bacteria, but was relatively unpolluted by other compounds. The hygienic situation will be worse by the effect of the regulation. Pollution from the Margajita-mining fields will settle out in Hatillo reservoir, and is not expected to impact the water quality or biota in this lower part of Rio Yuna.

The mining activities that drain to Arroyo Mejita do not give much pollution. Of the analysed heavy metals just before Arroyo Mejita confluence with Rio Maguaca, only manganese was found to be high (1650 µg/l – Class C). All the other parameters showed values of Class A (insignificant pollution).

Rio Maguaca enters Rio Yuna downstream of our sampling station, but the results from sampling in Arroyo Mejita shows that the present mining activity in the area will not influence on Rio Yuna even after the regulation.

The fish and crab population will be impacted negatively by the regulation, particularly in periods of low flow. There should therefore be established a minimum water flow in Rio Yuna downstream of the intake to Yuna Irrigation Canal.

9.6 Rio Masipedro

Rio Masipedro is planned to be transferred almost completely into the diversion tunnel from Alto Yuna dam to Rio Jima. The diversion point is some kilometres upstream of the starting point of Masipedro canal. To cover the need for water for irrigation and household in this area, it is mentioned as an option to transfer water from upper Rio Jima.

The planned regulation will in periods dry up Rio Masipedro totally, which will be detrimental to all aquatic life. The crabs will disappear and the fish will disappear. For a long stretch of the river it will in periods only be temporary water pools between the stones. Such temporary pools without fish is highly effective breeding places for mosquitoes, and this will easily result in increased mosquito plague. It should be some water flow left, at least which could support a stand of poecilides (mosquito-fishes) to control the mosquitoes.

The popular bathing places in Rio Masipedro will be destroyed. It is crucial for the local people in such warm climate to have access to near by bathing places. Some of the bathing places have to be replaced by new ones with alternative water supply.

It is believed that the red swamp crayfish will survive in the lower reaches.

9.7 Rio Jima between Caño Piedra and Lake Rincon

Rio Jima will receive the water from the tailrace canal of the power plant which will more than triple the water flow of Rio Jima today. In addition it will be large and rapid water flow variations due to the variation in the electricity need from the power plant.

This will result in large erosion problems in the stretch upstream of Lake Rincon, and it will be necessary to enforce the riverbank. Bank enforcement changes the shoreline habitat and often results in reduced biodiversity and biological production. Fish and crabs may easily be flushed away during rapid flow increases and may "strand" in periods of rapid flow reductions. Therefore a routine for smooth start and stop of the PowerStation should be worked out.

9.8 Lake Rincon

For Lake Rincon the diversion can be an advantage. Rincon has today significant oxygen problems in the deep water. It is more rich in nutrients than Hatillo. To day, it can be characterised as a mesotrophic lake with oxygen problems. The new addition of nutrient poor water from the mountain areas will dilute the nutrient content of the lake water. This will lead to decreased algal growth, and less organic material will settle to the deep water and consume oxygen. The diversion will lead to an oligotrophication of the lake and an improvement of the water quality.

The new diversion will most likely make it more easy to keep the lake surface at a higher, and more constant level, which is an advantage with respect to lake ecology. For the fish and fishery it is important to keep the water level high from April throughout June to secure good breeding conditions for trucha and carp.

If the water level variations will be higher than to day, the fish biomass and the outcome of the fishery will be less than to day.

9.9 Rio Jima downstream of Rincon

This river will get increased water flow after the regulation, which should give improved conditions both with respect to pollution and river ecology. The rapid flow variations which were mentioned as a problem in Rio Jima upstream of Rincon Reservoir, will be dampened in the reservoir, and it is not anticipated that this will be any problem in the lower part of Rio Jima.

If all the additional water is used for irrigation, the additional water will not create any improvement of river ecology.

The diversion may lead to increased problems by flooding in wet periods. Building of some flood protection dikes and some river bank strengthening should be considered.

10 ABATEMENT MEASURES DURING THE CONSTRUCTION PHASE

10.1 Measures against erosion

10.1.1 Road construction and Roads

Digging out roads in the steep valley sides in soft soils leaves large areas of denuded soils open for rain and water erosion. This problem applies to the inner side of the roads with the drain ditch, as well as the road itself, and the outward facing road fill. Even for temporary roads this will create wounds in the terrain that will slide and erode for tens of years if no stabilisation is done.

Recommended actions
The construction of roads should begin at the onset of the dry season with the excavating and bulldozering. Before the wet season sets in the road sides should have been sowed by a convenient grass type. In particular erosion prone areas the grass should be sowed in a soil stabilising screen/net which is efficient in establishing stabile road sides. The sowing is most easily performed by spraying out glue-treated seeds. Ideally the grass should have sprouted before the wet season sets in.

The road ditch should be lined with stones in erosion prone areas. The water in the road ditch should be released into existing brooks/streams. The road ditch should be released as often as possible, i.e. wherever there is a natural brook/flood brook. Road ditch outlets should not be allowed to be discharged into the valley sides in places where there has been no waterway before. If this is necessary in some places, necessary enforcement should be made to prevent erosion.

The permanent roads should be paved as soon as possible after the construction.

10.1.2 Parking lots, camp areas and construction sites

The same erosion preventing actions as given for roads is recommended for this kind of areas.

10.1.3 Runoff from tunnel blasting and tunnel drilling

The water from the tunnel excavation, either it be by blasting or full profile drilling, should pass a sedimentation pond prior to be discharged into the river. The fine, newly formed particles by drilling, grinding, etc. has sharp edges that can damage the gills of freshwater organisms. If the tunnel is blasted, the use of ammonia-nitrate as blasting material creates large amounts of ammonium in the runoff. If at the same time, the tunnel is sealed and tightened by use of concrete (particularly the spray type of concrete), the runoff can contain high amount of free ammonia, which may lead to fish kill in periods of low flow.

The sedimentation pond should be monitored with respect to ammonium, free ammonia, and pH. If necessary, pH should be adjusted to neutrality before discharge into the river.

10.1.4 Soil deposits and spoil rock deposits

In the first period after a major tunnel and hydropower construction work the spoil rock deposit is used for construction purposes, filling material for road construction, quarries, etc. After some years they are abandoned, and should be terminated in a proper way.

To prevent impact on water environment, the localisation is important, the water handling is important, and the final termination is important.

Localisation and water handling

These deposits should not be placed in too steep terrain. The best would be to locate them to natural depression with infiltration outlet. Such depressions are, however, not likely to be found in the vicinity of the construction area.

The second best would be to place the spoil rock deposit in a flat area with little runoff (little upstream catchment) and good infiltration capacities (sandy soils).

If they are placed in a valley-like depression, incoming water should be drained through by a pipeline of the necessary capacity to safely by-pass storm flows. Downstream of the deposits there should be constructed a sedimentation dam to settle out as much as possible of the eroded particles. The drainage from areas upstream of the deposit should be by-passed the sedimentation basin. If possible the runoff from the spoil rock deposit should be infiltrated in the terrain.

Runoff from blasted tunnel material should be controlled with respect to content of nitrogen and particularly ammonia and pH. Water with high concentration of ammonia and high pH can cause fish kills in periods of low flow. In such cases the pH in the sedimentation pond should be adjusted to neutrality before discharge.

Final termination of the spoil rock deposit

When there is no more interest of using the spoil rock deposit it should be levelled and shaped into nature-looking terrain and covered by vegetation. In material from full profile tunnel drilling it can often be sowed and planted directly, while material from blasted tunnels must be covered by fertile top soil first.

It is best first to establish some kind of grass cover, and after a while wild bush and trees will establish by them self.

10.2 Sanitary effluents from the construction workers camp

During the construction phase there will be large activity centres at the different construction sites. These will partly be residential camps for construction workers, and partly administration, workshops, machine parks etc. From these sites there has to be built sanitary systems with no direct discharge to the river. This is particularly important for Yuna River in the reservoir area, because this is just upstream of the drinking water intake for Bonao city. In most of the construction areas the terrain consists of rocky hillsides with poor infiltration capacity. Standard pit latrines may therefore not serve the intention of preventing hygienic pollution of the river.

If suitable infiltration soils cannot be found, toilet water (black water) and wash water (grey water) should be separated. Toilet water should be collected in watertight tanks and emptied into the city purification plant, or infiltrated at a safe place.

The grey water can be infiltrated in the terrain.

An alternative is to have mobile latrines of the type that are used in the military and at large sports arrangements. These can be emptied every day/every second day at the city sewage system, or at a safe infiltration site.

10.3 Oil and chemical spill

The construction work will need a large park of machinery like, trucks, tractors, excavators, bulldozers, drilling machines, cars, etc. These will need diesel and gasoline, motor oil, hydraulic oil, cooling liquid, battery acids, etc. There has to be established storage places of such chemicals, filling places, workshops, etc.

It is particularly important to secure that such compounds are not allowed to enter Yuna River which just downstream supplies drinking water for Bonao city.

The storage and fuel filling should take place on paved area, which is tightly drained to a collecting tank in case of accident spills. The workshop floor should be drained to a collecting tank from where the content can be removed and given the correct treatment.

The machinery parking area should consist of loose material with infiltration capacity, which can absorb small spills. This means that the area should not only consist of stones and gravel, but also contain sand and silt.

11 ABATEMENT MEASURES DURING THE OPERATION PHASE

11.1 Measures in Rio Yuna from Alto Yuna Dam to Lake Hatillo

The discharge from Alto Yuna dam should at least be enough to serve the following needs:

1. Drinking water for Bonao and the surroundings
2. Irrigation water to Yuna – Cañabon Canal, and others
3. Dilution water for the pollution discharges from the Bonao area
4. Water to support life for fish and other aquatic organisms

Point no 1 and 2 can easily be decided according to the specific needs given by the different user interests, while the needs for point no 3 and 4 are more difficult to assess accurately.

The most critical point, where the flow in Rio Yuna will be at its lowest, is just before the entrance of Rio Yaboa, which is at the entering point of the main discharges from the Bonao City. Both the drinking water and the irrigation water is abstracted upstream this point. It is in the dry periods that the problems for aquatic life and for the human use prone to pollution are greatest.

If the water is not polluted, it has been common to establish a minimum flow of water of approximately 10% of the average flow to take care of aquatic life and human use, like fishing, bathing and recreation. (e.g. in the Norwegian water legislation it is required to establish a minimum release of the size called “normal low flow”. This is in most cases close to 10 % of average annual flow). The average annual flow at Los Quemados is approximately 15 m^3/s. This should give a proposed minimum flow in Rio Yuna, just upstream the entrance of Rio Yaboa, of 1,5 m^3/s. The minimum release from the Alto Yuna dam has to be 1.5 m^3/s plus the need for irrigation and the need for drinking water supply.

If the river is polluted, the need for minimum flow is greater. Therefore, the 1.5 m^3/s require that the sewage from Bonao are collected and treated in a proper way. The way the sewage is handled to day is not satisfactory, and need to be improved if the regulation shall be carried out.

As the discharges from Falconbridge seems to be small and under control, and as more tributaries have entered the river at that point, we do not find it necessary to increase the minimum flow due to Falconbridge discharges.

Proposed measures:

1. A minimum release over the Alto Yuna Dam that takes care of

    - Drinking water for Bonao and the surroundings
    - Irrigation water to Yuna – Cañabon canal, and others
    - Dilution water for the pollution discharges from the Bonao area
    - Water to support life for fish and other aquatic organisms

    The minimum flow in Rio Yuna just upstream the confluence with Rio Yaboa should not be less than 1.5 m^3/s.

2. The sewage system from Bonao should be modernised. This comprises both the collection and treatment of the sewage.

11.2 Measures in the Lake Hatillo

The reduction in water renewal in Lake Hatillo will lead to problems confined with:

- Reduced recipient capacity for nutrients - Eutrophication
- Reduced recipient capacity for mining runoff - Heavy metal pollution
- Destroyed aquatic life – due to water level fluctuations

Proposed measures:

1. All these 3 impacts can be reduced somewhat by keeping the water level in the lake as high as possible, and reduce the water level fluctuation as much as possible. It should be worked out water level rules (regulations) for the lake.

2. The water pollution from the mining fields affecting Arroyo Margajita should be studied better, and there should be elaborated a cost effective pollution abatement plan for the river.

3. It should be made an analysis about the necessity for a fish stocking programme (trucha and carp) for the lake. This is particularly relevant if there is not possible to keep the water level relatively high, and within narrow fluctuation limits.

11.3 Measures in Rio Yuna downstream of Hatillo

The problems here are to secure the river enough water to have the necessary recipient capacity for pollutants, and to support aquatic life.

Proposed measures:

- Establish a minimum flow of approximately 10% of average annual flow, i.e. 3 m^3/s.

11.4 Measures in Rio Masipedro

The problems here are confined with having some waterflow left that can prevent the fish from disappearing, and to give enough water to feed some bathing places with water.

Proposed measures

- Establish a minimum release of 300 l/s
- Divert any sewage effluent from the river
- Bathing places must be upgraded/constructed

11.5 Measures in Rio Jima between Caño Piedra and Cañabon

The problems here are mainly confined with erosion and stranding/flushing-away of organisms due to fierce and rapid changing flow.

Proposed measures

- Strengthening of the river banks at certain points
- Elaborate rules/procedures for a smooth start and stop of the power station.

11.6 Measures in Lake Rincon

In Lake Rincon there will be mainly positive impacts. These can be optimised by keeping the water level as high as possible.

Proposed measure

- Elaborate water level regulation with the aim of keeping the water level as high and constant as possible.

11.7 Measures in Rio Jima downstream of Rincon

Here the impacts will in most cases be positive. However, there can be increased problems with erosion during periods of high flows.

Proposed measure

- Perform a study to evaluate if there is a need for some flood protective works and some river bank strengthening at certain points.

12 APPENDIX – PRIMARY DATA

Laboratorio de Calidad de Aguas

INSTITUTO NACIONAL DE RECURSOS HIDRAULICOS INDRHI

FORMULARIO DE REPORTE DE SALIDA DE DATOS

Solicitante	**ISA- INDRHI**	**Fecha : 14 / 11/ 02**
Clasificación	**Aguas Superficiales**	**Lugar : Río Yuna**
Operador	**Ing. Luis Almanzar**	

ORGANICOS GENERALES

Fecha de Muestreo	Amonio (mg/l)	DQO (mg/l)	Lugar y Fuente
05.11.2002	<LD	20	Río Yuna a 20mt. Antes conf. Río Blanco
05.11.2002	<LD	7,92	Río Yuna sitio Presa Río Yuna, alto Yuna
05.11.2002	<LD	35,64	Río Masipedro, obra de toma del canal
05.11.2002	<LD	31,68	Río Jima, salidad del tunel
05.11.2002	<LD	47,52	Río Jima, Jima Rincón
05.11.2002	<LD	31,68	Río Yuna, después de Yuboa
05.11.2002	<LD	47,52	Río Yuna, después del canal Falcondo
05.11.2002	<LD	11,88	Lago Presa Hatillo, aguas arriba muro
05.11.2002	<LD	55,44	Lago Presa Rincón, aguas arriba muro
Normas Ambientales Clase B	**0.5.(mg/l)**	**N/C**	

N/C ; No Contemplado en las Normas Ambientales

Laboratorio de Calidad de Aguas

INSTITUTO NACIONAL DE RECURSOS HIDRAULICOS INDRHI

FORMULARIO DE REPORTE DE SALIDA DE DATOS

Solicitante	**ISA- INDRHI**	**Fecha : 14 / 11/ 02**
Clasificación	**Aguas Superficiales**	**Lugar : Río Yuna**
Operador		

ANALISIS BACTERIOLOGICOS

Fecha de Muestreo	Coliformes Totales NMP/ 100ml	Coliformes Fecales NMP / 100 ml	Lugar y Fuente
05.11.2002	4 300	360	Río Yuna a 20mt. Antes conf. Río Blanco
05.11.2002	2 300	360	Río Yuna sitio Presa Río Yuna, alto Yuna
05.11.2002	2 300	<2.2	Río Masipedro, obra de toma del Canal
05.11.2002	4 300	2 300	Río Jima, salidad del tunel
05.11.2002	2 300	910	Río Jima, Jima Rincón
05.11.2002	2 300	360	Río Yuna, después de Yuboa
05.11.2002	2 300	360	Río Yuna, después del canal Falcondo
05.11.2002	360	<2.2	Lago Presa Hatillo, aguas arriba muro
05.11.2002	910	<2.2	Lago Presa Rincón, aguas arriba muro
Normas Ambientales Clase B	**1 000**	**1 000**	

Laboratorio de Calidad de Aguas

INSTITUTO NACIONAL DE RECURSOS HIDRAULICOS (INDRHI)

FORMULARIO DE REPORTE DE SALIDA DE DATOS

Solicitante	**ISA-INDHRI**	**Fecha :**	**13.11.2002**
Clasificación	**Aguas Superficiales**	**Lugar :**	**Río Yuna**
Operador	**Ing. Luis Almanzar**		

ANALISIS FISICO-QUIMICOS

Fecha de Muestreo	CE (µS/cm)	pH	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	CO3 (mg/l)	HCO3 (mg/l)	Cl (mg/l)	SO4 (mg/l)	NO3 (mg/l)	NO2 (mg/l)	PO4 (mg/l)	Total PO4 (mg/l)	D.T (mg/l)	Alc. (mg/l)	STD (mg/l)	Sed (gr/l)	Ras	Clase	Fuente y Fuente
05.11.2002	205	8,1	28,86	2,79	8,28	0	103,73	9,57	8,25	4,84	0,0165	<LD	<LD	83,5	85	163	0,0005	0,4	C1S1	Río Yuna a 20mt. Antes conf. Río Blanco
05.11.2002	200	8	24,85	3,77	9,89	0	91,53	10,99	8,25	4,4	0,0198	<LD	<LD	77,5	75	108	0,0005	0,49	C1S1	Río Yuna sitio Presa Río Yuna, alto Yuna
05.11.2002	136	7,7	11,62	6,2	5,98	0	61,02	7,44	10,23	4,84	0,0165	<LD	<LD	54,5	50	101	0	0,35	C1S1	Río Masipedro, obra de toma del canal
05.11.2002	119	7,4	11,62	3,77	6,67	0	48,82	10,28	10,89	3,96	<LD	<LD	<LD	44,5	40	87	0,0005	0,43	C1S1	Río Jima, salidad del tunel
05.11.2002	166	7,6	13,23	8,02	7,36	0	73,22	10,28	7,92	2,64	0,0066	<LD	<LD	66	60	105	0,0008	0,4	C1S1	Río Jima, Jima Rincón
05.11.2002	278	7,7	27,25	10,33	12,41	0	128,14	12,41	10,99	4,84	0,0165	<LD	<LD	110,5	105	201	0,0005	0,51	C1S1	Río Yuna, después de Yuboa
05.11.2002	275	8,3	27,25	10,33	11,72	18	91,53	11,7	12,31	4,84	0,0165	<LD	<LD	110,5	105	153	0,0008	0,49	C2S1	Río Yuna, después del canal Falcondo
05.11.2002	261	7,6	26,45	8,51	12,87	0	79,33	12,41	32,49	3,52	0,0132	<LD	<LD	101	65	164	0	0,56	C2S1	Lago Presa Hatillo, aguas arriba muro
05.11.2002	157	8,1	11,62	8,02	7,13	0	73,22	10,28	9,79	3,96	0,0297	<LD	<LD	62	60	81	0	0,39	C1S1	Lago Presa Rincón, aguas arriba muro
Normas Ambientales Clase B		**6,5 9**						**250**	**400**							**1000**				

Análisis realizados siguiendo las metodologías analíticas del Standard Methods 1992

Laboratorio de Calidad de Aguas

INSTITUTO NACIONAL DE RECURSOS HIDRAULICOS INDRHI

FORMULARIO DE REPORTE DE SALIDA DE DATOS

Solicitante	**ISA- INDRHI**	**Fecha : 28 / 11/ 02**
Clasificación	**Aguas Superficiales**	**Lugar : Río Yuna**
Operador	**Ing. Luis Almanzar**	

ORGANICOS GENERALES

Fecha de Muestreo	Amonio (mg/l)	DQO (mg/l)	Lugar y Fuente
19.11.2002	<LD	16	Río Yuna a 20mt. Antes conf. Río Blanco
19.11.2002	<LD	24	Río Yuna sitio Presa Río Yuna, alto Yuna
19.11.2002	<LD	8	Río Masipedro, obra de toma del canal
19.11.2002	<LD	28	Río Jima, Caño Piedra, Jima
19.11.2002	<LD	36	Río Jima, Jima Rincón, Cañalón
19.11.2002	<LD	28	Río Yuna, después de Yuboa, El Baribe
19.11.2002	<LD	20	Río Yuna, después del canal Falcondo, Hato Viejo
19.11.2002	<LD	4	Lago Presa Hatillo, aguas arriba muro
19.11.2002	<LD	16	Lago Presa Rincón, aguas arriba muro
Normas Ambientales Clase B	**0.5.(mg/l)**	**N/C**	

N/C ; No Contemplado en las Normas Ambientales
<LD : Menor del Límite de Detección

Laboratorio de Calidad de Aguas

INSTITUTO NACIONAL DE RECURSOS HIDRAULICOS INDRHI

FORMULARIO DE REPORTE DE SALIDA DE DATOS

Solicitante	**ISA- INDRHI**	**Fecha : 28 / 11/ 02**
Clasificación	**Aguas Superficiales**	**Lugar : Río Yuna**
Operador	**Ing. Luis Almanzar**	

ANALISIS BACTERIOLOGICOS

Fecha de Muestreo	Coliformes Totales NMP/ 100ml	Coliformes Fecales NMP / 100 ml	Lugar y Fuente
19.11.2002	2 300	360	Río Yuna a 20mt. Antes conf. Río Blanco
19.11.2002	2 300	360	Río Yuna sitio Presa Río Yuna, alto Yuna
19.11.2002	4 300	4 300	Río Masipedro, obra de toma del canal
19.11.2002	9 300	4 300	Río Jima, Caño Piedra, Jima
19.11.2002	15 000	7 500	Río Jima, Jima Rincón, Cañalón
19.11.2002	4 300	2 300	Río Yuna, después de Yuboa, El Baribe
19.11.2002	9 300	9 300	Río Yuna, después del canal Falcondo, Hato Viejo
19.11.2002	1 500	910	Lago Presa Hatillo, aguas arriba muro
19.11.2002	360	<2.2	Lago Presa Rincón, aguas arriba muro
Normas Ambientales Clase B	**1 000**	**1 000**	

Laboratorio de Calidad de Aguas

INSTITUTO NACIONAL DE RECURSOS HIDRAULICOS (INDRHI)

FORMULARIO DE REPORTE DE SALIDA DE DATOS

Solicitante	ISA-INDHRI	Fecha :	28.11.2002
Clasificación	Aguas Superficiales	Lugar :	Río Yuna
Operador	Ing. Luis Almanzar		

ANALISIS FISICO-QUIMICOS

Fecha de	CE	pH	Ca	Mg	Na	CO3	HCO3	Cl	SO4	NO3	NO2	PO4		D.T	Alc.	STD	Sed	Ras	Clase	Fuente y Fuente
Muestreo	(µS/cm)		(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)		(mg/l)	(mg/l)	(mg/l)	(gr/l)			
19.11.2002	210	7,9	24,05	5,47	9,89	0	97,63	6,74	10,34	5,72	0,033	<LD		82,5	80	109	0,22	0,47	C1S1	Río Yuna a 20mt. Antes conf. Río Blanco
19.11.2002	222	8	25,65	4,13	13,33	0	97,63	11,7	15,93	7,48	0,0198	<LD		81	80	130	0,1868	0,64	C1S1	Río Yuna sitio Presa Río Yuna, alto Yuna
19.11.2002	138	7,8	12,02	5,1	8,05	0	61,02	7,44	11,87	5,28	0,0198	<LD		51	50	116	0,218	0,49	C1S1	Río Masipedro, obra de toma del canal
19.11.2002	123	7,5	11,22	2,79	9,89	0	48,82	7,44	10,78	5.28.	0,0066	<LD		39,5	40	75	0,1948	0,68	C1S1	Río Jima, Caño Piedra, Jima
19.11.2022	170	7,4	13,63	7,29	9,2	0	67,12	9,57	8,91	5,28	0,0264	<LD		64	55	91	0,145	0,5	C1S1	Río Jima, Jima Rincón, Cañalón
19.11.2002	274	7,6	30,06	7,41	13,79	0	134,24	13,12	13,74	7,04	0,0099	<LD		105,5	110	215	0,1605	0,58	C2S1	Río Yuna, después de Yuboa, El Baribe
19.11.2002	287	8,1	32,46	7,78	13,33	0	140,35	13,83	14,39	7,04	0,0297	<LD		113	115	189	0,204	0,55	C2S1	Río Yuna, después del canal Falcondo, Hato Vie
19.11.2002	271	7,5	26,45	7,9	16,32	0	85,43	10,28	41,92	4,4	0,0099	<LD		98,5	70	164	0,2258	0,72	C2S1	Lago Presa Hatillo, aguas arriba muro
19.11.2002	161	7,8	11,22	7,41	9,66	0	73,22	10,28	9,46	3,52	0,0033	<LD		58,5	60	121	0,182	0,55	C1S1	Lago Presa Rincón, aguas arriba muro
Normas Ambientales Clase B		**6,5** **9**						**250**	**400**							**1000**				

Análisis realizados siguiendo las metodologías analíticas del Standard Methods 1992

Laboratorio de Calidad de Aguas

INSTITUTO NACIONAL DE RECURSOS HIDRAULICOS INDRHI

FORMULARIO DE REPORTE DE SALIDA DE DATOS

Solicitante	**ISA- INDRHI**	**Fecha : 7 / 12/ 02**
Clasificación	**Aguas Superficiales**	**Lugar : Río Yuna**
Operador	**Ing. Luis Almanzar**	

ORGANICOS GENERALES

Fecha de Muestreo	Amonio (mg/l)	DQO (mg/l)	Lugar y Fuente
*3/12/2002	<LD	<LD	Río Yuna a 20mt. Antes conf. Río Blanco
03.12.2002	<LD	24,4	Río Yuna sitio Presa Río Yuna, alto Yuna
03.12.2002	<LD	<LD	Río Masipedro, obra de toma del canal
03.12.2002	<LD	<LD	Río Jima, Caño Piedra, Jima
03.12.2002	<LD	31,68	Río Jima, Jima Rincón, Cañalón
*3/12/2002	<LD	19,8	Río Yuna, después de Yuboa, El Baribe
03.12.2002	<LD	23,76	Río Yuna, después del canal Falcondo, Hato Viejo
03.12.2002	<LD	27,72	Lago Presa Hatillo, aguas arriba muro
03.12.2002	<LD	27,72	Lago Presa Rincón, aguas arriba muro
Normas Ambientales Clase B	**0.5.(mg/l)**	**N/C**	

N/C ; No Contemplado en las Normas Ambientales
<LD : Menor del Límite de Detección
*** Estas muestras para DQO fueron tomadas de los frascos plásticos de las muestras de amonio ya que en las muestras de DQO vinieron sin identificación.**

Laboratorio de Calidad de Aguas

INSTITUTO NACIONAL DE RECURSOS HIDRAULICOS INDRHI

FORMULARIO DE REPORTE DE SALIDA DE DATOS

Solicitante	**ISA- INDRHI**	**Fecha : 7 / 12/ 02**
Clasificación	**Aguas Superficiales**	**Lugar : Río Yuna**
Operador	**Ing. Luis Almanzar**	

ANALISIS BACTERIOLOGICOS

Fecha de Muestreo	Coliformes Totales NMP/ 100ml	Coliformes Fecales NMP / 100 ml	Lugar y Fuente
03.12.2002	360	360	Río Yuna a 20mt. Antes conf. Río Blanco
03.12.2002	2 300	2 300	Río Yuna sitio Presa Río Yuna, alto Yuna
03.12.2002	2 300	910	Río Masipedro, obra de toma del canal
03.12.2002	4 300	2 300	Río Jima, Caño Piedra, Jima
03.12.2002	4 300	1 500	Río Jima, Jima Rincón, Cañalón
03.12.2002	>110,000	110 000	Río Yuna, después de Yuboa, El Baribe
03.12.2002	910	<2.2	Río Yuna, después del canal Falcondo, Hato Viejo
03.12.2002	360	<2.2	Lago Presa Hatillo, aguas arriba muro
03.12.2002	<2.2	<2.2	Lago Presa Rincón, aguas arriba muro
Normas Ambientales Clase B	**1 000**	**1 000**	

Clase B : Aguas destinadas a la preservación de la flora y la fauna; aguas aprovechables para el regadío de cultivos deportes acuáticos sin contacto directo, aquellas utilizadas en algunos procesos industriales y pecuarios y aguas para abastecimiento de agua potable después de un proceso de tratamiento

Laboratorio de Calidad de Aguas

INSTITUTO NACIONAL DE RECURSOS HIDRAULICOS (INDRHI)

FORMULARIO DE REPORTE DE SALIDA DE DATOS

Solicitante	ISA-INDHRI	Fecha :	07.12.2002
Clasificación	Aguas Superficiales	Lugar :	Río Yuna
Operador	Ing. Luis Almanzar		

ANALISIS FISICO-QUIMICOS

Fecha de Muestreo	CE (µS/cm)	pH	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	CO3 (mg/l)	HCO3 (mg/l)	Cl (mg/l)	SO4 (mg/l)	NO3 (mg/l)	NO2 (mg/l)	PO4 (mg/l)	Total PO4 (mg/l)	D.T (mg/l)	Alc. (mg/l)	STD (mg/l)	Sed (gr/l)	Ras	Clase	Fuente y Fuente
03.12.2002	215	8,2	25,6	5,88	8,28	0	85,4	10,3	16,15	4,84	0,02	<LD	<LD	88,5	70	110	0	0,38	C1S1	Río Yuna a 20mt. Antes conf. Río Blanco
03.12.2002	244	8	27	5	14,95	0	97,6	14,56	22,62	6,16	0,02	<LD	<LD	88,5	80	126	0	0,69	C1S1	Sitio de la Presa, Los Quemados
03.12.2002	142	7,7	12	5,88	7,36	0	54,9	8,88	16,04	4,4	0,02	<LD	<LD	54,5	45	79	0	0,43	C1S1	Río Masipedro, en Masipedro
03.12.2002	125	7,5	9,8	6,36	5,06	0	42,7	11,01	12,75	2,64	0,006	<LD	<LD	51	35	92	0	0,31	C1S1	Río Jima, Caño Piedra, Jima
03.12.2002	177	7,4	12	9	9,2	0	79,3	11,01	12	8,8	0,02	<LD	<LD	67,5	65	124	0,0015	0,82	C1S1	Río Jima, Jima Rincón, Cañalón
03.12.2002	310	7,5	35,4	9,48	11,73	0	146,4	13,14	15,27	7,48	0,02	<LD	<LD	128	120	193	0,0023	0,45	C2S1	Río Yuna, después de Yuboa, El Caribe
03.12.2002	306	8	34,6	9,48	11,73	0	128,1	13,14	16,7	7,04	0,013	<LD	<LD	125	105	187	0,0015	0,46	C2S1	Río Yuna, después del canal Falcondo, Hato Viejo
03.12.2002	267	7,1	25,6	9	14,03	0	79,3	12,43	44,88	3,96	0,009	<LD	<LD	101,5	65	180	0	0,6	C2S1	Lago Presa Hatillo, aguas arriba muro
03.12.2002	170	7,5	10,6	9,18	9,2	0	73,2	9,59	12	4,4	0,009	<LD	<LD	64	60	91	0	0,5	C1S1	Lago Presa Rincón, aguas arriba muro
Normas Ambientales Clase B		**6,5 9**						**250**	**400**							**1000**				

Análisis realizados siguiendo las metodologías analíticas del Standard Methods 1992

Clase B : Aguas destinadas a la preservación de la flora y la fauna; aguas aprovechables para el regadío de cultivos deportes acuáticos sin contacto directo, aquellas utilizadas en algunos procesos industriales y pecuarios

Laboratorio de Calidad de Aguas

INSTITUTO NACIONAL DE RECURSOS HIDRAULICOS INDRHI

FORMULARIO DE REPORTE DE SALIDA DE DATOS

Solicitante	ISA- INDRHI	Fecha : 31/12/ 02
Clasificación	Aguas Superficiales	Lugar : Río Yuna
Operador	Ing. Luis Almanzar	

ORGANICOS GENERALES

Fecha de Muestreo	Amonio (mg/l)	DQO (mg/l)	Lugar y Fuente
17.12.2002	< LD	20	Río Yuna en Blanco
17.12.2002	< LD	32	Río Yuna, Los Quemados
17.12.2002	< LD	32	Río Masipedro, obra de toma del canal
17.12.2002	< LD	36	Río Jima, Caño Piedra
17.12.2002	< LD	20	Río Jima, Jima Rincón
17.12.2002	< LD	28	Río Yuna, con Yuboa, El Caribe
17.12.2002	< LD	20	Río Yuna con canal Hato Viejo
17.12.2002	< LD	32	Lago Presa Hatillo, aguas arriba muro
17.12.2002	< LD	36	Lago Presa Rincón, aguas arriba muro
Normas Ambientales Clase B	0.5.(mg/l)	N/C	

N/C ; No Contemplado en las Normas Ambientales

< LD: Menor del límite de detección

Laboratorio de Calidad de Aguas

INSTITUTO NACIONAL DE RECURSOS HIDRAULICOS INDRHI

FORMULARIO DE REPORTE DE SALIDA DE DATOS

Solicitante	ISA- INDRHI	Fecha : 31 / 12/ 02
Clasificación	Aguas Superficiales	Lugar : Río Yuna
Operador	Ing. Almanzar	

ANALISIS BACTERIOLOGICOS

Fecha de Muestreo	Coliformes Totales NMP/ 100ml	Coliformes Fecales NMP / 100 ml	Lugar y Fuente
17.12.2002	910	360	Río Yuna a 20mt. Antes conf. Río Blanco
17.12.2002	2 300	910	Río Yuna sitio Presa Río Yuna, alto Yuna
17.12.2002	2 300	910	Río Masipedro, obra de toma del Canal
17.12.2002	4 300	2 300	Río Jima, salidad del tunel
17.12.2002	46 000	46 000	Río Jima, Jima Rincón
17.12.2002	2 300	2 300	Río Yuna, después de Yuboa
17.12.2002	910	360	Río Yuna, después del canal Falcondo
17.12.2002	<2.2	<2.2	Lago Presa Hatillo, aguas arriba muro
17.12.2002	360	<2.2	Lago Presa Rincón, aguas arriba muro
Normas Ambientales Clase B	1 000	1 000	

Laboratorio de Calidad de Aguas

INSTITUTO NACIONAL DE RECURSOS HIDRAULICOS (INDRHI)

FORMULARIO DE REPORTE DE SALIDA DE DATOS

Solicitante	**ISA-INDHRI**	**Fecha :**	**30.12.2002**
Clasificación	**Aguas Superficiales**	**Lugar :**	**Río Yuna**
Operador	**Ing. Luis Almanzar**		

ANALISIS FISICO-QUIMICOS

Fecha de Muestreo	CE (µS/cm)	pH	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	CO3 (mg/l)	HCO3 (mg/l)	Cl (mg/l)	SO4 (mg/l)	NO3 (mg/l)	NO2 (mg/l)	*Orto* PO4 (mg/l)	Total PO4 (mg/l)	D.T (mg/l)	Alc. (mg/l)	STD (mg/l)	Sed (gr/l)	Ras	Clase	Fuente y Fuente
17.12.2002	220	7,8	26,05	4,86	11,04	0	103,73	7,44	8,25	7,04	0,026	< LD	< LD	85	85	182	0,075	0,52	C1S1	Río Yuna, Blanco
17.12.2002	250	8	27,66	5,59	14,71	0	109,84	14,53	15,05	5,28	0,01	< LD	< LD	92	90	173	0,059	0,67	C1S1	Río Yuna (Sitio de la Presa) Los Quemados
17.12.2002	145	7,7	13,03	6,08	6,67	0	61,02	8,86	9,13	5,28	0,01	< LD	< LD	57,5	50	110	0,042	0,38	C1S1	Río Masipedro, en Masipedro
17.12.2002	117	7,3	10,02	6,56	2,76	0	48,82	8,86	7,38	4,84	0,02	< LD	< LD	52	40	98	0,042	0,17	C1S1	Río Jima, Caño Piedra, Jima
17.12.2002	174	7	13,83	7,53	9,43	0	85,43	9,57	8,58	1,76	0,007	< LD	< LD	65,5	70	136	0,054	0,51	C1S1	Río Jima, Jima Rincón, Cañabón
17.12.2002	322	7,6	36,87	10,33	11,5	0	158,65	13,12	10,89	8,8	0,03	< LD	< LD	134,5	130	219	0,035	0,43	C2S1	Río Yuna, después de Yuboa, El Caribe
17.12.2002	316	8	36,07	10,81	10,12	0	158,65	11,7	10,45	3,52	0,03	< LD	< LD	134,5	130	214	0,032	0,38	C2S1	Río Yuna con canal Falcondo, Hato Viejo
17.12.2002	273	7,6	26,85	9,36	13,56	0	85,43	10,99	43,34	3,96	0,03	< LD	< LD	105,5	70	209	0,023	0,57	C2S1	Lago Presa Hatillo, aguas arriba muro
17.12.2002	170	7	11,62	9,23	7,82	0	79,33	10,28	6,83	3,96	0,02	< LD	< LD	67	65	147	0,018	0,41	C1S1	Lago Presa Rincón, Rincón
Normas Ambientales Clase B		**6,5 9**						**250**	**400**							**1000**				

Análisis realizados siguiendo las metodologías analíticas del Standard Methods 1992

Clase B : Aguas destinadas a la preservación de la flora y la fauna; aguas aprovechables para el regadío de cultivos deportes acuáticos sin contacto directo, aquellas utilizadas en algunos procesos industriales y pecuarios y aguas para abastecimiento de agua potable después de un proceso de tratamiento

Laboratorio de Calidad de Aguas

INSTITUTO NACIONAL DE RECURSOS HIDRAULICOS INDRHI

FORMULARIO DE REPORTE DE SALIDA DE DATOS

Solicitante	ISA- INDRHI	Fecha : 14 / 1/ 03
Clasificación	Aguas Superficiales	Lugar : Río Yuna
Operador	Ing. Luis Almanzar	

ORGANICOS GENERALES

Fecha de	Amonio	DQO	Lugar y Fuente
Muestreo	(mg/l)	(mg/l)	
07.01.2003	<LD	16	Río Yuna a 20mt. Antes conf. Río Blan
07.01.2003	<LD	20	Río Yuna sitio Presa Río Yuna, alto Yu
07.01.2003	<LD	24	Río Masipedro, obra de toma del canal
07.01.2003	<LD	28	Río Jima, Caño Piedra, Jima
07.01.2003	<LD	8	Río Jima, Jima Rincón, Cañalón
07.01.2003	<LD	16	Río Yuna, después de Yuboa, El Baribe
07.01.2003	<LD	28	Río Yuna, después del canal Falcondo,
07.01.2003	<LD	8	Lago Presa Hatillo, aguas arriba muro
07.01.2003	<LD	12	Lago Presa Rincón, aguas arriba muro
Normas	0.5.(mg/l)	N/C	
Ambientales Clase B			

N/C ; No Contemplado en las Normas Ambientales

<LD : Menor del Límite de Detección

Laboratorio de Calidad de Aguas

INSTITUTO NACIONAL DE RECURSOS HIDRAULICOS INDRHI

FORMULARIO DE REPORTE DE SALIDA DE DATOS

Solicitante	ISA- INDRHI	Fecha : 14 / 1/ 03
Clasificación	Aguas Superficiales	Lugar : Río Yuna
Operador	Ing. Luis Almanzar	

ANALISIS BACTERIOLOGICOS

Fecha de Muestreo	Coliformes Totales NMP/ 100ml	Coliformes Fecales NMP / 100 ml	Lugar y Fuente
07.01.2003	910	<2.2	Río Yuna a 20mt. Antes conf. Río Blanco
07.01.2003	360	360	Río Yuna sitio Presa Río Yuna, alto Yuna
07.01.2003	910	360	Río Masipedro, obra de toma del canal
07.01.2003	4 300	910	Río Jima, Caño Piedra, Jima
07.01.2003	>110,000	110 000	Río Jima, Jima Rincón, Cañalón
07.01.2003	9 300	910	Río Yuna, después de Yuboa, El Baribe
07.01.2003	1 500	910	Río Yuna, después del canal Falcondo, H. V.
07.01.2003	<2.2	<2.2	Lago Presa Hatillo, aguas arriba muro
07.01.2003	910	<2.2	Lago Presa Rincón, aguas arriba muro
Normas Ambientales Clase B	1 000	1 000	

Laboratorio de Calidad de Aguas

INSTITUTO NACIONAL DE RECURSOS HIDRAULICOS (INDRHI)

FORMULARIO DE REPORTE DE SALIDA DE DATOS

Solicitante	ISA-INDHRI	Fecha :	14.01.2003
Clasificación	Aguas Superficiales	Lugar :	Río Yuna
Operador	Ing. Luis Almanzar		

ANALISIS FISICO-QUIMICOS

Fecha de Muestreo	CE (µS/cm)	pH	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	CO3 (mg/l)	HCO3 (mg/l)	Cl (mg/l)	SO4 (mg/l)	NO3 (mg/l)	NO2 (mg/l)	*Orto* PO4 (mg/l)	Total PO4 (mg/l)	D.T (mg/l)	Alc. (mg/l)	STD (mg/l)	Sed (gr/l)	Ras	Clase	Fuente y Fuente
07.01.2003	207	7,7	24,85	5,47	8,28	0	97,63	10,28	8,47	7,92	0,0231	< LD	< LD	84,5	80	115	0	0,39	C1S1	Río Yuna, Blanco
07.01.2003	205	7,7	24,05	3,65	12,18	0	91,53	4,61	12,2	7,48	0,0198	< LD	< LD	75	75	148	0	0,61	C1S1	Río Yuna (Sitio de la Presa) Los Quemados
07.01.2003	127	7,5	11,22	4,62	7,36	0	61,02	2,84	8,25	3,08	0,0066	< LD	< LD	47	50	82	0	0,46	C1S1	Río Masipedro, en Masipedro
07.01.2003	110	7,6	9,02	4,62	5,98	0	48,82	5,67	7,92	5,72	0,0198	< LD	< LD	41,5	40	66	0,0005	0,41	C1S1	Río Jima, Caño Piedra, Jima
07.01.2003	184	6,9	12,83	9,6	8,97	0	85,43	7,44	14,39	3,08	0,0165	< LD	< LD	71,5	70	149	0,0035	0,45	C1S1	Río Jima, Jima Rincón, Cañabón
07.01.2003	239	7,6	26,45	7,78	9,43	0	109,84	8,86	10,78	3,52	0,0132	< LD	< LD	98	90	143	0,0008	0,41	C2S1	Río Yuna, después de Yuboa, El Caribe
07.01.2003	270	7,7	27,86	9,11	12,18	0	122,04	11,7	12,86	7,48	0,0165	< LD	< LD	107	100	164	0,0008	0,51	C2S1	Río Yuna con canal Falcondo, Hato Viejo
07.01.2003	273	7,5	26,45	9,11	14,48	0	79,33	11,7	44,33	2,64	0,0132	< LD	< LD	103,5	65	226	0,0005	0,62	C2S1	Lago Presa Hatillo, aguas arriba muro
07.01.2003	167	7,4	12,83	7,78	8,51	0	73,22	8,86	8,69	5,72	0,0165	< LD	< LD	64	60	98	0,0005	0,46	C1S1	Lago Presa Rincón, Rincón
Normas Ambientales Clase B		**6,5 9**						**250**	**400**							**1000**				

Análisis realizados siguiendo las metodologías analíticas del Standard Methods 1992

Clase B : Aguas destinadas a la preservación de la flora y la fauna; aguas aprovechables para el regadío de cultivos deportes acuáticos sin contacto directo, aquellas utilizadas en algunos procesos industriales y pecuarios y aguas para abastecimiento de agua potable después de un proceso de tratamiento

Laboratorio de Calidad de Aguas

INSTITUTO NACIONAL DE RECURSOS HIDRAULICOS INDRHI

FORMULARIO DE REPORTE DE SALIDA DE DATOS

Solicitante	ISA- INDRHI	Fecha : 14/3/03
Clasificación	Aguas Superficiales	Lugar : Río Yuna
Operador	Ing. Luis Almanzar	

ORGANICOS GENERALES

Fecha de Muestreo	Amonio (mg/l)	DQO (mg/l)	Lugar y Fuente
11.03.2003	<LD	<LD	Aguas abajo Presa Rincón
11.03.2003	1,0358	<LD	Arroyo Margajita
11.03.2003	<LD	<LD	Río Yuna, puente Cotuí, La Mata
Normas Ambientales Clase B	0.5.(mg/l)	N/C	

N/C ; No Contemplado en las Normas Ambientales

Clase B : Aguas destinadas a la preservación de la flora y la fauna; aguas aprovechables para el regadío de cultivos deportes acuáticos sin contacto directo, aquellas utilizadas en algunos procesos industriales y pecuarios y aguas para abastecimiento de agua potable después de un proceso de tratamiento

Laboratorio de Calidad de Aguas

INSTITUTO NACIONAL DE RECURSOS HIDRAULICOS INDRHI

FORMULARIO DE REPORTE DE SALIDA DE DATOS

Solicitante	ISA- INDRHI	Fecha : 14 / 03/ 03
Clasificación	Aguas Superficiales	Lugar : Río Yuna
Operador	Ing. Almanzar	

ANALISIS BACTERIOLOGICOS

Fecha de Muestreo	Coliformes Totales NMP/ 100ml	Coliformes Fecales NMP / 100 ml	Lugar y Fuente
11.03.2003	<2.2	<2.2	Cotraembalse Rincón
11.03.2003	4 300	4 300	Rincón aguas abajo
11.03.2003			
Normas Ambientales Clase B	1 000	1 000	

Clase B : Aguas destinadas a la preservación de la flora y la fauna; aguas aprovechables para el regadío de cultivos deportes acuáticos sin contacto directo, aquellas utilizadas en algunos procesos industriales y pecuarios y aguas para abastecimiento de agua potable después de un proceso de tratamiento

Laboratorio de Calidad de Aguas

INSTITUTO NACIONAL DE RECURSOS HIDRAULICOS (INDRHI)

FORMULARIO DE REPORTE DE SALIDA DE DATOS

Solicitante	ISA-INDHRI	Fecha :	14.03.2003
Clasificación	Aguas Superficiales	Lugar :	Río Yuna
Operador	Ing. Luis Almanzar		

ANALISIS FISICO-QUIMICOS

Fecha de	CE	pH	Ca	Mg	Na	CO3	HCO3	Cl	SO4	NO3	NO2	Orto PO4	D.T	Alc.	STD	Sed	Ras	Clase	Fuente y Fuente
Muestreo	(µS/cm)		(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(gr/l)			
11.03.2003	4 210	2,2							3 301,08	264	1,28	5,25							Margajita, Hatillo, Maimón
11.03.2003	168	6,9	12,83	7,29	9,66	0	85,43	6,74	7,6	< LD.	< LD.	0,3	62	70	129	0,055	0,53	C1S1	Contraembalse de Rincón
11.03.2003	266	7,1	26,45	8,14	14,71	0	85,43	15,95	45,97	< LD.	< LD.	0,25	99,5	70	205	0,0198	0,65	C2S1	Río Yuna, Puente Cotuí-La Mata
Normas Ambientales Clase B		**6,5 9**						**250**	**400**						**1000**				

Análisis realizados siguiendo las metodologías analíticas del Standard Methods 1992

Clase B : Aguas destinadas a la preservación de la flora y la fauna; aguas aprovechables para el regadío de cultivos deportes acuáticos sin contacto directo, aquellas utilizadas en algunos procesos industriales y pecuarios y aguas para abastecimiento de agua potable después de un proceso de tratamiento

Table 12.1 Families of Ephemeroptera and Trichoptera at river sites on the 09-10.10.2002.

	Rio Yuna st1	Rio Yuna st2	Rio Masipedro st3	Rio Jima st4	Rio Jima st5	Rio Yuna st6	Rio Yuna st7
Ephemeroptera							
Baetidae		4	2	16	11	4	36
Leptohyphidae	3	20	256	168	332	496	1176
Caenidae				1			
Trichoptera							
Glossosomatidae	7	10	16	50		34	1
Hydroptilidae		24	2	4			2
Hydropsychidae		3	3	2	9	74	46
Heliopsychidae				4			
Trichoptera indet.					2		28

Table 12.2 Families of Ephemeroptera and Trichoptera at river sites on the 10-13.03.2003.

	Rio Yuna st1	Rio Masipedro st3	Rio Jima st4	Rio Yuna st10
Ephemeroptera				
Baetidae	6	15	15	
Leptohyphidae	128	251	92	
Caenidae				
Trichoptera				
Philopotamidae	1			
Glossosomatidae	400	17	17	
Hydroptilidae	8		1	
Hydropsychidae	15	1	2	6
Heliopsychidae	4	1	2	
Trichoptera Indet				

Table 12.3 Main taxa of macroinvertebrates at river sites on the 09-10.10.2002.

	Rio Yuna st1	Rio Yuna st2	Rio Masipedro st3	Rio Jima st4	Rio Jima st5	Rio Yuna st6	Rio Yuna st7
Oligochaeta		3	12	16	4	48	120
Gastropoda		1	1			55	40
Hydracarina						1	2
Crustacea		1				3	
Odonata	1	2	88	32		32	3

Ephemeroptera	3	24	258	185	343	500	1212
Plecoptera							
Coleoptera larvae		1	15	20		24	5
Coleoptera imago			1				
Trichoptera	7	37	21	60	11	108	77
Lepidoptera	1	1	4	4		26	132
Simuliidae larvae	1	12		8	516	376	1056
Simuliidae pupae		12			12		
Chironomidae larvae	5	44	56	144	30	32	440
Chironomidae pupae		4	16	16	6		72
Diptera indet		6	6	3	6	8	8
SUM	18	148	478	488	928	1213	3167
Number of taxa	6	13	11	10	8	12	12

Table 12.4 Main taxa of macroinvertebrates at river sites on the 10-13.03.2003.

	Rio Yuna st1	Rio Masipedro st3	Rio Jima st4	Rio Yuna st10
Turbellaria	1			
Oligochaeta	52	84	2	2
Gastropoda	2			26
Hydracarina				
Crustacea				
Odonata	6	21	14	
Ephemeroptera	134	251	107	
Plecoptera				
Coleoptera larvae	96	44	4	
Coleoptera imago	3	1		
Heteroptera		1		1
Trichoptera	425	19	22	6
Lepidoptera	2	5	10	
Simuliidae larvae				16
Simuliidae pupae				
Chironomidae larvae	68	116	52	10
Chironomidae pupae	16	12	12	2
Diptera indet		12	8	1
SUM	805	566	231	64
Number of taxa	11	11	9	8

Quantitative analysis of phytoplankton in samples from Rio Yuna just upstream Boca de Blanco (Station 1), October 10, 2002.

	Bio volume given in mm³/m³ (=mg/m³ wet weight)
Year	2002
Month	10
Day	9
Depth	1
Chlorophyceae (Green algae)	
Chlamydomonas sp. (l=12)	58,8
Penium polymorphum	0,4
Sum - Green algae	59,2
Chrysophyceae	
Ochromonas sp. (d=3.5-4)	0,6
Small chrysomonades (<7)	4,7
Large chrysomonades (>7)	3,4
Sum - Crysophyceae	8,7
Bacillariophyceae (Diatoms)	
Achnanthes minutissima v.cryptocephala	13,0
Cocconeis placentula	92,2
Cymbella turgida	3,0
Fragilaria ulna (morfotyp"ulna")	6,0
Navicula sp. l=15-20	2,8
Nitzschia sp.	5,3
Stephanodiscus hantzchii v.pusillus	24,1
Sum - Diatoms	146,4
Cryptophyceae	
Cryptomonas sp. (l=15-18)	4,0
Ubest.cryptomonade (Chroomonas sp.?)	3,7
Ubest.cryptomonade (l=6-8) Chro.acuta ?	0,8
Sum - Cryptophyceae	8,5
My-algeae	
My-algae	10,5
Sum - My-algae	10,5
Sum total :	233,3

Quantitative analysis of phytoplankton in samples from Rio Masipedro (Station 3), October 10 2002.

	Bio-volume given as mm³/m³ (=mg/m³ Wet weight)
Year	2002
Month	10
Day	9
Depth	1
Cyanophyceae (Blue-green algae)	
Anabaena sp.	0,5
Sum - Cyanophyceae	0,5
Chrysophyceae	
Ochromonas sp. (d=3.5-4)	1,0
Small chrysomonades (<7)	3,6
Store chrysomonades (>7)	1,3
Sum - Chrysomonades	5,9
Bacillariophyceae (Diatoms)	
Achnanthes minutissima v.cryptocephala	3,5
Cocconeis placentula	14,3
Cymbella turgida	7,0
Fragilaria ulna (morfotyp"ulna")	80,0
Navicula sp. l=15-20	0,3
Stephanodiscus hantzchii v.pusillus	0,9
Sum - Bacillariophyceae	106,0
My-algae	
My-algae	2,2
Sum - My-algae	2,2
Sum total :	114,7

Quantitative analysis of phytoplankton in samples from Rio Jima at Caño Piedra (Station 4) October 10 2002.

	Bio-volume given as mm³/m³ (=mg/m³ Wet-weight)
Year	2002
Month	10
Day	9
Depth	1
Chrysophyceae	
Ochromonas sp. (d=3.5-4)	0,5
Small chrysomonades (<7)	2,8
Large chrysomonades (>7)	0,9
Sum - Chrysophyceae	4,2
Bacillariophyceae (Diatoms)	
Achnanthes minutissima v.cryptocephala	1,2
Cocconeis placentula	14,3
Fragilaria ulna (morfotyp"ulna")	54,0
Melosira varians	3,5
Navicula sp. l=15-20	0,2
Stephanodiscus hantzchii v.pusillus	0,9
Sum - Diatoms	74,0
My-algae	
My-algae	5,1
Sum - My-algae	5,1
Sum total :	83,3

Quantitative analysis of phytoplankton in samples from Hatillo Reservoir at the damsite (Station 9), October 2002 surface sample 1 m depth.

	Bio-volume given as mm³/m³ (=mg/m³ Wet-weight)
Year	2002
Month	10
Day	17
Depth	1
Chlorophyceae	
Ankistrodesmus falcatus	1,1
Coelastrum reticulatum v.cubanum	87,4
Cosmarium contractum	6,6
Cosmarium sp.	16,7
Cosmarium sphagnicolum	0,4
Crucigeniella pulchra	0,9
Elakatothrix gelatinosa (genevensis)	3,0
Koliella sp.	3,9
Scenedesmus ecornis	27,0
Staurastrum smithii	15,9
Ubest. kuleformet gr.alge (d=5)	3,3
Unident.ellipsoidic gr.algae	1,9
Sum - Green algae	168,1
Chrysophyceae	
Craspedomonader	0,1
Dinobryon acuminatum	0,8
Ochromonas sp. (d=3.5-4)	2,1
Small chrysomonades (<7)	17,1
Sum - Chrysophyceae	20,1
Bacillariophyceae (Diatoms)	
Achnanthes minutissima v.cryptocephala	5,1
Fragilaria sp. (l=40-70)	2,1
Navicula sp. l=15-20	53,0
Rhizosolenia eriensis (var.?)	4,3
Sum - diatoms	64,5
Cryptophyceae	
Cryptomonas cf.erosa	8,0
Unid.cryptomonade (Chroomonas sp.?)	8,3
Unid.cryptomonade (l=6-8) Chro.acuta ?	2,9
Sum - Cryptophyceae	19,2
Dinophyceae	
Peridinium umbonatum (P.inconspicuum)	63,2
Unident.dinoflagellat	4,0
Sum - Dino-flagellates	67,2
My-algae	
My-algae	17,9
Sum - My-alge	17,9
Sum total:	356,9

Quantitative analysis of phytoplankton in samples from Hatillo Reservoir (Station 11 over the lakes deepest point), March 2003 mixed sample 1 – 10 m depth.

	Values given as mm³/m³
Year	2003
Month	3
Day	10
Depth (m)	0-10m
Chlorophyceae (green algae)	
Ankistrodesmus falcatus	0,7
Botryococcus braunii	0,7
Chlamydomonas sp. (l=8)	0,5
Coelastrum morus	0,8
Cosmarium contractum	9,0
Elakatothrix gelatinosa (genevensis)	12,7
Indet.coccoid green algae	19,5
Monoraphidium komarkovae	84,8
Monoraphidium minutum	0,8
Scenedesmus dimorphus	3,7
Scenedesmus ecornis	2,7
Sphaerocystis schroeteri	2,8
Staurastrum chaetoceras	463,8
Staurastrum smithii	31,8
Tetraedron minimum	28,6
Treubaria triappendiculata	2,7
Sum - green algae	665,5
Chrysophyceae (golden algae)	
Dinobryon korshikovii	3,7
Ochromonas sp. (d=3.5-4)	2,0
Small chrysomonads (<7)	33,1
Large chrysomonads (>7)	13,8
Sum - golden algae	52,6
Bacillariophyceae (diatoms)	
Achnanthes sp.	12,7
Fragilaria sp. (l=40-70)	28,6
Navicula sp.	812,5
Nitzschia sp.	0,2
Rhizosolenia eriensis (var.?)	48,4
Sum - diatoms	902,4
Cryptophyceae (cryptomonads)	
Cryptomonas sp. (l=15-18)	31,8
Sum - cryptomonads	31,8
Dinophyceae (dinoflagellates)	
Gymnodinium cf.lacustre	4,2
Peridinium cf.cunningtonii	37,2
Peridinium cf.umbonatum	71,6
Peridinium sp. (l=15-17)	0,3
Sum - dinoflagellates	113,4
Euglenophyceae (euglenoids)	
Euglena sp.	4,8
Sum - euglenoids	4,8
"µ-algae"	
"µ-algae"	77,0
Sum - "µ-algae"	77,0
Total volume	1847,5

Quantitative analysis of phytoplankton in samples from Rincon Reservoir at the damsite (Station 8), October 2002 surface sample at 1 m depth.

	Bio-volume given as mm³/m³ (=mg/m³ Wet-weight)
Year	2002
Month	10
Day	17
Depth (m)	1
Cyanophyceae (Blue-green algae)	
Cylindrospermopsis raciborskii	29,2
Sum - Cyanophyceae	29,2
Chlorophyceae (Green algae)	
Chlamydomonas sp. (l=12)	3,2
Coelastrum asteroideum	0,5
Cosmarium sphagnicolum	7,0
Scenedesmus ecornis	12,7
Staurastrum smithii	8,0
Treubaria triappendiculata	5,3
Unident. kuleformet gr.alge (d=5)	4,1
Unident.ellipsoidic gr.alge	3,2
Sum - Chlorophyceae	43,9
Chrysophyceae	
Ochromonas sp. (d=3.5-4)	5,2
Small chrysomonades (<7)	30,3
Large chrysomonades (>7)	6,9
Sum - Chrysophyceae	42,4
Bacillariophyceae (Diatoms)	
Achnanthes minutissima v.cryptocephala	626,2
Fragilaria sp. (l=40-70)	0,2
Navicula sp. l=15-20	575,1
Sum - Diatoms	1201,5
Cryptophyceae	
Unident.cryptomonade (Chroomonas sp.?)	33,4
Unident.cryptomonade (l=6-8) Chro.acuta ?	2,1
Sum - Cryptophyceae	35,5
Dinophyceae	
Peridinium cunningtonii	104,9
Peridinium sp. (l=15-17)	26,2
Peridinium umbonatum (P.inconspicuum)	45,0
Unident.dinoflagellate	4,2
Sum - Dinophyceae	180,3
My-algae	
My-algae	66,5
Sum - My-algae	66,5
Sum total :	1599,2

Quantitative analysis of phytoplankton in samples from Rincon Reservoir (Station 13 over the lakes deepest point), March 2003 mixed sample 1 – 10 m depth.

	Bio-volume given as mm³/m³ (=mg/m³ wet weight)
Year	2003
Month	3
Day	11
Depth	0-10m
Cyanophyceae (blue-green algae)	
Cylindrospermopsis cf.raciborskii	79,5
Sum - blue-green algae	79,5
Chlorophyceae (green algae)	
Chlamydomonas sp. (l=10)	5,6
Cosmarium sphagnicolum	2,1
Crucigeniella pulchra	1,6
Indet.cocc.green algae	1,4
Monoraphidium komarkovae	0,5
Scenedesmus sp. (Sc.bicellularis ?)	9,5
Staurastrum chaetoceras	6,5
Treubaria triappendiculata	1,3
Sum - green algae	28,5
Chrysophyceae (golden algae)	
Chrysochromulina parva	273,9
Craspedomonader	1,3
Cyster av chrysophyceer	0,8
Dinobryon korshikovii	1,9
Sum - golden algae	277,8
Bacillariophyceae (diatoms)	
Achnanthes sp.	23,1
Fragilaria sp. (l=40-50)	254,4
Sum - diatoms	277,5
Cryptophyceae (cryptomonads)	
Cryptomonas cf.erosa	3,0
Indet.cryptomonad	7,2
Indet.cryptomonad (Chroomonas sp.?)	27,6
Sum - cryptomonads	37,8
Dinophyceae (dinoflagellates)	
Gymnodinium cf.lacustre	4,8
Peridinium cf.cunningtonii	31,8
Peridinium cf.umbonatum	51,5
Peridinium sp.	7,3
Indet.dinoflagellate	1,9
Sum - dinoflagellates	97,2
Total volume	798,3